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Agent Mediated Auctions: The Fishmarket Metaphor

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A mis padres, hijos y esposa.

A mis amigos, a los de Pendes y a los otros.

I als membres de la Confraria de Blanes.

La quietud com un estar en les coses,
i l'ordre per fer encara més intensa
la quietud.
Puc retrobar la pau
si em cerco en el mirall de les paraules.

Miquel Martí i Pol.
Els Bells Camins[1]

[1] "Quietness as being in things, / and order to make stillness more intense. / Peace I may regain / if in the mirror of words I besiege myself."

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Foreword

Internet opens many new possibilities for commerce and is changing market conventions. The inmediacy of Internet makes commercial practices to change and new services and even new products to appear. Agent based technologies are crucial for these developments as this thesis shows. The particular type of market that this book focuses on is that of an *auction house* which has become one the most active lines of research at the frontier between electronic commerce and artificial intelligence. This is so because auctions have very clearly defined protocols and, therefore, are more amenable to be formalized and automatized. This thesis is the result of a pioneer work on such auction modelling and has achieved an international recognition. Furthermore it has opened a new and very active line of research in our Institute where there is now a quite numerous group of researchers working on agent-mediated electronic commerce, including several doctoral students. On the other hand, several industries have approached us expressing their interest to cooperate in this subject.

This thesis is also a consequence of earlier work of the author on computational dialectics which is one of the basic building blocks for the formalization of multi-agent systems communication. Moreover, the experience of the author in the design of the Mexican public procurement system — Compranet — has also been very influential in choosing auctions as an application domain. Finally, the decision to apply it concretely to the Blanes fish market auction house was due to the fact that the IIIA was formerly located in that mediterranean village.

Our collaboration with the author during these years has been very fruitful and enjoyable both scientifically and personally. We wish the reader also a very fruitful and enjoyable experience when reading this book.

Bellaterra, July 1998

Ramon López de Mántaras and Carles Sierra
IIIA, CSIC

Preface

Twice a day in many fishing villages, in Spain and around the world, the village fleets catch is sold at the fish market following a time-honored tradition. At first sight, the fish market is simply a place where goods are exchanged under a peculiar *downward-bidding* auction protocol. A closer look reveals an *institution* where goods are traded under exquisitely refined socially acknowledged conventions.

The fish market —as other standard commodities–trading institutions— serves an important social purpose by establishing an effective way of articulating buyers and sellers interactions. In fact, the fish market upholds the fairness of the negotiation process and the accountability of transactions by defining and enforcing stable conditions on:

- the availability, presentation and delivery of goods
- the eligibility requirements for participating buyers and sellers
- acceptable behavior of participants within the site
- the satisfaction of public commitments made by participants

I believe that similar functions may advantageously be instituted for multi agent systems. Be it to address some problems derived from the complexity of multi agent interactions, or —more prosaically— to make acceptable some real–world applications of multi agent technologies.

In this dissertation I present some ideas on how this can be achieved, and argue in favor of the interest and usefulness of such constructs. Specifically, I propose to build computational environments —**agent–mediated institutions**— that allow heterogeneous agents to interact successfully by imposing appropriate restrictions on their behavior. To guarantee that such restrictions are properly enforced I propose the notion of **agent governor** and argue that with those two elements (agent–mediated institutions and agent governors) a rather general notion of "accountability" is formally and computationally realizable. These proposals are grounded in a **dialogical stance** by which agents are thought of as entities that engage in dialogue under some explicit shared conventions.

The example of the fish market auctioning convention is used in the dissertation to guide the theoretical and pragmatic considerations, and a computational version of the fish market is built and used as the nucleus of a competitive test–bed for heterogeneous trading agents. The conceptual proposals, however, are shown to be powerful enough to extended the original fish market elements and account for other forms of auctioning and structured trading, and for less structured agent interactions as well.

The Fishmarket project started as a toy problem domain —with a hint of applicability— in which to test simple interactions among possibly complex agents. It happened to be a fortunate choice that has provided grounds for fruitful developments. The overall motivation and accomplishments of the project, and indication of the relationship between this dissertation's content and current research in the area are reported in Chapters 1 and 2.

In spite of its apparent simplicity, auctioning is a sophisticated coordination mechanism for competitive price–fixing in which intermediaries facilitate agreements between buyers and sellers through a highly structured interaction protocol. A description of auctioning in general and the Blanes fish market in particular constitute Chapter 3, and provide a concrete reference and the terminological basis for the rest of the dissertation.

Chapter 4 contains the core theoretical contributions of this dissertation. A "dialogical stance" is advocated by which multi agent systems are understood as formal or formalizable dialogues. Then, the notion of a dialogical institution is introduced and with it a detailed description of an idealized version of an auction house: the Fishmarket Institution.

While Chapter 4 focuses on the "social" aspects of multi agent interactions, in Chapter 5 I look into what is needed in each individual agent to be able to participate in a dialogical multi agent system. Thus, Chapter 5 proposes a formal model for dialogical agents and a specification formalism, and illustrates their application through a simplified version of the fish market bidding rounds. Chapter 6 presents the implementation of an auction house based on the previous ideas and Chapter 7 discusses how the Fishmarket institution, and its implementation can be converted into a rich multi agent test–bed environment and a flexible auctioning platform.

The last part of the dissertation, Chapters 8, 9 and 10, generalize the previous ideas in different directions. Chapter 8 is a speculation on the practical aspects of agent mediated auctions. Chapter 9 uses the dialogical framework developed in Chapter 4 to account now for a less structured form of agent interaction (negotiation), and explores another form of dialogical process (argumentation), to produce a framework for agent-mediated–argumentation-based negotiation. Chapter 10 assembles all the pieces together —to introduce the notions of agent-mediated institutions and agent governors— by generalizing the notion of dialogical institution and proposing a way of formally constraining agent interactions to make such interactions accountable.

A sketch of the contents of each chapter and the connections among them is given in Figure 0.1.

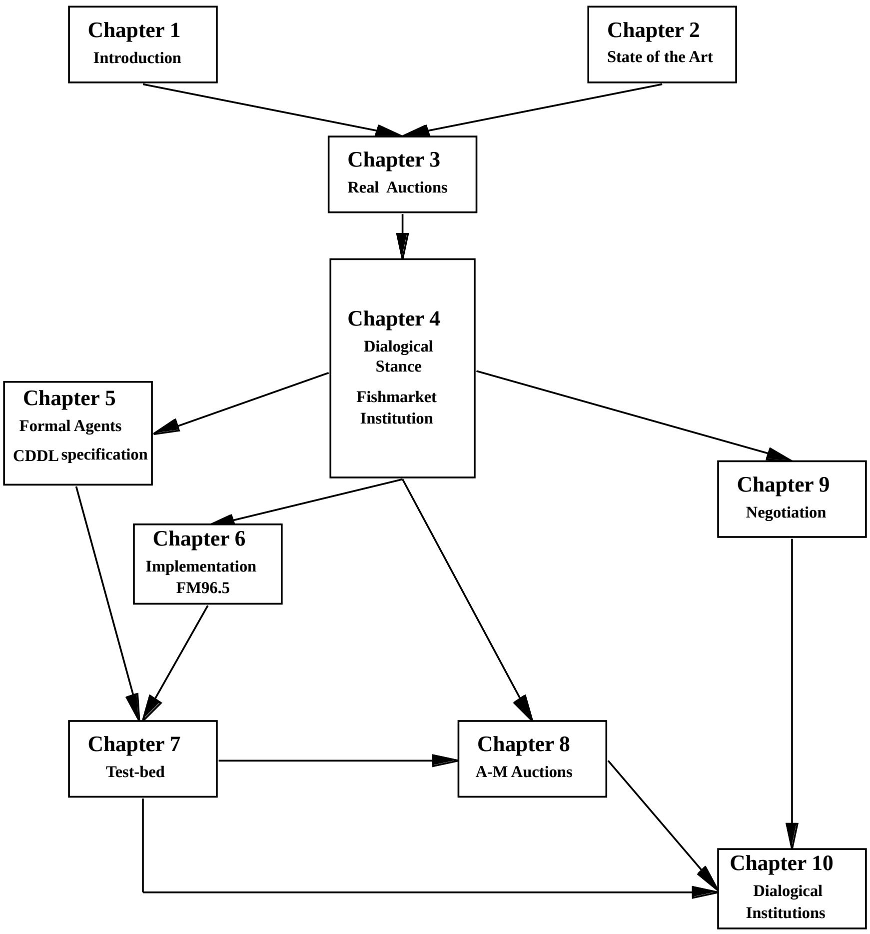

Figure 0.1: Chapter contents and links

Acknowledgments

My stay in Barcelona has been supported by the Mexican CONACYT, grant [69068-7245]. Some travel expenses to present results of this work have been funded through the Spanish CICYT project SMASH, TIC96-1038-C04001 and the European TMR number PL93-0186 VIM, CEC/HCM VIM project, contract CHRX-CT93-0401. Through Carles Sierra's encouragement and complicity, I was able to present some of these ideas in workshops and meetings in Budapest, Barcelona, Israel Lanjarón and London, and there received significant comments and suggestions of improvement.

Some fragments of this dissertation have appeared in print as papers of which I am a co–author. I would like to express my gratitude to these friends and collaborators who allowed me to use this collective material here, and acknowledge the provenance of those sources: Chapter 5 of this dissertation is based on [120], for which I would like to thank Carles Sierra. Chapter 6 uses material from [139] where Juan Antonio Rodríguez–Aguilar, Julian Padget and Carles Sierra intervened. Chapter 9 is based in [157] of which Nick Jennings, Simon Parsons and, again, Carles Sierra were co-authors.

Access to the Blanes fish market and thorough explanations of its inner workings were generously given by Xavier Márquez, (*Secretario* of the Confraria) and Josep Llauradó, (*patró major*), without their help this thesis might not have had such a rich and accessible model.

Finally, I wonder if there is ever any actual work that may be claimed as individual. I know that almost all I have ever accomplished has been the fruit of interacting with others. I also know that such collaboration is the source of much happiness, and being able to express gratitude is no minor part of it. Therefore, I wish to thank family, friends, teachers and collaborators. Eager readers may as well skip the rest of this section while I take my time to thank them properly.

Almost every word in this dissertation has been influenced by a conversation with someone, and many words (as I mentioned above) have already appeared in print under collective headers. I really think that most of what is new —and hopefully good— in this thesis is not mine alone and I would like to make public my gratitude and indebtness to six people whose contribution to this thesis has been specially significant.

First and foremost, I wish to thank Carles Sierra and Ramon López de Màntaras, my two thesis co-advisers. At the risk of understating, I should say that I have been an unorthodox student, and they assumed the dubiously rewarding task of "taming a tiger that had already tasted human flesh", so to speak. This process I thoroughly enjoyed but required from them the best of the epical catalonian *seny* and *rauxa*. I was fortunate to profit systematically from their experience, intuition, sense of rigor and quality, their infatigable energy, good humor *and* their knowledge. Along this process, I think I also was fortunate in building true friendship with them which is a truly valuable thing, I believe.

Julian Padget, Juan Antonio Rodríguez, Francisco Martín and Enric Plaza deserve also special thanks. Julian Padget played the fundamental role of an external observer who got gradually interested in the project, intervened in crucial tasks and contributed fundamental concerns. He supervised part of the FM implementations and with rigor questioned the mechanics of bidding, focusing a discussion on bidding properties and implementation issues that were to be fundamental in my thinking about accountability. Recently he again re–oriented our thoughts on specification towards π-calculus, and with his enthusiasm contributed to the internationalization of the Fishmarket project. Juan Antonio Rodríguez and Francisco Martín made the Fishmarket project real. They jumped into the wagon when it was taking formal speed and made it concrete and operational. They have carried all the implementational burden of the project, not a single code of line of which I can claim credit to. But in addition, they have provided many concrete problems and illustrations that have enabled the more philosophical or theoretical aspects of the project to move forward. Without their insatiable curiosity and reading ability, I would have never been able to gather such a rich bibliography, not to mention making it pertinent. The constant discussions with Enric Plaza on all sorts of topics —from alternative cultures to federated learning— forced me to keep an attentive and open perspective. His suggestions for the Fishmarket project were systematically pertinent and original, and he will surely recognize his hand in many choices of terminology, emphasis and direction. I know my thinking was influenced by his opinions more than by any readings I made, and I wish to thank him for that.

The idea of choosing the fish market auction as a problem domain to test agents was the result of a conversation with Carles Sierra and Pere Garcia. The first formalizations and all subsequent ones involved Carles Sierra and then Ramon López de Màntaras and Lluis Godo. The implementation of the FIshmarket model was possible thanks mainly to Juan Antonio Rodríguez, Francisco Martín, Julian Padget and Maurizio Giordano. Juan Antonio Rodríguez developed FM96.2, .3, .4 and .5 with the supervision and collaboration of Julian Padget, Andreas Kind and Julio García. He also has been directing Xavier Giménez and David Gutiérrez on the implementation on FM97.6 and 96.7. Francisco Martín hacked out FM96.0 and together with Juan Antonio Rodríguez produced *Jarisco* —the level-1 nomadic interface for buyer agents— the agent templates and the tournament specification. The idea of turning the problem domain into a tournament, I believe was Francisco Martín's, who also advanced many ideas on testing, and whose pointed questions on almost every topic kept me constantly humble. Juan Antonio Rodríguez was involved also in the development of the ideas of tournaments and tournament scenarios and Pere Garcia in their formalization. Mari Carmen de Toro forced me to think on pragmatic components and developed and tested the buyer agents presented in Chapter 7. The first questions on accountability were motivated by a discussion with Julian Padget and Juan Antonio Rodríguez on the implementation of the bidding-round protocol. Other ideas on accountability resulted from the discussion of the "Emporium" proposal with Carles Sierra, Julian Padget, Sarit Kraus, Hans Voss, Enric Plaza and Luciano Serafini, where other applications to electronic markets were discussed [46]. The chapter on Negotiation was the result of a collaboration with Nick Jennings and Simon Parsons who facilitated Carles Sierra's ideas and mine to take new dimensions. Theirs, mostly, is the negotiation example and the specific argumentation mechanism proposal.

The thesis also shows a few more influences which in spite of being less specific were no less significant.

Ideas need territorial grounding. I was lucky to spend three wonderful years in Barcelona thanks to the hospitality of the *colla* of the IIIA. That was feasible because more than a decade ago Jaume Agustí made me reconsider seriously the possibility of enrolling in a doctoral program and Ramon López de Màntaras facilitated my decision then and later on by giving me constant sound advice and demonstrating friendship to the point of facilitating paperwork. It was Ramon, again, and Francesc Esteva who invited me to the IIIA, and its members who welcomed me as part of a lively professional group, and have bear up with my eccentricities. Project SMASH entailed an institutional commitment of IIIA to multi agent systems, thus allowing me to make my research part of the group's interests.

No less significant has been the support of LANIA's Board of Directors who has kept my hope for a position in LANIA open all these years, and also preserved my sense of duty and public dignity by entitling me to pose as President of the Board without actually having to do any serious job.

From my undergraduate Mathematics teacher Javier Fernández Pacheco I must acknowledge his still positive impact on my irresponsible frivolity, and thanks to him, also, a vestige of clarity and an appreciation for notation may perhaps be glimpsed in my writing (the vestiges of *APL* notation are in his homage). Preoccupation with the significance of dialogues reflect the time when Santiago Negrete, Edgar González and myself were involved in "Dialogical Systems", then some –probably healthy– and altogether unavoidable contamination with Philosophy crept into my outlook on these issues. Whatever preoccupation with practical and social implications of agents might be extracted from my writing is the result of my experience at INEGI and the influence of many of the members of the Grupo Consultivo de Política Informática.

Néstor Duch Gary has, for years, stimulated my ecclecticism with pertinent discussions and suggestions. For this thesis he suggested me to look into North's ideas on institutions when I was re–inventing the wheel. Néstor Duch Brown not only was an unending source for Economic literature, but also has done his best to avoid me embarrassment when talking about Economics.

From José Negrete I learned to keep a sardonic view on life, and from Pablo Rudomín a serious hedonistic attitude towards research. Both influences were fundamental to keep me balanced and happy during these years (the Mediterranean atmosphere, the example from my friends from Barcelona, Amalia, and my innate propensity to enjoyment did the rest).

Other friends I have been lucky to make over the years, and to many of them I should individually thank as well since their influence and support made also this dissertation possible. I hope they will sense my gratitude throughout this work for I have kept them in mind.

Now I wish to thank family properly:

Gracias a mis padres quienes además de darme la vida me la sostienen, han sido y siguen siendo mis mejores y más constantes maestros y en mi ya larga adolescencia siguen siendo sabios cómplices de mi idealismo. A Mari y a Sergio quienes en las duras y en las maduras me han apoyado y empujado.

A mis abuelos Cayetano y Elena —con quienes en una excursión a Cudillero vi por primera vez una Lonja— quienes fueron y siguen siendo ejemplo y estímulo. A mis hijos que le dan sentido a mi existencia y a Amalia que me hace verdadera y cotidianamente feliz, gracias, mil mil gracias.

Gracias a todos, desde el fondo de mi alma.

Abstract

Traditional Institutions, such as the fish market, articulate agent interactions by imposing constraints on them. Constraints in the form of a bidding protocol, constraints on the time of trading, the quality of goods, the solvency of participants. Likewise, one can design agent mediated institutions in which participants —be they software agents or human agents— are constrained to behave according to clearly stated conditions.

This work explores the traditional fish market institution and develops a dialogical approach to describe *accountable* agent-mediated institutions. Based on that approach a model of the fish market is developed and then implemented as an electronic auction house. Using these developments, a competitive testbed for heterogeneous agents is constructed and the empirical issues of building agent–mediated auction houses discussed. The dialogical approach of the fish market is then extended to deal with more complex agent interactions, such as the ones needed in agent-based negotiation, and the formal notions of dialogical institution and governed agent are presented. These extensions illustrate how the notion of accountable agent interactions can be put to use in electronic commerce.

Part I

Introduction

Chapter 1

Motivation and Overview

Overheard in an auction room:

How do I bid in the auction?
—Just raise your hand.
But how do I know *it's the best price?*
—You'll get charged.

This thesis is *mainly* about auctions. Specifically about agent-mediated auctions. But —as this chapter's epigraph suggests— auctions seem to be extremely simple. So, what interest could it possibly have to study them?

One can argue that there are a few good reasons. I will attempt to put some of those forward, and in so doing I will also indicate what this dissertation contains and what the contributions of the Fishmarket Project have been.

I will organize my arguments along three lines:

- from the point of view of agent interactions,
- from the point of view of agent-based applications, and
- from the point of view of dialogical systems.

1.1 Auctions from a multi agent perspective

1.1.1 A Challenging Problem

From the point of view of multi agent interactions, auction-based trading is *deceivously* simple. Auction trading corresponds to the typical sort of situation where agents are purported to be ideally suited for (as postulated by for example Wooldridge and Jennings in [189], or Maes in [101]), requiring from them

—at least— the four attitudes of the *weak* notion of agency as described in Wooldrige's characterization ([190]): reactivity, situatedness, social ability and autonomy. So in a sense one could argue that even if it were extremely simple, at least the problem domain could arguably be *natural* as a multi–agent application. But notice that although trading in an auction demands from buyers merely to decide on an appropriate price on which to bid, and from sellers, essentially only to choose a moment when to submit their goods, these apparently simple decisions —if rational— involve complex deliberative processes.

Complexity is partly due to the wealth of information traders have access to or need to take into account in an auction: participating traders, available goods, their quality scarcity and expected re-sale value, historical experience on prices and rival participants' behavior, and so on. However, richness of information is not the only source of complexity in this domain. The actual conditions for deliberation are not only constantly changing and highly uncertain —new goods become available, buyers come and leave, prices keep on changing; no one really knows for sure what utility functions other agents have, nor what profits might be accrued— but on top of all that, deliberations are significantly time-bound. Bidding times are constrained by the bidding protocol which in the case of Dutch-auctions, like the traditional fish market, proceeds at frenetic speeds.

Consequently, if a trading agent intends to behave aptly in this context, the agent's decision-making process may be quite elaborate. It could involve procedural information (when to bid, how to withdraw), information and reasoning about supply and demand factors —which in turn may require knowledge or reasoning about the external conditions that might affect the auction— reasoning about individual needs and goals, and assessment of its own and rivals' performance expectations which may involve (in turn) other agent's needs and goals.

Thus it makes sense to think of auctions as a convenient *problem domain* for exploring, designing and testing agent architectures —in general– and trading strategies and tactics —in particular— that may range from simple reactive heuristics, to —say— intricate deliberative ones.

In fact, auctions are a truly convenient problem domain for these purposes since one can focus almost exclusively in the *individual* internal modeling of the trading agent because the *social* external behaviors are so simple. This consideration leads to three additional ones:

1. Objective agent testing requires careful consideration and explicit, stable, observable conditions —and tools.

2. If testing conditions and evaluation criteria are standardized, the performance of an agent in a standardized testing scenario can be tested competitively, as in a *tournament*, against other agents who also participate in a given auction.

3. If the social aspects are simple, and hence adapting an existing agent to this domain is straightforward, other people who are researching agent

Table 1.1: Individual Aspects in Agent Attitudes.

Aspect:	Auctions	Negotiation
Knowledge about the problem domain	U	U
Strategy–based tactics	U	U
Personality–based tactics	U	U
Beliefs about itself	U	U
Beliefs about others	U	U
Desires	U	U
Intentions	U	U
Emotion	NU	U
Communication	U	U
Planning	U	U
Communication	U	U
Evaluation (e.g.preferences or utility)	U	U

(U=usually; NU=not usually)

architectures or trading heuristics might also want to use this problem domain for testing their own agents.

These considerations were translated into achievements that are now reported in this dissertation. So, Chapter 7 discusses the test–bed environment FM97.7, which is an electronic auction house with rather flexible auctioning conditions *plus* the necessary tools to set up and evaluate tournament scenarios in which human and software agents can participate.

The participation of these heterogeneous agents is possible, because the interface requirements are crisply defined, and embedded in a remote control interface (or *nomadic interface* device).

But notice, by the way, that defining a tournament is in way designing an artificial market, thus FM97.7 can also be thought of in terms of what economists call *mechanism design*, as discussed in Section 2.6 of Chapter 2.

1.1.2 A Convenient Problem

The very simplicity of the *social* interactions of trading agents within an auction house, makes it natural to focus on the *individual* aspects of trading. Notice, however, that while bidding is a truly simple coordination convention, it nevertheless involves most of the *individual* aspects that more complex —or less structured— forms of trading such as negotiation require from agents.

Table 1.1 intends to show how close are the *individual* aspects of agent attitudes that are involved in bidding and those involved in negotiation. But notice that —as Table 1.2 shows— many of the *social* aspects which are fundamental for negotiation —and other apparently more complex forms of social coordination— are already involved in auctions as well.

Table 1.2: Social Aspects in Agent Interactions.

Aspect:	Auctions	Negotiation
Shared ontology	U	U
Shared contextual framework	U	U
Shared communication language	U	U
Common interaction protocol	U	U
Argumentation	N	U
Truthfulness	NR	U
Coordination strategies	NR	U

(U=usually; N=never; NR=not relevant)

Thus, one can explore individual aspects in a simpler social setting, and then transfer whatever lessons are obtained to the (socially) more complex trading environments such as open–ended multiple–encounter negotiation, for example. But one can also realize that in some of those more complex settings, the transference is *immediate* since the crucial trading features happen to be identical to those social conventions present in auctions. That is the case, for example, of stock trading in which a form of *double auction* is involved, or in haggling, where each bargaining turn is essentially a bid declaration. And, for that reason, whatever is learned, tested or developed for auctions, could ideally then be applied in these other settings in a relatively direct way.

These considerations are addressed in various parts of the dissertation. So, in Chapters 7 and 8, simple and more general variants of the dutch auctioning conventions are discussed, formalized and implemented, while in Chapter 9, using the same ideas that were developed for the description and formalization of the fish market auction, a form of very *unstructured* negotiation is formalized. And in Chapter 10, a formalization of agent–mediated institutions, markets, and auctions is accomplished, as a relatively straightforward extension of the ground-work for the fish market case.

Thus, auctions constitute a special, simplified form of agent coordination, certainly simpler, but nevertheless one whose constitutive elements will very likely throw illuminating light onto other more complex forms of interaction. That ought to make them a legitimate research topic. I will argue that they also constitute a good starting point for other interesting applications.

1.2 Auctions and Electronic Commerce

The Internet is spawning many new markets and Electronic Commerce is changing many market conventions. Not only are old commercial practices being adapted to the new conditions of immediacy brought forth by the global networks, but new products and services, as well as new practices, are beginning to appear. Hence, it is only natural that the strategic significance and the large economic potential of this area has been promptly acknowledged by the European

Commission (*cf.* [45]) and more recently by the USA (*cf.* [172]).

Electronic commerce has been identified both in the European community and the United States as a highly strategic area for research and development. In line with G7 directives [45], *Esprit* tasks 7.10 and 7.11 have identified specific areas and activities where the first European actions are being co-ordinated. More recently, the USA framework for Global Electronic Commerce [172] indicates a carefully planned strategy not necessarily in accordance with the European perspective. Substantial collective efforts such as *CommerceNet* [31] and more concrete ones, such as Amazon [3], Compranet [32] or Jango [83] are clear indicators of the emerging developments that will transform traditional commercial practices and institutions. Nevertheless, as pointed out by Negroponte [116], technology is already available for electronic commerce but new forms and instruments need to be attuned to actual market participants needs and concerns.

The Fishmarket Project aims to be a focused contribution to this very complex emerging reality. By developing new concepts, methodologies and tools based on multi–agent systems, and additionally, by contributing resources to address the issue of trust-building elements in Electronic Commerce.

There already are a number of examples of multi-agent applications in network-based trading, and the major promoting agencies —such as CommerceNet and the European Commission— acknowledge specifically agent technologies as fundamental in this market area. However if that market is to become an effective actual market, various non-trivial issues need to be addressed. Socio-economic conditions such as the adequate choice of technologies, innovative business practices, appropriate legal environment and timely entrance in these markets have been identified as determinant elements for a successful participation in this new competitive reality ([78]), and in all of these multi agent systems might be profitably applied. But three issues still appear to be particularly significant and difficult to contend with:

- Diversity, of goods, trading conventions, participants, interests.
- Dispersion, of consumers and producers, and also of resources and opportunities.
- Safety and security of agent and network-mediated transactions.

Thus it is not surprising that they have been the object of concern and positive attention both by the commercially interested parties as well as the academic community.

I propose to address those issues through a *mimetic strategy*, *i.e.* by adapting to the new context created by the Information Highway those traditional features that have proven effective in dealing with those same issues.

Traditional trading institutions such as auction houses –and the fish market in particular– have successfully dealt with the issues of diversity and dispersal. For instance, by defining strict trading conventions where goods of specified kinds (*e.g.* fish of certain quality) are traded under explicit time/location restrictions (*e.g.* twice a day at fixed times at the fish market building) under strict negotiation protocols (*e.g.* downward bidding). Participating agents are subject to terms and conditions –involving identity, credit and payment, guarantees, etc.– whereby the soundness of transactions becomes a responsibility of the institution itself, who in turn enforces those terms and conditions on its own behalf. In practice, the auction house upholds the fairness of the negotiation process and the accountability of transactions by defining and enforcing stable conditions on:

- the availability, presentation and delivery of goods
- the eligibility requirements for participating buyers and sellers
- acceptable behavior of participants within the site
- the satisfaction of public commitments made by participants

I claim that electronic market places will become acceptable by consumers and will become more conducive for actual trading if such *institutional* aspects are pertinently adapted to the new reality of global network–based trading.

In this spirit I advocate the implementation of **agent–mediated institutions** that allow for the definition and enforcement of explicit constraints on multi-agent interactions.

The Fishmarket Project aims to make a contribution there, by proposing innovative ways of addressing electronic market needs by combining various technological ingredients into new types of accountable tools and agent-mediated electronic commerce environments. Chapters 6 and 7 present *proof of concept prototypes* of these ideas and in Chapter 8, I identify immediate applications and suggest how to develop new ones in the near future.

1.2.1 Accountability Features in Agent-mediated trading

Current electronic commerce is probably a small fraction of its potential size, and a major inhibitor of its expansion is still the lack of confidence of the general public in complex electronic transactions such as those that are common in traditional market places. The G7 document, [45], states that

> Many businesses and consumers are still wary of conducting extensive business in cyberspace because of the lack of a predictable legal environment governing transactions and resulting concerns about contract enforcement, intellectual property protection, liability, privacy, security, and other matters.

This research addresses precisely that point. I intend to analyze, develop and test agent-mediated interactions for electronic commerce such as trading and negotiation. And I want to be able to identify features that make such interactions *accountable* —to agent owners and to other participants— and may therefore be handled through existing legal devices and standard business practices.

The underlying issue is none other than to have objective, observable and practical ways to *state and enforce* specific forms of behavior or limits to the actions or consequences of the actions of agents who interact with other agents *regardless of their internal composition* (i.e., be they software or human agents). If, for example, a given convention of behavior —say the rules governing an auction house— can be made explicit in such a way that an independent auditing can certify that a given software agent conforms to that convention and that an auction house failed to properly enforce the same convention during a particular auction, then the auction house would become *accountable* to the owner of any certified software agent that was treated unfairly in the auction. And consequently, in principle, the owner would be able to sue the auction house, and win.

A general theoretical proposal to characterize some accountable features and implement them is made precise in Chapter 10. The proposal is the result of assembling a number of elements that are motivated, introduced and developed along the dissertation, and a few demonstrable examples of devises and tools (that address accountability issues in the Fishmarket case) are reported in Chapters 6 and 7. Their practical impact is discussed in Chapter 8.

1.3 Auctions from a Formal Perspective

Accountable agent-mediated interactions in general, and auctioning in particular, involve worthy theoretical and technical challenges in addition to their empirical interest. They can be construed as formal systems and computational models with properties whose actual proof and testing may prove elusive, because such proofs involve, among other things, the dynamics and concurrency of interactions. Technically, these developments involve the combination of theoretical results and practical methods of different areas, such as negotiation, argumentation, artificial intelligence and law, learning, language design and implementation. In the following paragraphs I will talk about those that we have chosen to study within the Fishmarket Project and argue in favor of their interest. In the dissertation, however, I take a narrower view and deal only with the descriptive and prescriptive aspects of these topics. Predictive aspects are left for ulterior development.

1.3.1 Dialogical Aspects

Dialogues are pervasive and, to a large degree, unavoidable. Legal arguments, political debate, domestic disputes, didactic explanations, interviewing, psychotherapy, coordination of actions, negotiation, all tend to involve some form of dialogical interaction. But dialogues are also unavoidable since what is accomplished through them cannot be accomplished in a strictly monological setting, because some fundamental ontological, rhetorical or epistemic features would be lost. Thus, dialogues may be worth studying, although they are not simple entities. Certainly not from a formal perspective.

On one hand, dialogues involve multiple participants, who exchange illocutions in rich and complex languages. Thus, classical —*i.e.* monological, truth–semantical, non–dynamic— formal devices, are inadequate to deal with these complexities. But in addition, dialogues are typically *situated* (or opaque or unstructured), in the sense that participants need to react to the illocutions, depending on the conditions or elements present in a given context or situation. In many dialogical situations meaning is not necessarily established in an objective, *a priori*, form; nor are interventions subject to an objective, a priori, clearly expressible protocol. In typical dialogues, participants confirm, adjust, refine or establish their own meanings, intentions, beliefs and actions according to their individual interpretation of what is happening and what the other participants are saying. The first kind of complexity has been addressed through ad-hoc dialogical structures (cf. Hamblin [73], Rescher [137], or Hintikka [77] for different approaches), the second one has been the object of increasing attention, mostly from the idea of a situation, but also from the notions of *speech acts* and —closer to our concerns— *conversation* (c.f.[151, 25])

Certainly there are dialogical situations which are irremisibly opaque. That is the case, for instance, of psychotherapy, domestic disputes or everyday conversation, where meaning and commitments are mostly established through highly unstructured dialogical interactions. But then there are other contexts —such as auctions and other similar forms of mediated trading and structured negotiation— where *a priori* univocal shared interpretations (transparency) and more or less strict interaction protocols are not only desired but enforced.

From a formal perspective, agent-mediated auctions still contain intensional, structural and functional elements that are characteristic of complex dialogical contexts, but lend themselves to a much more straight–forward treatment because of their explicitness. For that reason I took them as the starting point for a systematic study of dialogical systems.

In this dissertation I break ground in this direction. I first impose a dialogical outlook on everything that happens within the auction house, and then focus on those contextual (social) elements that enable agents to exchange illocutions —the dialogical framework, the interaction protocols and the restrictions that these impose on the individual participating agents illocutions– within highly structured environments.

These two decisions are reflected throughout the dissertation:

1. As a *dialogical stance* (introduced in Chapter 4) that describes multi agent systems, and the fish market in particular, in dialogical terms.

2. As a dialogical methodology for the specification and implementation of the fish market auctioning conventions (Chapter 4), which is extended first to express simple variants of the fish market (Chapter 7), then to deal with persuasive negotiation (Chapter 9) and then to deal with agent-mediated environments in general (Chapter 10).

3. In Chapters 5 and 10, as formal developments: a dialogical formalism to represent the contextual elements of the fish market institution, negotiation

and agent-mediated institutions, and the social crust (so to speak) of agents that participate in the Fishmarket (Chapter 5) or in persuasive open-ended negotiation (Chapter 9).

4. In a formal characterization of the accountability of agents, as a way of limiting their dialogical behavior through "governors" (Chapter 10) within an agent-mediated institution. And, finally,

5. As the computational implementation of dialogical agents, auction houses and accountability enforcing tools (chapters 6 and 7).

Whatever results from this effort should give light to what can be done to model the full dialogical system —and not just the contextual elements— and perhaps other far less-structured interactions. The first glimpses are reported in Chapter 9.

1.3.2 Trust and Accountability

Even though that dialogical direction appears to be highly promising, auctions (and the fish market example), have the added attraction of being a convenient case study for other types of formal development, those specifically related with *trust* and the accountability features mentioned in Subsection 1.2.1. This justifies another research line that has been partly addressed in Chapter 10, to provide methods for formalization of accountability features of agent-mediated interactions and agent models that satisfy them. In addressing it, we opened two complementary research topics: agent-mediated institutions and governed agents. Both have intrinsic interest.

Agent–mediated Institutions

The study of auctions as highly structured dialogical interactions —and the association of these with the economic-theoretic notion of *institution* (*cf.* North's [121])— led to the more specialized notion of *agent–mediated institution*. Intuitively, these are a sort of virtual places where agents interact according to explicit conventions. We thought it worth studying them from a more formal perspective. And given this perspective, we thought it would be possible to identify and test accountability features *formally*. This led to the timid characterization of trust-related features in agent–mediated institutions that is suggested in Chapter 10 and partially exemplified in Chapter 6.

The next step would be to devise robust formal methods for specification and testing of accountability features in agent-mediated interactions. The idea is that in agent-mediated institutions, all agent interactions can be reduced to illocutions. Therefore, accountability is expressible in terms of how illocutions are constrained, or what characteristics can be predicated and tested on illocution utterance, and on illocution reception. Identification of relevant features

—for example "fairness", *i.e.,* that all participating buyers in an auction have the same opportunity to bid— appears to be rather straightforward, although it is really not so. And more elementary features such as "synchronicity" or "vivaciousness" emerge as fundamental. The problem is apparently very fertile and is sketched in Chapter 10.

Governed Agents

But even assuming the problem of specification and testing of accountable features is solved, these features ought to be *enforced.* If we want agents to be trustworthy, we need to be able to enforce the institutional conventions on them. Even if we cannot have any way of knowing what is inside them, or if we cannot claim any true control on their operation. This gives rise to another proposal addressed in Chapter 10: "to devise formal methods for the enforcement of accountability features in agent–mediated interactions".

For this task I again resort to a *mimetic strategy.* In the actual fish market, in Blanes (Girona), buyers interact with the auctioneer through a sort of "remote control" device that allows them to bid. Could we take that simple intuition, turn it into a more general rule-enforcement notion and implement a reasonably robust and powerful version of it?. Yes. We came up with the idea of an agent/co-agent pair in which the co-agent "governs" the agent's illocutory behavior. In its simpler conception the co-agent acts as a two-way illocutory filter, shielding the institution from malicious illocutions and channelling to the agent all pertinent messages from the institution. In more sophisticated versions, this "governor" actually supervises the agent and sees to it that the agent behaves properly by taking action —for or against the agent— whenever necessary.

1.4 Colophon

What in this chapter's epigraph appeared to be just a simple question of "to bid or not to bid", turns out to be a simple-to-express problem domain, that allows for the exploration of subtle theoretical issues and the construction of promising tools for the emerging Information Society.

A schematic view of what has been achieved so far can be seen in Figure 1.1.

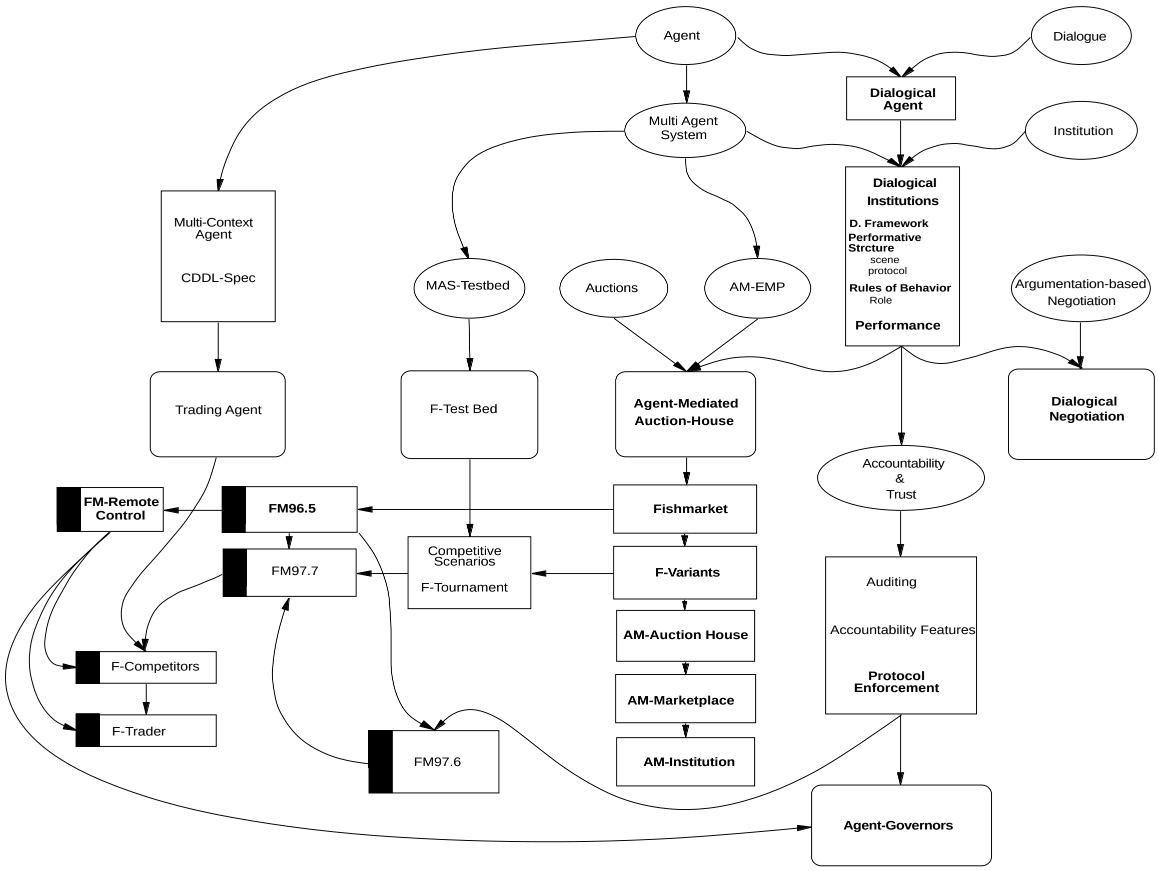

Figure 1.1: Main Contributions of the Fishmarket Project.

Chapter 2

Background and State of the Art

> Salomon saith: *There is no new thing upon the earth.* So that as Plato had an imagination, *that all knowledge was but remembrance;* so Salomon giveth his sentence, *that all novelty is but oblivion.*
>
> Francis Bacon: *Essays* LVIII[1].

2.1 Related AI Problems

This dissertation deals with a sort of *Multi Agent System* in which participating agents are assumed to be capable of engaging in dialogue, hence I call them *dialogical* agents. Although I do address the issue of defining and implementing specific agents, my focus is not on these specific agents, but rather on the common elements that these dialogical agents need to interact among each other. I define a framework which will allow me to describe both, multi agent systems *and* the environments where those dialogical agents interact with other agents subject to explicit shared conventions for interaction and behavior. I call such framework a *dialogical framework*, and the resulting environment, *dialogical institutions*. Furthermore, I illustrate these constructs through a running example of an electronic market place: an *agent mediated auction house*.

In order to characterize the intuitions underlying the *dialogical* agents, frameworks and institutions, I draw from classical notions of dialogical systems and

[1] Cited by J.L. Borges, "El Inmortal" (El Aleph).

address concerns that are closely related to those of the so–called *computational dialectics* community.

I am interested in the underlying intuitions, but also in the formalization and in the implementation of these ideas. Thus the classical notions, tools and techniques for *agent theories, architectures and languages* (as presented for example in [190] will be a part of my concerns, tools and techniques. However, due to my focus on the social interactions of agents I also touch upon some topics that are central to what is being called *coordination science* or the *Language–Action Perspective* ([42]).

Finally, I am also interested in the possible application of these dialogical constructs, thus on one hand I analyze the case of electronic auctioning; and on the other I explore the generalization of these concepts to automated negotiation and, in general, to electronic commerce. Because of these applications, I touch upon issues that have been addressed by the people who work in what is called *Market–based Programming* or *Information Economics*, as well as the area of *Automated Negotiation*.

In the following sections I will attempt to give a succinct view of what the current situation is in these areas, as they relate to this dissertation, and what are the —sometimes distant— origins of the more original contributions of this work.

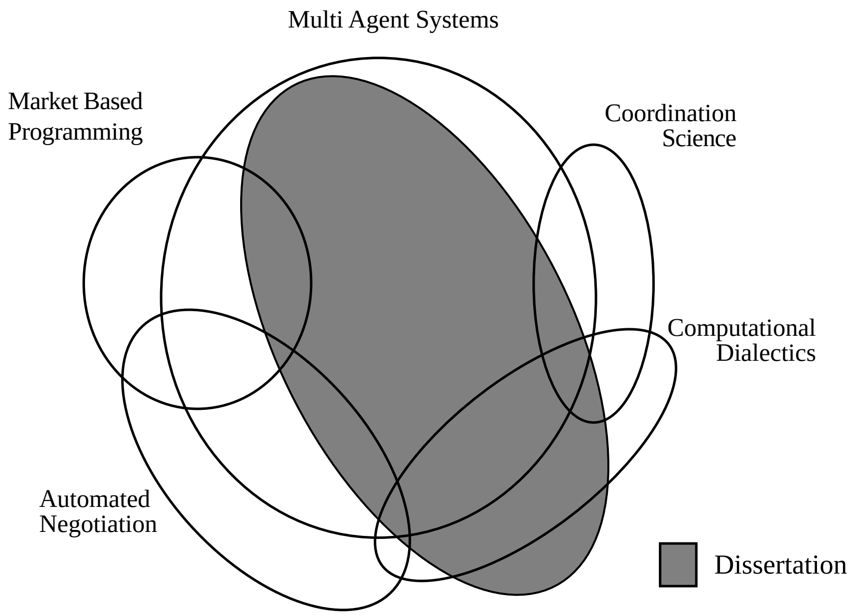

Figure 2.1: Topics addressed in this dissertation and their relationship with AI fields.

A schematic description of the positioning of this thesis among AI fields is given in Figure 2.1. As a complement, Figure 2.2 shows a minimalist description of the authors whose ideas have influenced this work.

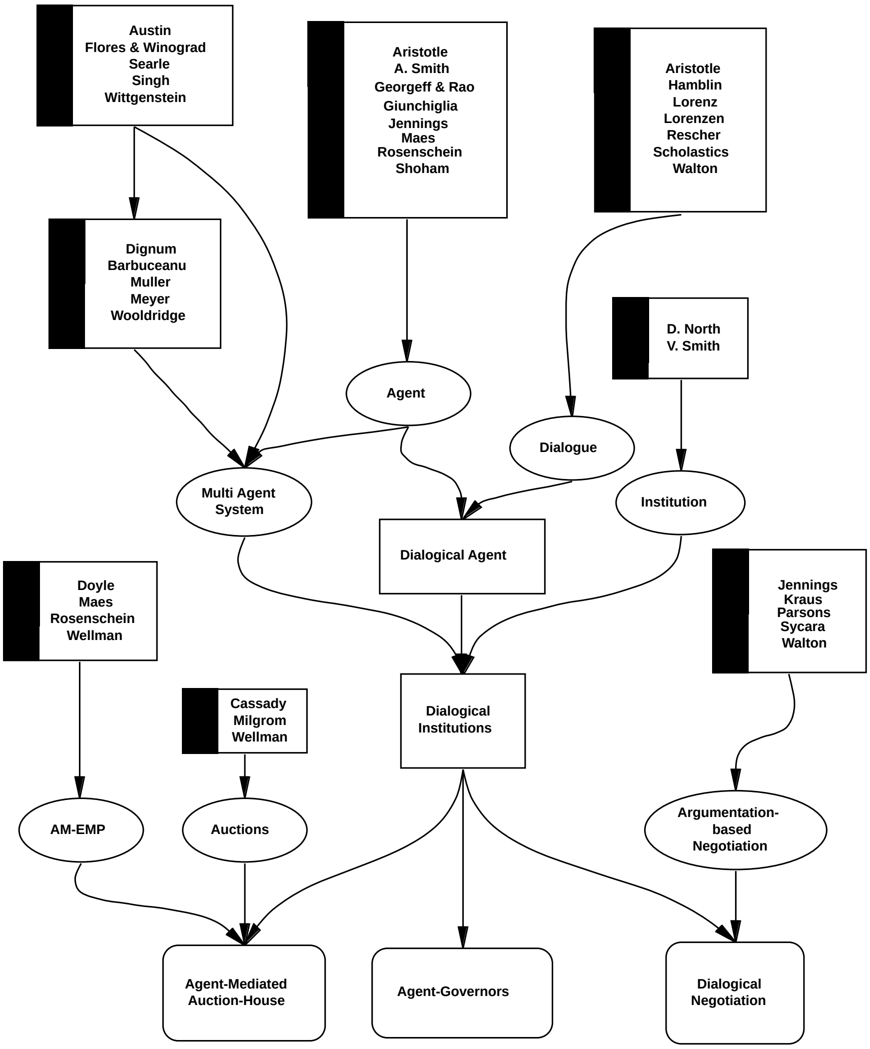

Figure 2.2: Principal lines of influence for the ideas in this dissertation

2.2 Agents and Multi Agent Systems

2.2.1 Agents

An agent —in AI (see e.g. [189])— can be seen as a computer system (hw/sw) which

1. has a degree of autonomy in determining its behavior,
2. interacts with humans and or other agents,
3. perceives the environment and reacts to it, and
4. exhibits a goal directed behavior.

The notion of **agent** to refer to an "entity that acts with a purpose, within a social context" is already present in Aristotle [7], and is developed by the Scholastics (Cf. e.g., Aquinas [5]) and other Metaphysics schools up to the present (e.g. the works in [177]).

The legal notion of agent as "a person who acts on behalf of a *principal* for a specific purpose and under *limited delegation* of authority and responsibility" is present in a restricted form (and with a different terminology) in prætorian roman law (cf. Kirschenbaum [91]); however it was elaborated thoroughly in the ensuing Roman (and Napoleonic) tradition and in English Common Law, and there takes essentially its current forms of *agent* in civil law and *agency* in commerce law.

Economists also use the term agent with similar "purposeful action on behalf of a principal, within a context" connotations, starting with Adam Smith, however the term has additional connotations that are not present in the AI usage (as can be seen in for example Arrow's [9]).

The earliest use of the term agent in AI seems to be the one by Rosenschein and Genesereth [141] (1985), in which the essential notion of "a program that is capable of executing an action vicariously" is clearly established (with a strong Economics flavor), even with connotations that correspond to what a few years later Dennett denominated the *Intentional Stance* [39]. Although Hewitt (in [76], and in later writings), advocates a notion of actor in an open system that is reifiable as an *bona–fide* agent. *Teleological* components have been part of many notions of AI agency (e.g. Shoham [154], Genesereth [58], Cohen and Levesque [28]) that have co-existed (in more or less belligerent terms) with so-called *reactive* conceptions (like Brook's [21]). And while that debate was fought in the theoretical arena, the anthropomorphization / tool–ification distinctions were being established thanks to the construction of actual working software agents (e.g., Maes [101], Etzioni [48] or Jennings [87]). Two populations of agents started to emerge. One, *mobile agents*, in which the software agent is "able to go and do things for its owner elsewhere" ([101, 48]), and others that would meet and interact with other agents within a more or less confined environment ([87]). The second type gave rise to the term *multi agent systems* to denote at least four not exactly identical types of entities: a collection of agents, some forms of simulations and experiments with collectivities of agents, a complex system in which certain actions are performed concurrently by independent processes, and the environments where autonomous agents might meet and interact. By 1992, however, these notions had been well enough acknowledged by the AI community and enough consensus was available for Mike Wooldridge and Nick R. Jennings ([190, 189]) to be able to make a convincing characterization (and survey) of agents and multi–agent systems, and propose a classification that has become standard.

In [190], Wooldridge proposes two notions of agency. A **weak** notion in which agents exhibit four basic properties:

- **autonomy** (agents act without human intervention)
- **social** ability (agents interact with other agents)
- **reactivity** (perceive the "world" and react to it)
- **situatedness** (exhibit some goal–oriented behavior[2])

And a **strong** notion in which a commitment is made to a *computer system*, that has *mentalistic* (BDI) attitudes and even possibly *emotional* attitudes. While he mentions other attributes that have also been ascribed to agents, although not as systematically: *mobility, veracity, benevolence* and *rationality.*

In [189] Jennings and Wooldrige establish three fundamental technical distinctions to describe three types of issues that agent developers face and for which pertinent distinctions became quite useful:

1. *Agent Theories* is concerned with the question of what an agent is, and the use of mathematical formalisms for representing and reasoning about the properties of agents (cf. [28, 136, 190, 62]).

2. *Agent architectures* include the processes from specification to implementation of software or hardware systems that satisfy the properties specified by agent theorists (see for example, [174, 72, 50, 49]).

3. *Agent languages* are regarded as software systems for programming and experimenting with agents which may embody principles proposed by theorists (see, for instance [154, 14]).

An orthogonal dimension for the domains of application of agents was sketched by Wooldridge and Jennings (in, for example [189]) but no systematic treatment of the existing and likely areas of application for agents was there developed.

The field, due in part to its eclectic nature, but also because of its natural affinity for Internet–based applications, has become one of the most active in the AI community in recent years. The general AI conferences like IJCAI, AAAI and

[2]In this dissertation I use a slightly different notion of *situatedness*, which is in accordance with that of, for example, Barwise and Perry [15] or [26]. In this later notion, intentionality is presumed as well but also a capability to *change goals as a reaction to a new situation* or state of the world.

ECAI reflect that phenomenon both in numbers and diversity, but also in its most opportunistic aspects. Sociologically, the nuclear agents community was mostly part of the DAI community in whose conferences and workshops seminal works were published. Today, four regular conferences and workshops on agents draw the specialists' community and appear to have achieved a reasonably high quality standard: ATAL, Autonomous Agents, ICMAS and MAAMAW. However more specialized ones are appearing and a journal has been recently announced.

Other surveys have appeared after [189], (for example [165] and [59]) in addition to specialized mailing lists, newsletters and URL's (e.g., [171, 152]) [3]. These and the proceedings of the above mentioned specialists workshops and conferences constitute accessible and up to date reference for the more significant trends in this rapidly expanding field.

2.2.2 Agent Theories

Many authors have thought of agents as *logical theories* that take environmental stimuli as formulas which are then contrasted, tested, transformed and deduced within or against those theories [43, 169, 174]. The theories may be flat [43], or highly structured from a hierarchical point of view [169, 174], and they can be intentional or reactive depending on the degree of deliberation the agent is supposed to have. Intentional agents are also referred to as *BDI* since Georgeff and Rao ([135]) presented a convincing argument and prototypes of working agents that could reason about Beliefs, Desires and Intentions. Purely reactive theories have seldom been proposed in spite of the challenge by [21], however agent theories that involve a mixture of deliberative intentional elements, together with ad-hoc heuristics or simple triggering conditions are not infrequent [101, 72, 38].

The formalization of these ideas may take different forms, but mostly there are two schools: *reificationists* and *modalists*. The first attempt FOL theories in which intentional–like operators and formulas that involve them are reified through *ad-hoc* FOL parameters, while the second attempt *ad-hoc* modelization of the intentional–like parameters with appropriate modal operators.

In [120] we proposed a "multi-context–layered architecture" for deliberative agents in which we adopted the "logical theory" conception, which I now present in Chapter 5 with minor modifications. We originally called it "layered" to indicate that it had an internal structure of different independent theories that would exchange formulas through a type of inference rule called "bridge rule". We suggested that the choice of the theories themselves was something that depended on the specific MAS and the tasks agents were supposed to execute, but our proposal allowed for BDI architectures as well as more reactive ones. The formalization of this proposal was based in the formulation by Giunchiglia *et al.* [61] of *context logics*. However our proposal includes the special requirement of a communication theory in every agent, and a shared ontology and communication language for all participating agents. These requirements constitute the basis of

[3] And there is a standard AI text with a strong agent-perspective (Russell and Norvig's [144])

the dialogical stance that I develop further in Chapter 4. Our proposal happened to be affine to some ideas presented by Dignum [43] and Traum [167], however the first has a stronger *Language–Action Perspective* flavor and commits to specific contents in the theory, while the second is more interested in natural language aspects of the communicational interactions.

Haddadi [72] holds also a communicational view of agents, based on a formalization of Searle's Speech Acts—as is the case in Dignum. She also proposes an architecture which is hierarchical and does not commit on any special type of application, but rather suggest universality of her constructs.

Developed speech acts based agent theories with action-relevant semantics are presented by Vandervecken [175] and Singh [160].

2.2.3 Agent Architectures

One may have a rather elegant abstract definition of what an agent is, but then one has to say how it will become a software object. This task is what Wooldridge ([190] and elsewhere) calls the agent architecture.

One alternative is to have an executable notation to start with, and the agent theory being expressed in that notation, the architecture is immediate. That is the approach of Fisher and Wooldridge in [50], for example. Other authors propose some sort of an equivalence between a theoretical construct and an implementational one. While for some that equivalence can take a formal justification (e.g., Rao [135]), for others it is a more loosely related specification convention (for example, Barbuceanu's [14]).

In [120] we took the formal road to the second choice, by using an extended version of Peleg's Dynamic Logic [127]. The theories (with their deductive components and the bridge rules) are taken as primitive programs. The notion of deductive closure is formalized in the extended Peleg's formalism, and by indicating alternative orders of execution of the different theories, an agent's resulting program is defined. The MAS results simply from the concurrent execution of all participating agents. I discuss it in more detail in Chapter 5.

In Benerecetti *et al.* ([17]) a hierarchical set of theories constitute an agent and bridge rules are defined between theories in the same way as between units in this framework. The main difference between their work and our's lays in the fact that they do not study the communication between agents nor the semantics of the dynamics of reasoning. In the Fishmarket project, we are now exploring a further generalization of these ideas, in order to treat generalized *dialogical structures* –be them agents, interacting groups of agents, or groups of interdependent multi-agent systems– in an abstract uniform way.

The relations between this proposal and Dignum's [43], Bretier Sadek's [20] and Traum's,[168] are less immediate, but no less significant. These three works, as well as [120], on which Chapter 5 is based, acknowledge the fundamental importance of dialogical aspects of multi-agent interactions, but each in turn addresses complementary issues in this respect. While Dignum and Van Linder [43] presents a detailed four level agency model and in particular a very rich treatment of the so called social level, our focus has been in the abstract "layering" of these levels. But both proposals share a similar understanding of the communication/action relationship and this is reflected in similar operational treatment of specific speech acts. Nevertheless, formal interpretations respond to different preoccupations. We were concerned with a computational interpretation of deliberation and illocutions, hence the dynamic logic approach; while [43] advances a remarkable interpretation of meta-actions as model transforming mappings. It should also be noted that although both proposals treat sequences of speech acts, none addresses explicitly the underlying fundamental aspects of dialogical roles, protocols and, in general, the overall discourse structure. I am convinced this is a very important task, and one in which fruitful future collaboration would be desirable.

Bretier and Sadek present in [20] a concrete theory of rational interaction proposing a specific reasoning method to implement it, while, in Chapter 5, I am concerned with more descriptive formal aspects. But even though the *foci* are quite different, affinities of the two approaches are more than superficial, as evidenced, for instance, in the implementation of reasoning about action in both works.[4]

Likewise, D. Traum, in [168], deals with specific speech acts and some general properties of agents and agent communication that can be readily incorporated into this specificational framework. Moreover, [168] brings into focus the very important aspect of planning in discourse, which is quite relevant for the description and implementation of complex agent interaction protocols [5]. Agent interaction protocols is one aspect of multi-agent systems that we, in the Fishmarket project, have found to be particularly significant, both from a theoretical and an applicational perspective. The experience with the fish market bidding protocol suggests that intended formal properties, as well as those inherent to a given implementation, result elusive even when institutions are static. In order to deal effectively with complex negotiation protocols and with emergent and *ex-post* agent interaction protocollization, the kind of tools developed by Traum may prove valuable.

A promising venue in this direction is offered by "π–calculus" (cf. [109]) and a first formalization of the Fishmarket using it has been started by Julian Padget and Russell Bradford ([124]) from the University of Bath . In π–calculus a rich description language for concurrent and distributed processes is available. Thus issues like synchrony, collective speech acts, process interleaving, that are opaque in the CDDL description become quite nitid in π–calculus. Furthermore, it is possible to debug and test the specification directly, since the notation itself is quite suggestive and formal tools are available for that purpose.

[4]In [20] reasoning about action is done by means of events, that can be combined by sequence (;) and undeterministic choice (|) and the implementation of the reasoning method is based on a saturation method that terminates. To do so, the number of derivable formulas from a KB must be finite. In the execution control specification of Φ, we applied analogous techniques, and, in particular, closure operators require a finite number of possible illocutions, and a finite number of conclusions being generated by inference rules and bridge rules in order to terminate.

[5]In [167], D. Traum develops a powerful plan execution ontology.

2.3 Dialogical Systems and Computational Dialectics

Dialectics, dialogue and *dialogical* are affine terms. They all come from the greek $\delta\upsilon\alpha\varsigma$ which presupposes at least two agents interchanging expressions with the purpose of modifying the beliefs or commitments of at least one of the participants. Aristotle [7] introduces the term *dialectics* to describe a special type of argumentation in which a dubious premise (the *thesis*) is proved valid by refutation, but recognizing the bounded rationality of participants he describes a protocol for defending and attacking the two sides of the thesis. Other connotations have been added to the term since[6]. By the early sixties Lorenzen [99] proposed an intuitionistic completeness proof, based on a form of *dialogical* proof procedure. The term was taken later by others like Hamblin, Woods and Walton, and Rescher [73, 181, 137] to mean different generalizations of dialectical forms of argumentation. It has been adopted in the "informal logic" community to mean any sort of formalism that involves some form of dialogue [35, 181].

There is no prevalent taxonomy of the many forms these dialogical systems may take, but most authors (starting with Aristotle [8, 6]) acknowledge relevant differences in the teleological aspects of the dialogue. Other aspects such as the epistemic, rhetorical and structural aspects of dialogues are systematically studied, and also permit richer distinctions. Four types: argumentation, learning, coordination and cathartic (emotional) dialogues are worth distinguishing, although in most everyday examples different types of dialogue are usually embedded into one another[181, 35, 118, 180].

What I advocate as the dialogical stance (in Chapter 4) for multi agent systems is grounded in those classical notions of dialectics, although no effort was made to take advantage of the refutational dynamics of the properly *dialectical* tradition. I have been interested in characterizing dialogues [66, 119][7], in implementing dialogical systems [115, 114] and in their applications to Knowledge Based Systems [65, 117]. From that experience I decided to focus on the structural aspects of dialogical systems that would be useful for agent coordination. Thus the focus chosen in this thesis for the treatment of auctions and negotiation, although the aspects of persuasive argumentation included in Chapter 9 are closer to the work of the Computational Dialectics community.

Computational Dialectics. CD is an interdisciplinary field at the intersection of Artificial Intelligence (AI) and Argumentation Theory (cf.van Eemeren et al.[173] that uses computer systems for modeling and supporting dialectical processes, i.e. argumentation and negotiation among several actors or agents. The state of the art is reflected by the recent publications of the leading researchers in the field, including [55, 71, 100, 132, 180, 179].

[6][137, 181] have accessible historical outlines.

[7]In [119] we present an argument for strong irreductibility of dialogical to monological reasoning

2.4 Coordination Science

Originating mainly in Searle's Speech Acts Theory [149], a strong current of language *pragmatics* has been influencing some of the approaches in Computer Science and AI in particular.

The crucial contribution is the distinction — advocated by Searle, but also by Wittgenstein (e.g. in [187]), Austin ([11]) and others— that there are other types of formulas beyond assertive propositions (as Classical Logic is preeminently concerned with) with the concomitant insight that certain *illocutions* are essential for the social *coordination of actions*. The impact of these realizations has been theoretical as well as applied.

The formal impact has come in the form of gallant attempts to build logical systems that deal properly with declarations, requests, etc. e.g., [151, 160, 16]. Which in turn have propitiated the clever utilization of pragmatist intuitions in the analysis and formalization of communication acts, for our case, in those communication acts that involve agents [43, 72, 14, 168]. The applied impact has resulted in the construction of tools that focus on the pragmatist distinctions.

In [151] Searle and Vandervecken advance a formalism for Illocutionary Logic in which the basic ontology for that project is carefully developed and discussed. In [175] a semantics is finally presented. Independently, Belnap in [16] introduces an alternative formalism for illocutory acts that is then taken over by Huhns and Singh to produce [160].

A considerable part of the applied insight on speech acts has been instigated by a disciple of Searle, Fernando Flores, and his collaborators. In the early 80's, Flores, Ludlow and Medina Mora developed a speech-acts founded electronic mail, *The Coordinator* which was based on Flores' PhD. thesis [52]. Then Flores and Winograd published a polemic and influential book [186] in which they advocated a "*language–action perspective*" for the design of computer supported cooperative work tools and practices. Those ideas matured into a methodology and automated tools for "business process management". One of the contributions of this latter work was a speech-acts standardization of the notion the *workflow paradigm* which became influential in the Computer Supported Cooperative Work community, and was incorporated into CSCW commercial tools such as Lotus Notes ([105]). This notion of workflow describes complex coordination interactions in terms of client–server *conversations*. Each conversation involves four well identified stages:

1. A *request (offer)* stage. In which the client request the server (or *executant*) to perform a canonically expressed action (that is, one involving clear satisfaction conditions, timing, etc.)

2. A *negotiate accept* stage. In which client and server clarify and punctualize whatever is needed in order either to agree on the execution of the (modified) action, or not to execute it.

3. An *execution* stage. In which, the server carries out the agreed action, perhaps by delegation or through other subsidiary action–conversations.

4. A *termination* stage. In which the server reports back to the client the completion of the action, and the server declares the satisfactory termination of the request. An "incompleteness" report is also possible, and then a corresponding reply of the client closes the conversation, with the possible opening of a new one.

In addition to this elegant simplification of Searle's canonical illocutions, they introduce a convenient set of failure conditions and the corresponding "incompleteness recovery" actions[8].

In [105], interactions are taken to be "commitments to act " (in Searle's terms), and are uniformly represented in canonical four-stage cycles (demand-negotiation-execution-acceptance), and interpreted in terms of "commitment satisfaction ". Although this approach has a significant theoretical background (as suggested in [52, 186] and personal communications), most of its written versions are proprietary. It is the methodology —as reported in a few case studies or the software products (AT's *workflow*) [185, 102, 40]— where details can be glimpsed at. Flores, Medina Mora, Winograd and Ludlow profess an ostensible dislike for classical AI tenants, and seem to avoid any logical formalization, although Austin-like distinctions underlie their illocutionary treatment, and Singh-like semantics may prove adequate for a rather comprehensive formalization. They do not talk of "protocols ", but their commitments map is, in a way, a "scene outline ". I think that their emphasis is on "building tools for effective communication ", while ours is on an institution that facilitates agent interactions[9]. Perhaps the efforts to accomplishing both purposes (when both are focused in the social aspects of communication) tend to produce similar results no matter how different the ideological positions might be[10].

2.5 Automated Negotiation

Negotiation is proposed in Distributed Artificial Intelligence (DAI) as a means for agents to communicate and compromise to reach mutually beneficial agreements [33, 189]. Negotiation is especially beneficial in multi agents systems (MA), where the agents are self-motivated [142] as in the electronic market place. For example, Sycara [166] presented a model of negotiation that combines case-based reasoning and optimization of the multi-attribute utilities and applied it to labor

[8]Flores and his collaborators are difficult to follow in print, although they are gifted (albeit) occasional presentators. However [186] deserved a passionate review in the AI Journal which was reprinted in [25]. This review however did not stress the "Language–Action Perspective (LAP)", as much as the "situated reasoning" notion of conversation. A renovated and quite more formal approach to LAP has recently appeared in Europe. A first conference was held last year ([42]), and it now seems to be a yearly event where the debate centers around the Flores-Winograd-Ludlow-Medina Mora ideas.

[9]They abhor the idea of an agent, although their "servers" are reifiable as agents

[10]I have had the rare opportunity to keep a running conversation with them that now lasts well over a decade, and although our common interests have been many and varied I have to confess that the conversation has lasted, probably, because of the belligerent tone it tends to keep.

negotiation. Kraus and Lehmann [93] developed an automated Diplomacy player that negotiates and plays well in actual games against human players. Other models of negotiations were used for resource allocation and task distribution (e.g., [33, 184]).

Much of the existing work on agent-based negotiation is rooted in game theory, (e.g. Rosenschein and Zlotkin's [142]). Although this approach has produced significant results, and has been successful in many negotiation domains, it embodies a number of limiting assumptions about the agents' knowledge and utility functions. Even when this approach is extended, as in Kraus' [95], to cope with conditions that change over time, it does not address the problem of how these changes can be accomplished by one agent influencing another, nor does it cope with the problem of introducing new issues into negotiations.

Changing preferences through persuasion, in multi-agent systems, was addressed in Sycara's seminal work on labour negotiation [166], and extended and formalized by Kraus *et al.* [94]. However, this work is set within the context of a particular agent architecture, assumes a fixed and shared domain theory, and deals with five particular types of argument (threats, rewards, appeals to precedent, appeals to prevailing practice, and appeals to self-interest). Furthermore, Kraus *et al.* do not deal with the introduction of new issues or imperfect rationality.

In contrast, the model developed in [157] (that I reproduce in Chapter 9), accommodates partial knowledge, imperfect rationality and the introduction of new negotiation issues —which are relevant features in many application domains— while only imposing minimal requirements on agents' internal states and using a general rhetorical language.

2.6 Market-based programming

A significant body of literature on multiagent modeling in AI has been inspired by Economics. Classical notions of agency (Arrow [9]), bounded rationality (Simon [158]), Game Theory (Binmore [19]) or Decision Theory (Raiffa [133]) and economics-oriented formalizations of rationality have been used by, for example, Simon [159]; Doyle [44]; Sandholm [146]; Wellman [182]; Russell [145]; Zlotkin and Rosenschein [193] to deal with agent rationality in domains that are similar to those explored in this dissertation (mostly negotiation and coordination). But these works are concerned, primarily, with the characterization of rational behavior of the agents from a *predictive* point of view; while —here— I will be concerned exclusively, with the *descriptive* (dialogical) negotiation context.

The price–fixing mechanism is a central concern of the "Contract Net " [161]. The Fishmarket proposal is in a way very akin to theirs, since we both bring forward the need for an "institutional" treatment of agent interactions. But in another sense, ours is an almost exact opposite of their proposal. A contract net convention is adequate only when some conditions are satisfied by the network over which the contracts are negotiated. These conditions have to do with the size and "openness " of the network. Advertising, searching and agreement in a contract net have exponential features that may significantly affect performance, and produce obvious clogging and quickly turn the institution ineffective. If the network wide and open as the Web (or as many regular market communities) a structured institution –like the fishmarket– can be more efficient (as long as appropriate enticement to users is achieved). Our proposal can be scalable along many dimensions –admissibility conditions, types of goods, timing,...— and becomes effective through the quality of management performance that is insensitive to network issues –permanence of the auction sessions, treatment of sellers and buyers, accountability of the auction house.

In analogous fashion, Market–based Programming (as in for example [183, 170, 147]) ends up constructing agent–mediated systems that are rather close to the ones we have built in this project, although the theoretical outlook appears to be exactly symmetrical to ours letting the market coordinate itself through setting prices for services in an efficient manner.

Economists have dealt with auctions in a way that is markedly different from ours. Classical emphasis being mostly on Game-Theoretical description of price-setting strategies and characterization of optimality conditions [108, 104]. However, some recent work with more empirical concerns, [98, 27, 13, 12] may possibly benefit from the use of controllable environments like ours to carry out experiments on actual bargaining situations. North's reflections on "institutions" is quite relevant to our own proposal, though his emphasis is more on assessing the value (and costs) of institutions, not in the description, modeling or construction of the institutions (as we are here) [121]. Agent mediated market–places as for example the Bazaar and Kasbah projects (cf. e.g. [24, 70]), on the other hand, are much more similar in motivation and development to ours, although the theoretical and the specific forms of interaction may differ.

Part II

The Fishmarket Metaphor

Content

In this part, I discuss the Fishmarket Metaphor in detail.

I begin, in Chapter 3, by introducing one example of a real fish market, the one in Blanes (Girona). The description is rather detailed because it will serve as a concrete reference for the rest of the following chapters. It is preceded by a brief discussion of the standard notions of auctions and price-setting mechanisms —and some historical comments— to help establish the terminology and concepts that will be explored in the rest of the dissertation. To give a flavor of the more subtle issues involved, though, I finish by examining some of the institutional aspects of the Blanes *Llotja* that are amenable to be reconsidered in agent–mediated auctions.

Chapter 4 can be divided in two blocks. The first one introduces the conceptual machinery –the dialogical stance— that is used throughout this dissertation to describe the fish market and then extended to produce other institutions. The second block takes that machinery and produces a *dialogical description* of the fish market institution. The dialogical stance entails a methodological proposal by which multi agent systems are seen as dialogical processes where agents coordinate actions by exchanging illocutions and reacting to them. The description of the fish market as an agent–mediated institution shows how this stance can be put to work with highly structured interactions. The technical components introduced here (notation, constructs and distinctions) are used in the rest of the dissertation as well.

Chapter 5 serves two purposes, first it stresses the difference between *agents* and agent–mediated *institutions*; second, it shows how the dialogical stance can also be applied to individual agents, whose internal architecture can also be understood as a dialogical process of some type. Chapter 5, also proposes a formal agent architecture based on Giunchiglia's context logics, and proposes a specification formalism based on Dynamic Logic.

Chapter 6 reports on the implementation efforts that have produced a computational version of the Fishmarket institution (FM96.5), based on the description of Chapter 4. The implementation difficulties of the bidding protocol and the need to guarantee compliance by part of external agents resulted in a *nomadic* *interface* device that is the only means through which external agents interact within the institution. This idea, which is again a consequence of the dialogical stance, is discussed here and re-taken in Chapter 10 to introduce the notion of *governed agent*.

Finally, in Chapter 7, the specific conventions of the Fishmarket institution are (locally) modified to produce a numerous collection of *F-variants*: institutions that are similar to the Fishmarket but constitute different auctioning conventions which may be of interest for experimentation. With these F-variants in mind, FM96.5 is turned into an architecture-neutral test–bed for trading agents, and prototype auditable and flexible agent–mediated auction houses are presented.

Chapter 3

Auctions and the (real) fish market

Mercatum *autem a* commercio *nominatum. Ibi enim res vendere vel emere solitum est; sicut et* teloneum *dicitur ubi merces navium et nautarum emolumenta reddentur. Ibi enim vectigalis exactor sedet pretium rebus inmpositurus, et voce a mercatoribus flagitans*[1].

Isidoro

3.1 Preamble

Picture the situation:

The village fleet is unloading. The sea-weathered fishermen's faces are starkly carved by the slanting morning light. Shining slivers of living silver slip into coarse wooden boxes. And while buyers inspect the day's catch with carefully studied displiscense, boats, gears, produce and bystanders occupy their proper places in what, by all evidence, seems a well-rehearsed choreography.

Suddenly, a loud, clear voice resounds under the high vaulted ceiling. It is the master auctioneer calling for attention. The anticipated litany starts: "*Anchovy: twenty four boxes: 1300, 1295, 1290,...*" A sharp "*mine!*" by the woman next to you brings the series to a halt; a discrete ruffle propagates in all directions and quick gestures indicate some sort of public acknowledgment of a transaction.

[1]We use *market* or *commerce* to designate the place where things are usually bought or sold, likewise *teloneum* is the place where ship cargoes are unloaded and sailors paid. There, the tax collector fixes the prices of things and in a loud voice invites merchants. (Etymologiae XV;2:45).

The master auctioneer re-enacts the call once more. And once more, and over and over again, the by now familiar process of interrupted arithmetical series is replayed until the last box of fish is sold.

You are witnessing the time-honored institution of "*La Llotja*" the downward bidding fish market of Spain[2].

At first sight, the llotja is a *place* where goods are exchanged. But a closer look reveals also a social convention of undeniable utility and misleading apparent simplicity: a socially adopted *ritual* in which individuals perform well-defined roles.

One complex action, *trading*, is performed by a collectivity of participating agents: buyers, sellers and intermediaries. The form of trading performed in the fish market involves a process of negotiation where prices for goods are agreed to by the interested parties, however, negotiation is actually performed under a peculiar convention in which it is not the fisherman who caught the fish and brings it to the market who offers the fish to the buyers, but an intermediary, the *auctioneer*, who calls for *bids* and who adjudicates the purchase to the highest bid —in fact, to the buyer who first calls a price.

The concatenation of many *rounds* of such negotiations constitutes a day's work at the llotja, but the ritual involves other subsidiary actions as well. Take the auctioneer's role, for instance. He not only calls the goods and states the sequence of prices, he also recognizes the actual buyer and the actual buying price, and he also presents the goods to be sold and may set the starting price —and by so doing establishes bounds to the negotiation.

Buyers are involved also in various actions, certainly they express commitments to purchase boxes of fish but they also (for instance) participate in a process of accreditation whereby they are admitted to the llotja as *bona fide* buyers, only if they can prove *solvency* by posting a bond or some other form of guarantee. And buyers at some point —if they succeed in winning a bidding round— have to make effective the purchase, and then take away the fish they bought.

As we shall attempt to show in the following sections, it is this intricate performance of collective actions and conventions what makes the *llotja* work. Because, in spite of its apparently folkloric features, the Spanish fish market is a rather standard competitive–bidding commodities-trading marketplace and as such embodies fundamental properties of what D. North calls an *institution*: a collection of artificial constraints that shape human interaction [121, pp. 1 ss].

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[2] An ethymological digression. The Catalonian word *llotja* (XIV c.) produces the Spanish *lonja* (XV c.) "centro de contratación de mercaderías". *Llotja*, as well as the Italian *loggia* apparently come from the old frankic, *laubia* "forest clearing", "gallery", which in turns seems to come from *laub*, "leaf". The word for "bidding" (*pujar (sp)* XII c). is a direct import from Catalonian "to ascend" that comes from the Latin *podiarem–podium*, which is analogous to the Latin *auctare*, "to increase" where the English *auction* comes from. Notably, however, the word for auction (*subhasta (cat), subasta (sp.)*) is recent (XIX c.) although it comes from the Latin *sub hasta, vel ad hastam venditio* ("to sell under a spear", because a spear or lance, as a symbol for public property, was planted where war booty or tax debtors property was put up for sale. The old Spanish word, *almoneda* (from the Arab *nada* "to shout" (X c.)), is no longer used, but the equivalent old catalonian *encant* is still. [34, 47, 123].

In the next section I will present the standard notions and terminology associated with auctions[3]. I will use these notions and terminology throughout the dissertation, and in particular, I will draw upon these elements to describe (Section 3.3) in thorough detail the way the Blanes llotja works. In the final section of this chapter (Section 3.4) I will reflect on the *institutional* aspects of the Blanes llotja to establish the grounds for the idealized version of the fish market that I develop in the next chapter.

The choice of the Blanes llotja was originally a matter of convenience. I wanted to have a real referent to guide my design of an electronic market–place, one that was accessible and rich. Blanes is a typical Catalonian llotja, it is rather close to the IIIA's present location, and since the IIIA was originally located in Blanes, there were personal acquaintances and easy access to the *Confraria*. However, it turned out to have objective positive advantages as well. Not only was Blanes one of the first electronic auctions in Spain, but technologically it is still one of the most advanced; and unlike most others it holds both an electronic auction in the afternoons, as well as a traditional oral one —like the one just described— in the mornings. It also happens that Blanes has one of the oldest documented fish market regulations in Spain.

3.2 An overview of auctions

3.2.1 Auctioning as a price–setting mechanism

Auctioning is a price–setting mechanism based on a competitive bidding (tendering) process in which buyers (resp. sellers) present their offers to a group of sellers (resp. buyers) and the "highest bidder" (lowest tender) wins[4].

This process is governed by *auctioning conventions* that establish, at least:

1. The eligibility of participants,
2. what information is made available to which participants, and when,
3. how bidding progresses,
4. how the "highest bidder" is identified and how much it has to pay.

Depending on how precise one needs to be —or the purpose of the description— one may say that a given set of auctioning conventions defines an *auction* or (more accurately) a *type of auctions* or (more narrowly) a *bidding mechanism.* I will postpone any definitional commitment for the moment, and use loosely the

[3]In writing that section —which also includes an historical outline— I profited from Cassady's seminal text [22] and from the Economic-theoretic classics (Vickrey [178], Milgrom and Weber [108], McAfee and McMillan [104]) and recent surveys ([162, 188]). However, since my interests are quite different from theirs, occasionally I had to introduce new terminology and distinctions, which, I trust, are easy to tell apart.

[4]In order to avoid the constant reference to the symmetrical processes of competitive *selling* and competitive *procurement*, I will, from now on, use only the competitive *selling* version of auctions, in the understanding that most of what I say applies to both *mutatis mutandis.*

notions of "auctioning" and "auctioning conventions". Note however that my use of this (minimal) "auctioning conventions" is consistent with the intuitive definitions of auction in the specialized literature ([22, 108, 162, 104, 176, 188]). I will therefore use —loosely as well— the term "auction" to denote the process of auctioning a collection of goods in an "auction", the corresponding event, whenever it is subject to an explicit set of "auctioning conventions" that include at least the four types of **conventional features** I mentioned in the preceding paragraph.

There are four auctioning conventions that are particularly common, and which have deserved close theoretical scrutiny from Economists: English, Dutch, Sealed–bid and Vickrey[5]. But there is a number of parameters and conditions that can be varied within the above mentioned essential features, and many other equally varied relevant features as well. And as "mechanism design" works have shown, by choosing different conventions, quite different forms of negotiation may result [103, 176, 188].

Auctioning is not the only price–setting mechanism that exists. Negotiation (or private treaty pricing), discounting and fixed ("take it or leave it") public pricing are common and effective (non–competitive) mechanisms [103, 162, 22]. And then there are also other forms of competitive price–setting mechanisms that some authors take as auctions, while others may not.

Cassady, for example, [22, p. 11], requires auctions to be reactive in the (narrow) sense that the time between a call for tenders is open and the corresponding tender is submitted is "short". With that condition he excludes some auctioning mechanisms such as sealed–bid and Vickrey auctions that are not only rather common, but fundamental from an Economics–theoretical [178, 104, 108, 162, 188, 176] and AI [183, 146, 147] perspective. I don't think in this case Cassady's distinction is relevant and will include sealed–bid and Vickrey auctions in my intuitive, formal and operational conceptions of auctions.

On the other hand, I do think it is relevant to pinpoint the *asymmetry* between the one who calls for bids (or tenders) and those who competitively submit the co-responding bids (or tenders). Some markets use specific price–setting mechanisms, —the *exchange*, *double–auction* or the classical Walrasian *tâtonnement* process— in which that asymmetry is blurred because participants may perform either or both roles of seller and buyer, and competition may involve collective (multicasting–like) calls as well as individual negotiations. Some authors ([22]) explicitly exclude all these (symmetric) competitive price–fixing mechanisms from their classification of auctions, while others (e.g. [104, 162, 27]) mention illustrative cases of auctions carried out using these symmetric forms. I can accommodate the exchange or double auctions mechanisms within the framework I propose in this dissertation, by using an *ad-hoc* description, but to decide how different these symmetric forms are from other auctioning mechanisms, seems to me more a matter of taste and convention, than one of principle and consequence, although I lean towards calling exchanges and double auctions

[5] Discussed below in Subsection 3.2.3

by their names and distinguish them from other more classical auctions[6].

Auctioning has been used in many markets. In some (like fresh–fish first–market; rights to natural monopolies) they are the preeminent form of trading, in others (art and antiques; cattle) they are common but exist alongside other equally prevalent forms of trading, while in still others (real estate) they seem to be favored only under rather specific circumstances. Auctions seem to be an appropriate mechanism (see Wolfstetter [188, p. 369], Cassady [22, pp. 20–2]) for:

- goods whose price is volatile, either because it is highly differentiable through quality and availability (e.g. fish, wool), or because valuation is highly differentiated among potential purchasers (art), or because substitutive goods are also highly volatile (Treasury bills and other securities);
- goods for which there is no reliable reference price, usually because buyer valuations are unknown to the seller (low liquidity stock, Radio–electric spectrum frequency allocation)[7];
- goods for which special transparency and expeditiveness conditions are needed (e.g., for liquidation or fiduciary purposes).

In Chapter 8 I will review how the so–called "auctions on line" are operating, and discuss the features that make internet–based auctions interesting. Perhaps that will permit us to identify new markets where agent mediated auction houses may prove valuable.

3.2.2 Auctioning terminology

I have used **auctioning** for the price–setting mechanism and **auctioning conventions** to describe restrictions on the alternative ways auctioning is to be performed. The verb "to auction" I use for the process of auctioning a collection of goods and "auction" for the event where a specific collection of goods is auctioned. I will follow the common usage of related terms whenever a prevalent usage exists, however, recall the acknowledged abuse of the term "auction" as an adjective to characterize a special set of auctioning conventions that regulate the auctioning process (as in a "sealed–bid auction"); and in the noun phrase **Auction house**, the *institution* that performs auctions as well as the *place* where an auction takes place (the *llotja is* an auction house).

An auction takes place during a given **market session**, but more than one auction may take place in the same session either at successive times or at different locations or **auction halls**.

Auctioneer is the agent who in representation of a seller but being part of an auction house staff conducts an auction. An auction house usually has more

[6] In Chapters 4, 7, 8 and 10 I gradually make more precise my own definitions of auctioning conventions, auction houses and other trading institutions

[7] Somewhat cynically, also for goods for which unwarranted expectations on value can be induced on buyers ("mock" auctions of cameras and radios on 42th. Street or Tottenham Court).

staff that may perform specific roles for buyers or sellers, for example place "absentee bids" for buyers who are not present in the auction room.

Bidder is a buyer who submits an "offer" or **bid**. A **bidding turn** is an opportunity that the auctioneer gives a bidder to submit a bid.

Bids are expressed as **calls** by a bidder to an auctioneer, and they may consist of a "declaration" of a buyer of his or her intention to purchase a good for a certain price, or by a buyer "accepting" (**mineing**) a **price quote** for a good offered for sale by the auctioneer.

Bidding turns can be **sequential** if each bidder is given its turn successively according to a pre–established ordering. **Concurrent** if all bidders get a bidding turn simultaneously.

A bid is **valid** if it is acknowledged by the auctioneer in a bidding turn (according to whatever conventions had been established).

An **opening bid** is the first valid bid in an ordered sequence of ascending bids, or (abusing language) the first opening price quote in a descending sequence of price quotes offered by an auctioneer.

Bidding is said to be **upward** if for any new bid to be valid it has to be larger than any previous valid bids. It is **downward** if the only valid bid is the highest bid by a buyer after the opening bid by the auctioneer followed by a sequence of descending price quotes. Bidding is said to be **haphazard** if the values of valid bids are independent of other bids.

If bidders may alter their bids in response to their competitors behavior — either because they can submit a new bid, or because inaction of competitors constitutes information— we say that bidding is **reactive**, otherwise we say it is **passive**.

Bidding may be **by voice** ("oral"), **written** or **electronic**, depending on the medium used by the auctioneer and the bidders.

A bid is **closed** (or "silent") if it is known only by the bidder and the auctioneer at the moment it is made, it is **private** if only the winning bid is known at the end of the bidding round, **public** if all bids are accessible to other bidders once all bidding turns end, and **open** if every bid is accessible to all other bidders before the bidding round ends.

A bid is **sealed** if it is written and silent.

A **phantom** bid is a silent bid that is publicly acknowledged by the auctioneer, but for which there is no bidder.

Goods are usually presented in **lots**. A lot can be formed by either:

- an individual **item** (a picture by Rembrandt), or
- an **indivisible collection** of items (e.g. a dining room set), or
- by **multiple units**: a divisible collections of similar items (n boxes of sardines of which the winning buyer may choose $0 < l \leq n$).

An **auction set** is the collection of lots to be sold in an auction. If various lots are sold simultaneously, the auction is said to be **simultaneous**, otherwise it is called **sequential**. If lots can be introduced into the market while the auction is in progress the auction is said to be **continuous**, otherwise it is called **fixed**.

A **bidding round** starts with the presentation of a lot to be auctioned, and ends when the lot is either **adjudicated** (sold) or **withdrawn**.

In a simultaneous auction, if a number of lots are to be sold simultaneously they are sold in a single bidding round.

A bid is **unique** if the bidder can express at most one declaration or quote acceptance in each bidding turn, **multiple** otherwise.

A bid is **single chance** if the bidder has only one bidding turn in each bidding round, **multiple chances** otherwise.

A **step factor** is the difference in *value* between two successive price quotes. The **time step** is the *time* between two bidding turns. The **latency period** is the *time* between two bidding rounds.

The **catalogue** of an auction is a published description of the relevant characteristics (bidding round (ordering), description, opening price, estimated re–sale value, etc) of the lots in the auction set.

An opening or **starting price** is usually attached to each good. Some items may have a **reserve price** that is set —usually by the seller in combination with the auction house— as a protection for the seller's interests and is usually unknown to buyers. Most goods may have a known **re–sale price** (or "fair market value") which is the (estimated) value it will get in the secondary market. The **sale price** or '"first price", or "knock–down" or "hammer" price is the price at which the highest–bidder was adjudicated a good. However it does not necessarily mean that *that* is the **final purchase price** the winner pays. Two features need to be taken into account. First, although in most auctioning convention the winner pays the highest price bid, in some single chance bidding auctions the winner pays only the "second" best price (Vickrey auction) or an average of all the valid bids. Second, in most commercial auctions, the buyer may have to pay additional **transaction costs** or a "buyer's premium" which usually include commissions, taxes and similar costs and fees.

Sellers may also have to pay "transaction costs", involving commissions, consumibles and taxes which are subtracted from the sale price to produce the **seller's revenue**.

3.2.3 Four Common Auctioning Conventions

Most authors classify auctions in terms of the way bidding progresses. Cassady's classical taxonomy [22], for example, uses that criterion to define ascending, descending and "haphazard" auctions and then uses other features (essentially privacy and tie–breaking criteria) to further characterize different types (close to twenty). Economic theoretic works [108, 104, 178] tend to follow Cassady rather loosely and stress those features that may distinguish alternative equilibrium conditions, sticking mostly with the four basic types I will discuss here[8]. I

[8]The geographical denominations for auctions "English", "Dutch" and "Japanese", are frequent, however they are neither universally, nor consistently used. Cf. Wolfstetter [188, p.370]:

introduce and discuss them here mainly for terminological reasons, note however that taking advantage of the rich terminological distinctions already noted, one could establish a richer –and hopefully neater– taxonomy.

UB. Upward-bidding or *English* auction.

The auctioneer calls for an opening bid. If any, she rises it step by step until no more bids are present. The good is adjudicated to the highest bidder.

Usually there is quite a bit more to an auctioning convention than merely a rule for admitting new valid bids.

For instance, in this minimalist description, the opening bid needs to be further specified since it may be obtained through different schemas. A rather common schema is by the auctioneer declaring a *starting price*, if no one takes it, the auctioneer goes downward until a price is taken, and then proper upward bidding starts; another schema is for the auctioneer to take "phantom bids", *i.e*, the auctioneer acts as if an opening bid has been received and then starts moving upwards by acknowledging true bids or more phantom bids. Note that such schemas could possibly act against the seller's interest, thus a *reserve price* may be fixed by the seller and unless the highest bid is higher or equal to the reserve price, the good is *withdrawn*.

More refinements: A (higher) valid bid may be upcoming, how much does the auctioneer have to wait for it? Sometimes a three–announcements ("going, going, gone") **waiting convention** is used, traditionally a candle was lit and the highest bidder at the time the candle died out would win[9].

Additionally, ties are possible. Hence re–bidding, drawing lots, bidding by

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> ...in the financial community a multiple–unit, single–price auction is termed a Dutch auction, and a multiple–unit closed–seal bid auction is termed an English auction (except by the English who call it an American auction). Whereas in the academic literature, the labels English and Dutch would be exactly reversed.

"English" is the most standard of the three, it was chosen perhaps by the fact that this basic convention was well described in English and prevalent in England well before this century, and it is the convention still used by the notorious English auctioneers Sotheby's and Christie's. However it was probably already the prevalent convention in Rome, and before and elsewhere, and could have had any other denomination for that matter.

"Dutch" auctions are so called probably because of the important horticultural market in Aalsmeer, Holland; and the technological devices developed in Utretch for that market and exported world–wide in the 1950's. But it could as well be called almost anything else for it is the prevalent convention in fish markets around the world. Even the Oxford Dictionary acknowledges the practice in England before the Dutch horticultural market originated:

> *AUCTION 3*:... 1881. Daily News 29 Dec. The captain sells the fish by auction, putting the highest price on the basketfull to be sold, and gradually lowering it till someone closes with his offer.

This type of auction has been referred to also as "mineing" since the descending price sequence is stopped when a buyer says "mine". Notice however that "mineing" can also be used in upward bidding if the auctioneer —rather than the bidder— states the prices.

The "Japanese" (concurrent, open, multiple chances) auction was introduced in Japan after WWII to contrarrest the traditional *ura–ukeoi* distribution cartels, according to Cassady (who was probably responsible for that cultural innovation) [22, pp. 38 and 63-6].

[9]The reserve price was then written on a piece of paper placed underneath the candle.

turns, order of registration, even situation within the auction room may be used as a **tie–breaking convention**.

DB. **Downward-bidding or *Dutch* auction.**

The auctioneer calls a *starting price* and goes downward step by step until a first buyer stops her.

This is the essence of the fish market auctioning convention, however, again there is quite a lot more to it. Tie–breaking criteria, solvency of bids, criteria for the presentation of goods and their selection by buyers, speed, choice of the step factors, existence of reserve prices, etc. We'll have the opportunity to examine in detail the Blanes auctioning conventions which will give a better indication of how these and other features are used to define the auctioning conventions in an actual institutional environment.

CB. **Concurrent–bidding, or Japanese, or *sealed–bid* auction.**

The auctioneer calls for bids. All bidders present their bids within the same given period. The highest–bidder wins.

Interesting variations stem in this case from the privacy of the bids, the length of the bidding turn, the possibility to change bids in reaction to competition and the tie–breaking criteria.

Thus, for example, if bids are *concurrent*, *sealed* (written and closed), *unique* (at most one bid for each lot), and *single chance* (no possibility of reacting to other bidders' actions) one gets the basic *(closed) sealed bid auction*[10]. If bids are public and submission periods short enough to prevent negotiation amongst bidders, but long enough for them to react to competition (multiple chances bidding) one has the *japanese* auction.

A special case of concurrent–bidding deserves special attention because of its popularity among Economists and in AI literature, the Vickrey Auction:

VA. **(Basic) Vickrey or Second Price auction.** Each bidder submits a single sealed bid. The highest bidder wins but only has to pay the price of the second–highest bid.

Proposed by Vickrey in [178], this form of auction was designed to show that, under convenient assumptions, two obviously different forms of auctioning (in this case, Dutch and Vickrey) would paradoxically bring the same revenue to the seller. This result was to be generalized into the following elegant theorem [104, p.710]:

[10] Which, in customary applications such as (in general) public procurement, is used for single item auctions with *very long submission periods.* This is what Cassady took as a distinguishing factor to exclude them as auctions. Note, however that with shorter periods but otherwise essentially analogous conventions he accepts as *bona fide* "whispered auctions" (Venice, Singapore: fish) and "handshake auctions" (Karachi, Turkey: dry fish, camels), however opaque the tie–breaking and termination conditions may be in these latter ones.

Theorem 1 (Revenue Equivalence Theorem) *(Vickrey 1961; Ortega Reichert 1968; Holt 1980; Harra & Raviv 1981; Myerson 1981; Riley & Samuelson 1981)*

Regardless of the type of auction (dutch, english, sealed bid or vickrey) the highest price paid by a group of rational bidders is on average the same.

This counterintuitive result is founded on the convenient ("benchmark model") assumptions:

A1 The bidders are risk–neutral

A2 The independent–private–values assumption applies

A3 The bidders are asymmetric

A4 Payment is a function of bids alone

And the following underlying ones:

U1 Each bidder knows the rules of the auction.

U2 Each bidder knows its own (true) valuation.

U3 Each bidder is assumed to know the number of bidders, their risk attitudes, and the probability distributions of valuations; and to know everyone else knows that he knows this, and so on.

U4 Each bidder bids an amount that is some function of its own valuation.

As we will have an opportunity to discuss later, more realistic assumptions show that (even subtle) differences in the auctioning conventions entail differences in equilibria[11].

3.2.4 Historical Sketch

The llotja is not a vestige of a medieval institution, but a contemporary version of an institution with more than twenty five centuries of documented history, and an archetypical example of other highly evolved institutions that have proven effective for trading[12].

[11] With that view in mind, Varian [176] discusses a variation of the Vickrey auction, GVA, in which consumers report their utility functions to the auctioneer who then allocates the goods in a way that maximizes the reported utilities subject to the resource constraints. He proves that under such conditions, it is in the interest of the consumer to report its *true* utility function. A (truly) significant result for automated negotiation.

[12] Most of these historical references are in [22]. I tried my best to corroborate them and only occasionally was able to improve or add to them.

Ancient Auctions

Auctions are an old invention. Herodotus describes (circa 450 B.C) the regular (but, by then abandoned) auction market for wives in Babylonian villages. Once a year in every village, those maidens who that year reached their marrying age would be auctioned: the beautiful ones to the highest bidders (on an ascending bidding protocol), and the ugly or lame ones (in a symmetrical convention) to those who would take them for the least price. Eligibility requirements and a precise refund policy are there dutifully reported [75, Book I-196, pp.246-49][13]. Slave trade, at least from Plato's time (IV c. B.C) to the U.S. "Old South" (XIX c.), used auctions as its prevalent price–setting mechanism [22, pp. 34 et ss]. The tradition of auctioning captives in the Mediterranean coast is reflected in classical Spanish "*romances*" like *El Cautivo y el Ama Buena* [41, Romance 65, vv. 2–6][14]. Romans also used auctions to liquidate goods. For example, emperors Caligula and Marco Aurelio successfully sold items this way, the second actually held an auction of family heirlooms and furniture that lasted two months (*cf.* Frank [54] (pp. 39-40, n.12 and p. 77) cited in [22]). And at least once the empire was adjudicated to the highest bidder: emperor Didius Julianus paid 6250 drachmas to each praetorian guard for the dubious privilege of succeding the decapitated emperor Pertinax in 193 A.D. (two months later, he was in turn decapitated by Septimio Severo's legions) [47]. In China, dead buddhist monks' property was liquidated through auctioning (VII c. A.D.) [192] (cited in [22, p. 29]).

3.2.5 Origins of Contemporary Auctions

Although ancient references to bidding and auctioning do indicate some institutional aspects such as regularity of the trade, standardization of goods, eligibility conditions on participants or guarantees, auction houses and fully developed auction–based markets are probably a rather recent development.

Art, real–estate and ships had been sold by auction in England at least from the late XVI c. Art auctioneers such as Sotheby's and Christie's were established as art dealers in the middle of the XVIIIc. (1744 and 1766, resp.) although it is not known if they preeminently sold by auction then as they do today [22].

[13] A vestigial *bachelor(ette)* auction by the State of Washington Jaycees was web–promoted in 1995. It used a simple sealed bid protocol.

[14] This *romance* tells the story of a Christian captive who is sold to a Moor (at an exorbitant price, after being in auction for a week) and then redeemed by the Moor's wife (or daughter):

> *"Mi padre era de Aragón y mi madre de Antequera*
> *cautiváronme los moros entre la paz y la guerra*
> *y lleváronme a vender a Jerez de la Frontera.*
> *Siete días con sus noches anduve en el* almoneda*;*
> *no hubo moro ni mora que por mí una blanca diera*
> *si no fuera un perro moro que por mí cient doblas diera. . . "*

This *romance* was already present in the earlier versions of the *Romancero* (*Cancionero* (1496), *Cancionero de Romances* (1550)) —which collated orally transmitted traditional songs and versified stories— and survives in present–day Castille, Galicia, Catalonia, Portuguese and Sephardic oral traditions.

Auctioning is today the prevalent price–setting mechanism in fish markets around the world [22, *passim*, specially Chpts. 2 and 3][15]. According to ethnographic descriptions (e.g., Amades [2]) and current practices, it would seem that auctioning and in particular downward–bidding have been traditional practices in fish markets. Nevertheless, the famous flower and fruit market of Holland originated only as late as 1887[16]. Likewise, the fish markets in Germany were organized at the turn of the century (Hamburg 1887, Geestemunde 1888, Bremerhaven 1892, Cuxhaven 1908, Kiel 1947). While Japan, Hong Khong and the Phillipines had theirs organized only after WWII [22].

There has been a long tradition of auctioning wool in Australia, where the exchange has been automated since the early sixties and is now available through Internet.

3.2.6 Auctioning in Spain, Catalonia and Spanish America

In [22, p.21], Cassady claims that to his surprise the only auctioning he could find in Mexico was the "government pawn shop *remate*". He was probably misled by the use of the word, since it is used to designate most forms of auctioning, including evidently, private and fiscal liquidation. The earliest mention of the Spanish *almoneda*(the present–day *remate*), for liquidating debts by auction is consigned in the early medieval legal compilation of Alfonso X's *Partidas* which follows Roman law tradition[17]. The practice is still legislated in similar terms and migrated to Spanish America where it is also practiced for analogous purposes for private as well as public interest [47, Subasta]. Remate operations have survived in different forms up to date[18]. Some banks (La Caixa (Barcelona) and Caja Madrid, for example) auction today pawning loans through a sealed bid convention which uses their extensive ATM networks.

Another standard traditional auctioning practice in Spain and most of Spanish America, is the practice of *licitación pública* (sealed bid public tendering) for government contracting and purchasing. A process which recently became fully accessible via Internet for the Mexican Federal Government [32].

The Mexican Central Bank holds a weekly public auction of Treasury bills (CETES) since the late seventies. More recently, —as a delayed consequence of the *Tequila effect*— the Mexican Central Bank took over the private banks collaterals for defaulted loans, and set up a massive auctioning schema through a

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[15]He explicitly mentions —and sometimes describes in more or less detail— the fish auctions in: New Beddford and Seattle (US), Hull and Grimmsly (UK), Venice and Chiggia (It.), Lisbon (Port.), Haiffa and Tel Aviv (Isr.), Turkey, Karachi (Pak.), Japan, Hong Khong, Singapore, Manila (Phill.). But according to the Blanes informants also most Atlantic Coast and Mediterranean fishing towns in Spain, Portugal, France and Italy currently have downward–bidding fish markets

[16]Cassady relates the picturesque story of the *first* horticultural auction in Holland. In Broek op Langendijk, a farmer called Jongerling followed the advise of a passing boatman to get a better price on his produce [22, 36]

[17]Real Academia Española. *Diccionario de Autoridades.* Ed. Fac.

[18]"Candle auctions" must have been common, since the archaic phrases *subasta a vela y pregón, a la llama* and *a mata candelas* (auction "by candle and shout", "to the flame" and "by killing candles") have found their ways to contemporary dictionaries [110].

filial Institution, Fobaproa. The first sealed–bid auction (of goods amounting to some 20 million USD, of the estimated 50 billion USD total auctionable portfolio) took place the first week of July 1997 (Excelsior 9.8.97: p.1, S.A–2).

It is not clear when downward–bidding fish markets originated in Spain. However, by A.D. 974 there were fisheries and fishermen in Sant Pere de Roda (Girona), and a fisherman's guild (*confraria*, (cat.) or *cofradía*, (sp.)) was established in Sant Pere de Tortosa (Tarragona) by 1114 (the first in Spain), other documented early guild regulations exist for Albufera del Mar Menor (Cartagena) (1321), Lequeitio (Vizcaya) (1386), and San Pedro de la Rápita (Alicante)[19].

Exchanges were not uncommon in medieval European Cities. Barcelona built its *llotja* building in the early XIVth. century., and rebuilt it to its present form between 1380 and 1392 [56]. Originally a general commerce exchange, it became increasingly financial. This very building housed the Barcelona Stock Exchange until 1992, by then the oldest surviving exchange in the world ([79, pp. 165–6]). Other *lonjas* existed in Valladolid, Toledo, Madrid and Bilbao, which also evolved like Barcelona's into financial and commodity exchanges.

Catalunya had a long tradition of Mediterranean commerce, starting in Phoenician times and expanded during the Roman Empire. In the middle ages, in addition to merchant and fishermen guilds, other institutions were established to coordinate this maritime commerce. The *dita* was a contemporary Catalonian version of the italian credit letters, by which debts could be paid without resort to coins. The *Consolat de Mar* was a network of commercial "ambassadors" (*consols*) of Catalonian cities, who with extraterritorial powers would reside in ports where the catalonian fleet had recurrent commercial activities. *Consols* would defend catalonian interests in these foreign cities and promote business for catalonian merchants. They inhabited buildings where, around a central court, there were facilities for merchants (lodging, tavern, warehouse, bath, oven, chapel). The first Consolat–like institution in Catalunya was the *Universitat dels Prohoms de la Ribera* in Barcelona, recognized by Jaume I in 1258 [138]. The *Consolat* (proper) of Barcelona was instituted in 1347. Other catalonian cities also had consolats (Perpinyà, 1388; Girona, 1385; Tortosa, 1363; Sant Feliu de Gu´xols, 1443). Commercial and maritime regulations in Catalunya were compiled into the *Llibre del Consolat de Mar*. This book was based on the older code of (*Costumes de la Mar* (1260–70) and included the common practices (*costums*) the existing norms and the jurisprudence dictated by the consular tribunal of Barcelona. The definitive version of the *Llibre del Consolat de Mar* was issued in the middle XIVth. century, and because of its thoroughness and rigour was the most widely used code in the Mediterranean [53, 56].

Merchant guilds were promptly linked with the *Consolat*, and acting as professional bodies, promoted commerce, granted licenses to engage in it, levied fees to pay for the fleets protection and issued insurance (Cf. [138, 56]).

Auctions were the usual procedure to settle shipping rights disputes and liquidate debts, though. In fact the *Llibre del Consolat de Mar* mentions auctions in Article 55 "*On how a ship can be put on sale between the captain and the*

[19] [47, Pesca]

shareholders" [36, p92], where it notes under what circumstances the captain or the shareholders may force a public auction to sell the ship and any prerogatives the forced partner may have in such case. For example:

> "...If the ship has already made a trip, a majority of shareholders may force the captain to a public auction of the ship to the highest bidder, unless previous contrary agreement or promise[20]."

and

> "...But if among captain and shareholders a public auction of the ship is opened, there will be no priority among them since both are simple shareholders...but if at the moment auctioning starts it is convened to give priority to the one who places a tender first, it must be honored..."

Likewise, in the older "Ordenanzas" [36, p.485] , chapter 24, "*On the execution of the belongings of the guilty party*" time and publication conditions are stated for the *liquidation through public auction to the highest bidder* of "the ship and other goods" of a debtor to pay for debts and court costs.

In Blanes there was a *confraria* by 1705, however Blanes was one of the few Catalonian ports where *lleudes* (taxes on maritime commerce) were levied by the end of the XIIIth. Century ([138, p59])[21]. And —more significant— fishing regulations and regulations for the sale and purchase of fish, for Blanes and the neighboring town of Palafolls, were published as early as 1401 and 1413 [130]. No mention is there made of auctioning, although careful provisions for appropriate *agency* and *competitive conditions* are made. For example:

> 1.- *Primerament que si dos mercaders o treginers auran feta companyia de dos ensemps, que aquesta aytals no puschan pendre part de una mercha sinó per II si en la venda del pex saeran presents, sots pena de XX sólidos. Entés emperó que si algun mercader, aixi de laüt com si mena mul, serà en la dita merca ab son missatge, o fill si*

[20]

> "...*Emperò, si com la dita nau o leny haurà fet viatge, així com desús es dit, si tots los personers o la major partida volran* encantar *o* aportar a encant *la dita nau o lenya al dit senyor, ell ho poden fer, que lo senyor desús dit no pot ni deu en res contrastar. Si donchs entre lo dit senyor e los dits personers alguna convinença o promissió no serà, la dita nau o leny se deu es pot* encantar*: és a entendre, que los dits personers han de poder destrènyer o fer destrènyer a la senyoria al senyor de la nau de fer lo dit* encant pùblich*. Perçò, car segons dret e raó e egualdat e costuma, que qualsevulla cosa que sia fet e mogut algun contrast, totavia apodera e deu 'esser seguit to ço que la major partida de força volrà: e allò se deu seguir e als no. E axí, si tots los personers o la major partida o força volrà encantar ab lo dit senyor de la nau o del leny deu fer encant ab los dits personers, en aquesta guisa, que* quie més hi dirà*, aquell lo deu haver*".

[21] Only four other ports are mentioned that had earlier *lleuves*: Tamarit (1243), Cotlliure (1249), Tortosa (1252) and Cambrils (1258)

> *n'aurà qui sàpia comprar e vendra, que aquests aytals puxen prendre part abdosos*[22].
>
> 2.- *Item que si algun mercader o altre comprador de peix aurà feta alguna merca de pex e aurà missatge quey sia prest, e altres mercaders sien a cabal qui no agen companyia, que en aquell cas no's puga pendre part sinó de mercader a mercader, peró ent'es que si aquells de les companyies saran aquí, que en aquell cas lo mercader puga prendre part a lo seu missatge*[23].
>
> ⋮
>
> *Item que negú treginer no gos prendre part sinó per I mul, e si mene II muls ab fill o ab missatge qui sàpia comprar e vendre, que pusquen pendre part quescú per si, sots pena de XX sólidos si lo contrari fan*[24].

Downward bidding was the standard selling convention in Spanish fishing villages at the turn of the century. By 1940, for example, Jose Amadés [2, pp. 826 et ss] makes a lucid description of the "old" practice in Catalonian towns, conducted by the boat captain —not by an intermediary— and even reports the way in which the opening price was set when price was more uncertain than usual (*l'eixauc*).

Currently, 225 towns in Spain have a *lonja* which can be managed by the local *cofradía*, or leased out by the government to a private operator. Privatization in Spain will allow these institutions to become standard private enterprises in the very near future. However, even though all fishing towns have a fish market, considerable differences in practices and technification exist among them.

In the following section I will describe in detail how the *llotja* operates in *Blanes*. My description attempts, on one hand, to be testimonial of the practice as it occurs, since there seems to be no detailed description of such auctioning convention. Hence I will be thorough and candid. On the other hand, I use the Blanes *llotja* as a paradigmatic example to illustrate and contrast the more general (and abstract) idea of an *agent based institution*; thus, terminology, features and distinctions that permeate through the whole of this dissertation are grounded in the following description. However, because of this ulterior motive, I have limited the description of the fish market only to those activities that takes place in the *llotja* from the moment the fisherman brings his catch (already arranged in boxes) into the building to be "received" by the *llotja*, to the moment the buyer is ready to take her purchases out of the building. Furthermore, I have intentionally kept an institutional perspective —never attempting to describe the

[22] Coalitions are not permitted, but a merchant can be represented (or helped) by an "agent or son who knows how to buy and sell". Note the clear subsistence of the Roman *potestas* and *formula exercitoria*, [91, Chp III].

[23] A "messager" (agent) can trade on behalf of a principal whenever competing buyers or sellers are also present

[24] If a merchant brings more than one mule (cart), with son or servant, each one should act on its own or get fined. This norm was a 1413 addendum to the original (five) norms.

process from the point of view of sellers or buyers, but from that of the *llotja* staff.

3.3 Blanes fish market

The distinguishing feature of most fish markets is their bidding convention. Blanes uses a continuous, multiple units, simple DB auction with electronic and voice mineing. Exactly how it works is detailed in the following pages. The description follows actual practice, since no written rules or conventions exist[25]. Apparently the conventions here presented are similarly observed in other fish markets, but no effort has been made to validate their generality, and are perhaps best understood as the current practice in Blanes.

For the sake of clarity, I will first describe a few elements surrounding the *llotja*, then I will discuss each participant's roles and the activities that take place during and around the auctions.

3.3.1 Contextual elements

Blanes is a small typical fishing town in the southernmost extreme of the Catalonian Costa Brava, in the Province of Girona, which has combined since medieval times fishing with agriculture and industry. Recently, tourism has become a substantial part of the local economy, but its fishing fleet, the fish market, local fish mongers and packers still constitute an important part of the village activity.

Like most other fishing ports it hosts a local fishing fleet whose catch is sold twice a day in the local market (*llotja*), which is operated by the local fishermen's guild *(Confraria de Pescadors de Blanes)* under a lease from the government.

The *llotja* is housed in a spacious building which was adapted in 1985 and recently remodeled (1993). It is located in the Northwestern end of the Blanes Cove (see Fig. 3.1).

The local fleet is composed by close to 70 boats of three very different types. Each boat is apt for fishing only with one of three distinctive fishing arts: *palangre* (multiple hooks on a long baited line) for endemic and migratory species such as turbot, tuna, sabre, squid...; *arrastre* deep water trailing nets for a variety of species in the coastal platform (shrimp, octopus, turbot, ...); and *traineres* that catch blue schooling fish (sardines, anchovies, sabre...) using fixed net cages. Gears, motor power, minimal sizes for some species, fishing seasons and reserve areas are regulated. The *confraria* and the *llotja* are bound to observe and enforce those regulations.

[25]The description is based on a series of visits that the members of the Fish market project have made to the Blanes *llotja*. There, we were thoroughly informed by everyone present, but specially by Xavier Márquez, (*Secretario* of the Confraria), Josep Llauradó, (*patró major* and retired fisherman), Albert Ros i Coll, (auctioneer–fisherman), and Eugenio Vela, (buyer). In addition, Maria del Carmen de Toro made intensive buyer interviewing for [38]. My description makes poor justice to the wealth of information they made available to us, but I have done my best to be accurate.

Figure 3.1: Blanes fishing fleet and the Llotja building

The fleet fishes five 12–hour days a week under strict regulations on departure time. Arrival is mostly determined by the market hours and success of catch. *Traineres* fish all night (and exceptionally, on continued journeys), they bring blue fish that is sold in the morning session which usually starts at 7:30 am. The rest of the fleet departs at night to get back for the afternoon market session, except when migratory species are particularly abundant and permission is granted for continued fishing journeys. Each captain decides where, when and how long to fish under these restrictions.

Revenue for individual fishermen in Catalonia is straightforward[26]. It all comes from the day's auction income. The whole of the day's catch is to be sold in the *llotja*, but a 2% commission, 14% VAT and consumibles such as ice and fish boxes are charged as transaction costs. Half of the resulting total final revenue goes to the owner of the boat, the other half is allotted to the crew in equal parts with the following convention: the captain gets two parts, pilots and machinists gets a part and a half, everyone else gets one part.

The *llotja* settles each boat's accounts every two weeks.

The Blanes *Confraria* has occasionally considered the possibility of developing alternative commercialization strategies. The most recurrent proposal, according to the informants, has been to set a reserve price and sell withdrawn

[26] Atlantic coast and Andalusian fleets have different conventions, although in some ports the Catalonian convention is also used. These were already established in the Llibre del Consolat de Mar

goods directly in the massive Barcelona (Mercabarna) fish market. Although Mercabarna —which is little over an hour away by car from Blanes— is cleverly used as a reference and buffer market by buyers and sellers, no real second–market option is currently available to members of the guild. Local shipbuilders have also advanced the possibility of a vertical integration of the fleet into the final consumer market, through an ambitious satellite–based demand–packaging–delivery system, however deeply conservative attitudes on the part of the guild members would probably be a considerable obstacle to such radical innovations.

Blanes was one of the first *llotjas* in Spain to consider the possibility of automating part of the auctioning processes[27]. After much deliberation and some false starts, the current design was commissioned to a system developer from nearby Girona, Autec, in 1990. The design allows free–roaming buyers who inspect the incoming goods at their chosen pace and will, rather than the classical Dutch auction hall in which buyers are confined to a "voting" desk, and produce is paraded in an amphitheater[28]. The system also involves a market data base that is updated on–line as produce is admitted into the auction hall and purchased, this data base also enables on–line accounting functionality.

3.3.2 Llotja Building

The Blanes *llotja* is a relatively large modern building, located in the far end of the fishermen's wharf in the port of Blanes (Fig. 3.2). The building itself consists of a large market hall, an incoming wharf, a delivery wing, offices, warehouse and a "social" area as shown in Figure 3.3.

The auction hall is where auctions take place, goods are introduced and tagged there, and then displayed and sold too (Fig. 3.4). The building is open 24 hours a day, although sellers and buyers usually start arriving half an hour before the scheduled sessions begin (7:30 am and 4:30 pm.).

Offices house accounting staff and computers, and a special area where the market boss or a designated member of the staff can visually supervise the market sessions.

The Warehouse area is used to store empty containers and ice. Additional space is available for boat gears and also for buyers' boxes.

The social area, in the upper floor, includes a visitors gallery and a restaurant–bar which is open to the public (and market participants) during and beyond

[27] Fish markets in France started automating as early as 1967 according to the Blanes informants, and Cassady describes automation efforts in Holland, Japan, Australia and the US in the early sixties as well [22, Ch.XIV].

[28] The Blanes design was adopted by the *llotjas* of Port de la Selva and Llançà. Three other *llotjas* in Catalonia have automated auctioning systems: Palamós, Roses and Tarragona, however, these last three follow the Dutch-hall model. Other *lonjas* in the rest of Spain were also automated using the Dutch-hall model, however some went back to traditional voice auction, usually supported with a Dutch clock. *Dutch clocks* are large displays in which descending price quotations are shown in an auction hall. They are manufactured in Holland, and have the appearance of a large clock dial in which the needle points (clockwise, at a constant speed) to a circular descending list of numbers. Dutch clocks seem to be the only automated device in many *lonjas*, and many lonjas (including neighboring Arenys de Mar) have no automation whatsoever.

Figure 3.2: The *Llotja* building

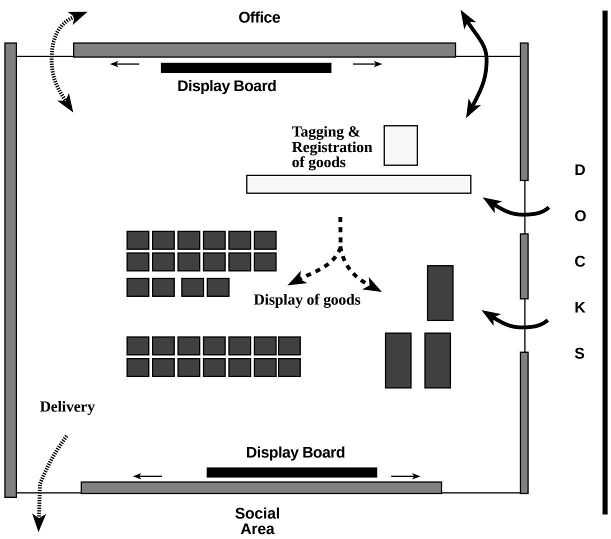

Figure 3.3: Blanes Llotja Floor Plan

Figure 3.4: The Auction Hall

market sessions.

3.3.3 Participants

There are sellers, buyers and intermediaries (market employees). Blanes allows also the presence of bystanders.

(A) Sellers

A seller is (technically) a boat, or (in fact) the fisherman or fishermen who own or operate a given boat that is registered in Blanes. Thus, even if a boat is owned by many people, it has an individual account, and when a given owner —or collectivity of owners— owns two or more ships, each ship is considered to be a different seller in the market. The boat does not have to be part of the local guild, but it needs to register with the port captain and the *llotja* for that journey, in order to be able to sell its cargo[29].

Outside the llotja. Sellers prepare their catch for sale while they are fishing or sailing back to port. They arrange the catch in standard containers (wooden boxes for blue–fish, larger plastic containers for other species, a flat pallet for very large specimens like tuna). Each box is supposed to contain produce of the same *type*, i.e., a single species and uniform quality[30]. Boxes of the same type should have similar weight.

[29] Analogously, Blanes boats may decide to sell their fish in another *llotja* when they fish far away from Blanes, usually when they follow migratory species. This applies to Spanish boats in Spanish ports, foreign boats are not admitted in Spanish markets.

[30] Boxes with a mixed variety of small specimens (*morralla*) are also sold

Figure 3.5: Unloading a boat

Once a boat docks its crew unloads the cargo and sorts the boat's boxes of produce (see Fig. 3.5).

In the llotja. Sellers activities in the market place are confined mainly to two tasks: to have their boxes admitted by the *llotja*, and get paid (Fig. 3.6).

Produce is taken by the crew into the market hall already sorted out. All boxes of the same type of produce (species and quality) are put together to form a lot.

Figure 3.6: A boatload to be tagged

These boxes are then weighted, classified and tagged by the admitter, and then displayed in the auction area, and finally auctioned, independently of those boxes that come from other boats.

Transactions are all registered on the spot by the *llotja* staff and individual accounts for each boat and crew are kept by the *confraria*. Every two weeks sellers accounts are settled by the *llotja* and fishermen get paid.

Strategies and tactics. Sellers can apparently do little to improve the price their goods draw. But prices within a single market session may fluctuate dramatically, and fishermen can profit or loose because of that. Two independent forces act on these price fluctuations. One is somewhat external: the uncertainty of supply. Another is a direct consequence of the fisherman's actions, the acknowledged prestige of the boat.

According to what our Blanes informants claim, fishing must be a very inexact science. And although all sorts of heuristics are used, the final outcome of a fishing trip is quite unpredictable: in a single day different boats, even fishing the same waters may draw quite different catches. Thus, buyers may have a very opaque perception of the actual auction set, even when they do their best to find out what the actual supply may be. Take, for instance, the beginning of the white octopus season. Consumer demand, then, is very high and supply is difficult to estimate, thus the first boats to bring white octopus may draw considerable better prices whenever the following boats are delayed, or these do not bring the same species. While if supply was at first abundant, but later turned out to be insufficient, the last boats may draw considerable better prices if they bring any octopus at all. Thus choosing a strategy for fishing and traveling, as well as using clever tactics for withholding or revealing information, on some occasions may turn out to be very profitable.

On the other hand, a surprisingly large bias in price is awarded to the prestige of a boat. Specific boats are generally acknowledged to handle their catches either above or below average, and buyers (and the market) reflect these perceptions in price. According to the Blanes informants, a fisherman can take care of the days catch in substantially different forms, and this care can be reflected in a perceivable difference in quality of the fish as it arrives to the auction hall. For instance, stopping palangre fishing of squid for ten minutes every hour to arrange caught squid neatly in ordered layers, in a box with abundant ice, and separating squid from ice with a plastic sheet may decrease the total weight of the night catch, but may give a substantial premium on price —well above thirty percent— over a sloppilly handled similar catch in which color, taste and integrity of the squid may suffer substantial damage.

Figure 3.7: Preparing boxes for sale

Paradoxically, however, fishing strategies and catch handling habits appear to be deeply ingrained in fishermen. To the point of allowing buyers to make automatic differential valuations on quality, and even market participants to play cruel jokes on boats that bring the largest catches at the expense of being systematically late[31].

Along these same lines, it may perhaps result interesting to note that in the not that distant old days, buyers would arrange their goods in baskets, presenting the best looking fish –or prawns– on top, and the many times lesser pieces hidden below. Also, since sales were by unweighted baskets, produce could be arranged in clever ways to simulate a larger quantity than what was actually for sale. Buyers were usually equally knowledgeable of these tricks and countered them in similarly devious ways (Fig. 3.7).

(B) Buyers

Buyers in the *llotja* are individuals —or individuals acting in behalf of companies— each one having set up an appropriate credit line with the market. Once the basic credit line is established, the buyer is entitled to purchase fish, she receives an electronic *mineing* device, and a current account is kept of all her transactions.

Types of buyers. Buyers belong to three largely different groups: large wholesale buyers who buy cheaper fish in large volume for packing, distribution, freezing and industrialization; fishmongers who own fish shops in town or peddle fish in the neighboring towns; and restaurant owners.

Purchasing strategies and goals are markedly different for the three groups. Restaurant owners tend to look for high quality product to stock their regular menu, they also take advantage of specially abundant catches or unusual species, but seem to be rather independent from competitors (except for price pressure). Retailers also keep an eye on species that allow them to keep a regular stock, but depending on the market sector they address, they may be more or less receptive to special opportunities in quality, timing and price. For example, whereas there are retailers who sell in the afternoon and early night, and hence are willing to pay a premium to fill their bundle on time to be out selling; there are other retailers who store and distribute the following day, thus can wait for competitive pressure to go down. This group is highly sensitive to competition ("if the fish shop next to mine gets good quality prawn, I can't just not have some"). Wholesalers and packers in general play on thinner margins and higher volume, thus tend to concentrate in the morning auction where there is less variety in the catches, or when a particularly large catch is brought in, but it is an heterogeneous group and valuations may differ substantially among them.

Credit requirements are different for the three groups, as well. Wholesalers have to set up a credit line of 1.5 million pesetas, retailers credit lines are usually between 300,000 and 500,000 pesetas, and restaurant owners above half a million pesetas. Conditions are somewhat discretional, but they essentially follow standard commercial credit conventions. If a buyer, for example, tends to overdraw,

[31] Explanation is temerary, but a "repeated interaction" or very long–term valuation frameworks may perhaps justify these apparently irrational behaviors.

a larger credit line is required of her. Guarantees and bonding instruments are the usual commercial banking ones.

Figure 3.8: A buyer

Purchasing. Buyers' main objective in the market is to purchase fish, an action towards which they only need to push a button of their *mineing* device at an appropriate time. By so doing, they say *mine!* to a lot at the price being displayed at the very instant they push the button. If her/his standing credit is good, and no other buyer pushed the button at exactly the same time, the buyer who first touches her button is entitled to take as many boxes of the auctioned lot as she wishes.

Buyers keep their mineing devices locked in special compartments within the market hall. Whenever they wish to participate, they remove their corresponding device and proceed into the market hall. They may enter the market hall any time, and are free to move around and leave and reenter as they wish (Fig. 3.8). This movement allows them to inspect incoming ships' cargoes as well as displayed goods. They may be also aware of other buyers' presence and activity, as well as disguise their intentions to bid. In fact, since the display boards are visible from the social area, buyers may conceal their presence by mineing bids from the bar.

Once a lot is sold, it is taken away by the purchaser (Fig. 3.9). The market is

Figure 3.9: Buyers taking their purchases away

not responsible neither for warehousing fish, nor for actual delivery of purchased boxes.

Delivery room. In the *llotja*, all sales are final[32]. Thus if a buyer has won a lot, the cost is immediately charged to his/her account. It is thus quite possible that in a given market session a buyer may exceed its credit allowance, if this happens and he calls a bid, the bid is deemed *invalid*. In fact the mineing device is automatically disabled and is not enabled again until the credit line is reactivated (through negotiation or actual payment).

A buyer may update her account or negotiate an extension to her credit line at any time during the market session, but usually they settle accounts once a week after a session.

Credit status and current account state is a private matter between the market and the buyers. Thus, although a buyer may guess the purchasing power of rivals she does not have access to the actual figures.

A 2.5% commission and the containers are charged as buyer's premium.

(C) Bystanders.

Bystanders and tourists are allowed in the market hall during market sessions. In a sense they act as witnesses to the transactions and to the upholding of the institutional conventions. They also constitute potential secondary consumers and are thus welcome by sellers and buyers.

[32]Under exceptional circumstances a buyer may realize that a lot is below its apparent quality. If the auctioneer agrees that the lot was improperly tagged or tricked, the buyer is refunded and the lot is re-auctioned (by voice) as the last lot of the boatload

(D) Llotja Staff

The market institution is responsible for providing a trained auctioneer who manages the auction itself, an admitter who classifies, weights and tags incoming produce, accounting staff who update buyers' and sellers' accounts, and support personnel who move boxes of fish around the market hall. There is also a market boss (*Secretari* of the Confraria) who acts as final authority during auctions.

Figure 3.10: The seller admitter tagging fish

Admitter The admitter is responsible for tagging incoming boxes of fish (Fig. 3.10). In so doing, supply information is automatically fed into the *llotja* data base.

This admission process is done for each boat, whose catch is to be presented by type of fish caught, and boxes of homogeneous type —species and quality— of fish are tagged (Fig. 3.11). Tagging consists of determining:

- the *type* of good that is being sold. Which in turn depends on:
  - which of the usual species of fish and seafood caught by the fleet is in the box, and
  - an indication of quality given by a code number associated to the species (usually a size–based code)[33])

[33]For shrimp, the limit case, there are 10 quality groups

Figure 3.11: Tagging fish

- the *weight* of the box, and
- the *position*, a sequential number, for the box and lot in the auction set.

Figure 3.12: Tag for a box of shrimp

Each box is weighted automatically, and automatically assigned an auctioning position, but classification is discretionally left to the admitter who may split —or join— lots. That classification affects the lot's starting unit–price (usually pesetas per kilogram), since it is automatically calculated for each lot. Starting price is usually set 20% above the last final price for that good type in a previous market day, however the admitter may change that figure discretionally. This information is handled by a data base and a tag similar to the one in Fig. 3.12 is automatically printed and deposited in each box.

No reservation price is set for any item. All items are sold (because at some price there is always someone willing to pay for a box of fish).

Presentation of Goods. The order in which lots and boxes are presented to the admitter is decided by the seller and respected by the admitter. However, the sequence in which sellers are ordered is strictly defined by the order in which the corresponding boat entered port.

Once a box is tagged, it may be handled only by market support staff until the moment it is sold ; then it is to be removed by the buyer from the display area.

Auctioneer The auctioneer manages the bidding rounds. He identifies the lot to be sold, validates the type of good, and the starting price, if things are to his liking, he starts the bidding and when the lot is mined by a buyer he adjudicates it if there are no conflicting bids.

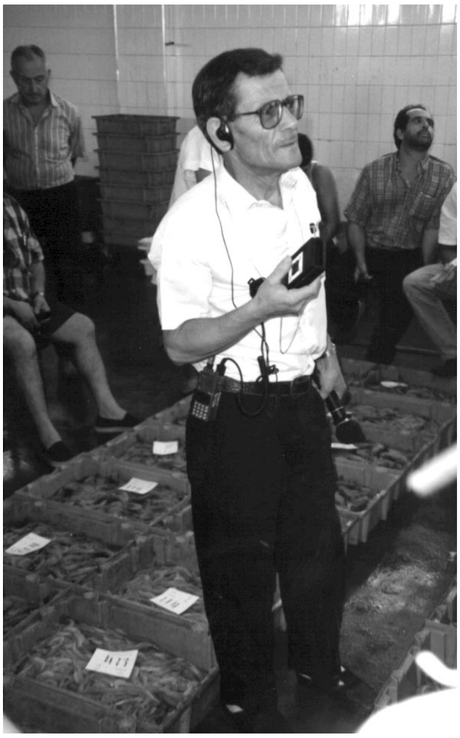

Figure 3.13: The Auctioneer

If the starting price is inadequate he may change it. If a lot has to be split (because of ostensible differences in quality), or separate lots are joined (because a better price can be paid by wholesale) or an additional lot is to be auctioned (e.g., a devolution, or a split), he has the authority to do so.

The auctioneer performs these actions by using a special *remote control device* that allows him to activate, stop and change the lot's information that is automatically displayed on two large public electronic boards. However, he also has a microphone and can override vocally the information displayed in the boards and conduct a bidding round by voice only. Cf Fig. 3.13.

The auctioneer also has a two–way communication device that keeps him in touch with the market boss and the *llotja* accounting staff. The market boss can communicate special directions —close the market, change the order of sale, raise the starting price of a good— or validate the auctioneers discretional decisions —to raise the starting price of a good, accept an unsupported bid. Whenever the electronic bidding system is overridden by the auctioneer, he has to make sure the vocal information is properly annotated by the staff.

When bidding proceeds by electronic mineing, the highest bidder and collisions are automatically detected and handled by the system, however on vocal mineing, it is the auctioneer who has to decide who mines a quote and either draw lots to break a two–way tie, or re–auction the lot when more buyers collide.

Bidding has a rhythm that depends on many factors, some of which the auctioneer can control. Time step (between quotes) is either automatically set by the system, or his total responsibility in voice bidding. Latency periods between lots of the same boat are in his absolute control, however waiting for a boat's load to be admitted and displayed may slow down or interrupt an auction beyond his best wishes. The auctioneer tries to fit the auction rhythm to the buyers state of interest and attention. The auctioneer also may act as a salesman, motivating buyers to bid by giving indications on supply, demand, quality, etc., playing on humor and authority.

The *llotja* priorizes seller's interests, thus, auctioneers discretional decisions are governed by the underlying assumption that he does things to get better prices for fish. He strives then to facilitate competing buyers to reveal the highest existing valuation as often as possible.

Market Boss The market boss oversees the market operation. In principle, he is responsible for letting the auctioneer know when the first lot is auctioned, and validates with the auctioneer the closing of the session. This is usually a routine situation, but on some occasions —when there is a storm, when there is no catch, when there is evident collusion in buyers or undue pressures, or when there is a major social upheaval— a market session my be delayed or suspended by the market boss.

The market boss also supervises the admitter and auctioneer discretional decisions and can override these.

The *secretari* of the *confraria* is the designated market boss, but he can delegate the functions on other staff members. The *secretari* is en employee hired by the guild of fishermen.

The *confraria* has a "council" as its governing body and a *patró major*, a fisherman, who acts as president of the guild for executive decisions. Neither the council nor the *patró major* intervene in the day to day market operation, although they do have a say on policy issues and conflicts.

3.3.4 Information available to participants

Electronic Devices

Figure 3.14: Bidding

Display Boards. There are two large display boards in the market hall, one at each end of the hall, where information about each (electronic) bidding round is displayed (see Fig. 3.14).

These displays have 15 fields (see 3.15). The first seven give information about a lot to be auctioned. Fields 8 through 12 display information on an actual sale. Number 14 on historical data and number 15 information about collisions and other anomalies. The actual content is explained in Table 3.1.

Most of this content is self evident, but a few comments might be useful. Field 6 shows the bidding clock, which ticks downwards while the sale is in progress. Price is shown as pesetas per kilogram and constitutes the actual auctioneer's quote that is supposed to be "mined" by a buyer. Field 13 is not in use, originally, this slot was intended to reflect a volume discount that the *llotja* used to give buyers to compensate for the irregularity in boxes' weight. But since in the electronic mineing convention, boxes are now always sold by weight, this compensation no longer applies. In field 15 different messages can

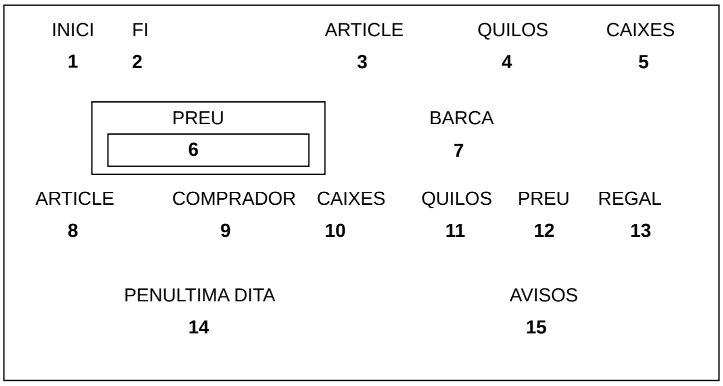

Figure 3.15: The display board

Field	**Label**	**Content**
1	INICI	The number of the first box in the lot to be auctioned
2	FI	The number of the last box in the lot to be auctioned
3	ARTICLE	Type of good
4	QUILOS	Weight
5	CAIXES	Number of available boxes
6	PREU	*Bidding clock.* Displays the current unit–price–quote
7	BARCA	Name of the Boat where the lot comes from
8	ARTICLE	Type of good
9	COMPRADOR	Buyer's name
10	CAIXES	Buyer's quantity option (boxes taken)
11	QUILOS	Total weight of these boxes
12	PREU	Unit price paid
13	REGAL	Not in use.
14	PENULTIMA DITA	The last available final bid for the same type of good.
15	AVISOS	Collision or invalid sales.

Table 3.1: Auction Room Display Boards: field content.

be displayed:

- *Collision* followed by a number. Two or more buyers pushed their mineing devices button at exactly the same time; the number is supposed to be an indication of "pressure". It is neither the number of colliding bids, nor the speed at which the collision happened in a bidding turn, but rather a combination of these.

- *Invalid Sale.* An indication that some buyer pushed the button before the bidding clock started.

- *Canceled sale.* An indication that the auctioneer overrid the round, either because a lot is to be split, several lots are joined into one, or a buyer requested an exceptional treatment: involuntary or erroneous bid, malfunction of the mineing device (usually a credit update problem), or devolution of an adjudicated lot.

The Blanes bidding convention is private, in the sense that identity of a buyer is only known when she is the highest–bidder. Collisions and other invalid transactions do not reveal buyer's identity. However, since these anomalies may require a reaction from the buyer her identity may be then revealed.

Figure 3.16: Electronic mineing

Mineing devices These are infrared emission devices which emit a single signal in different (coded) frequencies (Fig. 3.17). The *llotja* automated system has sensors in the auction room that read the signals.

The buyer devices have only one button, hence each buyer can send only one signal, but the pulse can be short or long. If the pulse is long, the signal is taken to be the acceptance of a price and the willingness to take the whole lot. If the pulse is short, it means the buyer will take a quantity option. Thus the short pulse stops the display clock and after a short latency, automatically, the "number of boxes" counter is activated. The buyer, then, has the opportunity to choose any number available by sending a second pulse in the appropriate time. Imprecisions can be overridden by the auctioneer.

Auctioneers control device In contrasting difference with the buyers' devices, the auctioneer's device has four buttons, only three of which are used:

- (Button a) to start and stop the bidding clock,
- (Button b) to change the starting price,
- (Button c) to cancel a bidding round

Voice Mineing

Figure 3.17: A *voice auction* in Blanes

Whenever a voice auction takes place —either because the auctioneer so decides, or by convention in all the morning auction sessions— slightly different conventions for price quoting and mineing are adopted.

The auctioneer has to vocally identify the lot, good type and number of boxes. The context determines if the quote will be a unit price by the box (in morning sessions) or by kilogram (in the afternoon), but instead of quoting in pesetas, the quantity denotes *duros* (five peseta units). Boat owner is ostentionably known by buyers.

Price quotes proceed very rapidly, stopping at hundredth (or thousandth) units to call the full figure and then swiftly counting down by tens (resp. hundreds). The auctioneer uses hand signals to indicate the opening of the bidding turn and the magnitude of the call (Cf. Fig. 3.17)

Mineing is stated by a clear "*yo*".

If the lot is adjudicated, the winner is identified by the auctioneer and the final price re–stated. Then the buyer may take a quantity option by stating the number of boxes she wants. Whatever is left is re–auctioned in the same way.

Collisions have to be identified by the auctioneer, if he detects two simultaneous calls he tosses a coin to adjudicate the lot. If he identifies more than two, he re—auctions it. Buyers may complain or haggle but the auctioneer word is final.

Transactions are "dictated" to the accounting staff in the afternoon voice bidded rounds, and handwritten by the auctioneer and countersigned by buyer and seller in the morning sessions.

Incidental Information

Tagged goods are displayed in the market hall. Ordered in well differentiated groups that correspond to different boats. Each group arranged in boustrophedon order in neat rows of boxes. Tags, as mentioned before, contain boat id, species, quality, weight, number of lot and box, and date.

Since boats arrive at different times, in most market sessions the full catch is not known in advance, but is gradually made known as boats arrive and goods are being sold.

Buyers may circulate freely in the market hall and inspect boxes at will. In the morning session, they even take samples to feel, weigh and count (Cf. Fig. 3.18.

Once a lot is up for sale, the corresponding information is displayed in the two display boards.

Participating buyers also see what other buyers are present, but bystanders may have a misleading effect, since not every buyer is known to everyone else.

Buyers do not know the amount of money other buyers bring to the auction. Neither expected purchases, nor accumulated purchases, are indicated in any way.

The use of mobile phones is not restricted, thus buyers and sellers may use them to be aware of the prices being set in other markets. In that way they can also arrange to present bids on behalf of external buyers or place bids themselves through other buyers (in Blanes or in other markets).

Historical information on catches and daily market session prices, as well as weekly averages, is available from the market in printed form.

Figure 3.18: Buyers sampling the morning catch

3.3.5 Bidding

A *bidding round* starts when a lot is presented for auction, and ends when it is adjudicated. The lot is presented —by ostention— by the auctioneer and its logged information displayed in the display boards: type of good, number of boxes, weight, last paid price, seller's name... When the auctioneer gives the command to start, the bidding clock starts a fast descending pace until a buyer gives a *mine* command that fixes the clock at that instant's *apparent selling price*[34].

If a single valid bid is presented, the good is adjudicated to the bidder whose identity is then displayed, and who may choose as many boxes of that lot as she wishes at the selling price. If she takes a quantity option on the lot, the remaining boxes are re–auctioned with a starting price 1.2 times the selling price.

If a tie, an invalid sale or a cancellation occur, the bidding round is repeated with a 20% price step (i.e., with a starting price that is now 1.2 times the (apparent) selling price).

3.4 Discussion: Institutional Aspects

As North [121] postulates, an institution articulates buyers' and sellers' interactions by *imposing constraints* on their behavior. In the case of the fish markets, these constraints are what I had referred to as *auctioning conventions*.

[34] *Apparent* because the bid might be invalid or a collision is taking place.

Figure 3.19: A bidding round

One may be tempted to reduce the analysis of auctioning conventions to a collection of rules of behavior. But such view, I claim, is insufficient[35].

Recall (Subsection 3.2.1) that the auctioning conventions were supposed to include at least four essential conventional features:

- who are eligible to participate in the llotja auctions,
- what information is available to participants (and when),
- how bidding proceeds, and
- how the winner is identified and how much she pays,

Even a superficial inspection of the Blanes conventions just reported shows that at least,

- rich contextual elements (an underlying legal system, some common notions of prestige and honorability…)
- shared conventions for interaction
- as well as rules of individual behavior

are at issue. And furthermore, the foregoing description does little to show how the conventions correspond to institutional goals, or how they are *imposed* on participants.

In this section I will try to illustrate the finer points the *llotja* needs to address in order to *institutionalize* its auctioning conventions in a way that those buyer's

[35]Contrast Wolfstetter [188, p. 369] that "defines" auction as "*…a bidding mechanism, described by a set of auction rules that specify how the winner is determined and how much he has to pay*" against Mc Afee and McMillan [104, p.701] "*An auction is a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants*".

and seller's interests are articulated in an effective way. I will discuss a few of the rules and conventions of the Blanes *Llotja* to set the intuitive foundations of the institutional aspects that I will develop in the rest of the dissertation.

3.4.1 Rules and rule enforcement in the *Llotja*

Let's start by distinguishing two types of rules. Ones that are **structurally enforced** —such as the electronic handling of collisions— and others that are **discretionally enforced** through the participation of staff members or by the voluntary disposition of sellers and buyers.

Here are some examples,

Structural rules

In electronic mineing, collisions are automatically detected and dealt with. The *llotja* uses for that purpose the following rules:

Rule 1 *Bidding turns have a fixed time step of one second.*

Rule 2 *All mineing signals within a bidding turn are acknowledged.*

Rule 3 *If more than one mineing signal is received within a bidding turn, a collision is declared.*

Rule 4 *If a collision is declared, the lot is re-auctioned with a price increment.*

Rule 5 *Price increment is a constant 20%.*

Even if there might be an incentive for buyers wishing not to have the price increment in the re–auction rule, they can do nothing to avoid application, no collusion with the auctioneer is possible, no backing away from a bid is feasible. The application of these rules is not subject to interpretation by anyone, and as long as the clock and the mineing devices work properly, they are blindly and uniformly and universally applied.

Enforceable discretional rules

The situation is quite different in the following cases:

Case 1: Credit update. The *llotja* guarantees that every box that is sold, is paid to the original fisherman so as a default rule it has the following "no-money no-mineing" structural rule:

Rule 6 *If a seller overdraws its credit bound, its mineing device is inhibited*

Which in fact means that the mineing device works for bids up to the amount that levels off the credit line. That is, if the buyers credit is 500,000 pesetas, and has already spend 450,000 pts., she can still buy lots whose value is up to 50,000 pts., but no more.

In such a case, it is in the interest of the buyer to have an automatic raise in her credit limit. And it is also in the interest of the seller —as long as the buyer does not default the payment— to get the highest valuation that this buyer may produce.

Consequently, it is the *Llotja* who has to decide to take the risk of a quick credit update, or let a higher bidder be silent in a round. In principle the Llotja can deal with this issue by calculating how much financial risk is absorbed by the Llotja with respect to the cost of unfulfilled higher mineing.

In Blanes, the *Llotja* opts for a strictly *discretional* rule, which allows the auctioneer and the llotja staff to react to a petition by the unsuccessful buyer. The norm could be expressed like:

Rule 7 *If a mineing device is inhibited, and the buyer requests a credit update during a bidding round; then, if there is no credit penalization on the buyer, the update is granted, and the lot is re–auctioned by voice.*

In practice, the rule involves a rather quick dialogue between auctioneer and buyer to make the credit–update request on time; another quick dialogue between auctioneer and staff to validate credit history (and not grant the automatic update to an acknowledged bad creditor); and a few latent *post-hoc* corrective mechanisms, like the market-boss faculty to decide against the auctioneer–accounting staff decisions on grounds that are not exclusivelly financial (retain or disuade that specific client, keep appropriate auction rhythm and attention, etc.)[36].

Case 2: The uniformity of lots. For the presentation of goods, Blanes has the following rule:

Rule 8 *Sellers must separate produce of different quality into different lots.*

This rule is designed to facilitate price discrimination —the fundamental reason for using auctioning rather than any other price–setting mechanism— among selective buyers (retailers and restaurant owners); thus, it tends to be good for buyers and sellers. However, sellers have an incentive to cheat on it,

[36] Recall that the mineing device is automatically inhibited when credit is surpassed, but it may also be malfunctioning. The buyer has to realize the mineing device is not working, and then request the auctioneer to declare the bid invalid. The auctioneer, in turn, may or may not acknowledge the request depending on the specific buyer and the specific circumstances surrounding the request (frequency of these requests, prestige and experience of the buyer, pace of the auction), because he can always claim that if the buyer cannot bid it is the buyer's responsibility and not the institution (because if the mineing device malfunctions it is up to the buyer to fix it, and if it is inhibited the buyer should have updated credit on time). But, this strict interpretation contradicts the principle of getting the highest possible price, since this buyer *is willing* pay more than anyone else.

for if they can have labeled as a high quality lot, one that hides lower quality elements, they can get a better unit–price. Buyers would rather not be cheated, obviously, and would prefer to have some mechanism of defense against abusive sellers.

The Blanes *llotja* has in place three enforcement mechanisms (beyond seller's voluntary compliance) for this rule:

1. The admitter's tagging, where every box is individually evaluated and tagged by a staff member.
2. The auctioneer election of a lot at the start of a bidding round, where he can split a tagged lot and auction it in parts, so that quality differences are readily discernible by buyers.
3. The devolution and re–auctioning of tricked lots.

Notice that each mechanism is progressively more costly in time to the whole market, and that impact is partially reflected in a progressively higher cost on prestige and price to the cheating seller.

However, this rule can still be circumvented by a seller, because the sequence of the three filtering mechanisms is not fail–proof. Consequently, those sellers for whom the trade–off between prestige and income loss against a better income is not clearly against themselves, may attempt to cheat.

Discretional rules of difficult enforceability

Case3: Selling outside the Llotja. For the *availability of goods*, Blanes has the following rule:

Rule 9 *Sellers should not sell any goods outside the Llotja.*

The Llotja, on one hand, because of its commercial intermediation character, is subject to a governmental regulation that requires it to charge taxes; and on the other, in order to pay its own operation costs, the *llotja* is forced to charge a commission. This is translated in a rule for *transaction costs* that says:

Rule 10 *Every sale must pay a 14% VAT and 2%commission.*

Seller's thus have an *individual* incentive to cheat on Rule 9 if they can sell outside the llotja and not pay taxes and commission, but have a *collective* dis–incentive because private negotiations lower supply and shift transaction control to the demand side.

The Blanes *llotja* relies on the general fiscal discouraging mechanisms (fiscal inspectors, tax investigations, denouncing) to discourage this practice and has no specific mechanism to avoid it.

Rule 9 is under further cheating pressure since Blanes has the following *reserve price* rule:

Rule 11 *There is no reserve price for any good.*

and the following rule for *market opening conditions*:

Rule 12 *To open an auction session there is no minimum number of buyers.*

Thus, if in a given market day a seller considers that there are few potential buyers, or that those that are there will not pay a reasonable price, he will keep his produce; and either hire a truck to take the produce elsewhere, or negotiate a private deal with an absent buyer.

The *llotja* can choose different strategies to deal with this last type of situation. For instance, it can be active to guarantee the presence of enough good potential buyers or lay back and let sellers establish contact with potential buyers by phone or radio so that Rule 12 does not affect the willingness of buyers to buy at the *llotja*. Or the *llotja* may facilitate transportation, or contacts, to have produce sold in another market if the seller needs to.

3.4.2 Institutional Consequences of Choice

The above examples illustrate some of the subtle aspects and degrees of purpose, utility, risk, convenience, flexibility and effectiveness that different conventions may entail. They also illustrate the rich variety of options an institution has at hand to establish its *auctioning conventions*, this latter point I would like to explore here.

The fact that the Blanes *llotja* adopted electronic mineing introduced many structural rules in substitution of some discretional ones. This was probably positive in terms of *fairness and reliability* to both sellers and buyers, although it had a costs in *flexibility*.

Was the balance good for business? Could Blanes automate the auctioning conventions any more? Certainly, but for what purpose?

Merely to reduce discretionallity does not seem to be a good guiding criterion for an innovation. Take for instance the *latency period* between the auctioning of two lots, the system can easily take over the auctioneer's discretional decision, but would the auctioning process become any better? Does auctioning rhythm have any effect on buyer's dispositions? Very probably. And who looses by keeping discretionallity in that issue? Probably no–one. Hence why automate that rule then? Discretionallity seems useful, as well, in less clear–cut situations as the *credit–update conventions* because the *llotja* can then react with flexibility to its own risk–exposure situation without really affecting any interests and in favor of more and better business. As long as there is adequate supervision by the *Confraria*, and adequate check–and–balance situations between competing buyers, auctioneer and staff and market boss keep functioning, the *catastrophic risk* of a costly collusion between a buyer and the llotja staff can be overcome with standard insurance and legal resources.

These comments should indicate, that the issue is not to automate or reduce discretionallity. The institutional profile of the llotja is given by a combination of choices. These choices will translate into advantages, risks, hidden costs and intangible benefits and expectations which can perhaps best be described in terms of *trust*.

Even if an auction house, like the Blanes *llotja*, is a sellers's institution, it cannot be blind to the needs and legitimate interests of the buyers. If the supply of goods is reliable, buyers will tend to come to Blanes. If classification of goods is accurate and few tricked lots are ever returned (or paid as well classified ones), buyers will count on the *llotja* staff and will be willing to accept a label of "high quality", and pay the corresponding premium right away. The trust–building effort would be reflected in that case in better prices.

What is then the moral for agent–mediated auctions? The long historical tradition of an institution is not necessarily an indication of effectiveness. Nor a guarantee for survival. Blanes may be doing things wrong and still survive. It may be loosing sales or hampering sellers or buyers legitimate interests, or even providing less than optimal revenues to everyone, but as long as it is a trusted institution —or a more trustworthy institution— it will probably operate. Thus if new forms of auctioning can be designed because technological innovations such as agent technology make them feasible, tradition and existing practices shouldn't be the sole guidance for design. But rather a careful assessment of the trust building features that old and new practices entail, together with a cold analysis of the inherent benefits and costs, what should carefully be assessed to invent a new institutional profile for agent–mediated institutions.

That I will address in the following chapters.

Chapter 4

A Dialogical Version of the Fish Market

It is better to be vaguely right than precisely wrong.

G. F. Shove[1]

In this Chapter I will define an *idealized* version of the fish market. It will be *idealized* on three accounts. First, because I will describe a somewhat simplified version of the Blanes fish market. Second, because I want this version to consider the intervention of software agents, and not only human beings. And third, because I will focus on the *dialogical* aspects of the fish market. These dialogical aspects will serve me to characterize the context in which software agents interact, and also the conventions to describe those interactions. This, idealized *dialogical* version of the fish market I will call the "Fishmarket Institution", or simply **Fishmarket**. It is formalizable in the sense that most of what I state can be made precise in a formal way, but I will not do so here. The formalized version of Fishmarket I will call $\mathcal{FM}$, a partial version of which I present in the next chapter.

In the following sections I will first argue in favor of this peculiar dialogical perspective and will introduce the notions of dialogical agent and dialogical process (Section, 4.1). With those elements I will give a superficial overview of the Fishmarket (Section, 4.2) and then a detailed definition (Section, 4.3), as well as some notational conventions. In a final section I will discuss what I have accomplished.

[1]G. F. Shove. "The place of Marshall's *Principles* in the development of economic theory", *Economics Journal* 52 (1942), 294–329, p.323

4.1 The Dialogical Stance

Let's assume that —perhaps inspired by the enlightening experience of the Blanes fish market automation— we decide to construct an electronic auction house, and that we would like to be able to buy and sell goods in this auction house *through* the Internet.

How can we go about constructing it? What do we *ought* to change in the auctioning conditions? What can be preserved?

Let's attempt a crude argument for feasibility:

- *Participants*: There have to be sellers and buyers, who may be either human beings interacting with the auction house through a standard interface or, conceivably, programs (or *software agents*) that could act on behalf of human beings; an option that would also be appropriate for at least some of the staffing of the auction house.

- *Goods*: Certainly sellers and staff would have a problem with the introduction and tagging of fish on the Internet. Buyers may also have difficulties in evaluating products, but several ways of contending with this *referential problem* come to mind. One is to trade with goods whose description is standardized in such a way that permits all the differentiation that the market needs, to the point that one can trade directly on those descriptions[2]. Another alternative is to deal with goods that are "software–grounded" (or all whose relevant referential features can be based on software and software–mediated transactions) digital goods (images, text) and also information–rich traditional goods such as stocks and bonds, airline tickets, etc. This type of object "exists" as a digital entity and its property or utilization rights is currently digitally transferred between successive owners without special considerations.

- *Bidding*: We would need to be careful to adapt to the peculiarities of the Internet the classical notions of "privacy", "presence", "simultaneity", and so on, but no serious obstacle seems at hand to describe different bidding conventions that could be realistic, safe, rapid,.... At least the type of *structural* rules of behavior, such as, collision detection and handling, bidding progression, etc. appear to have no difficulty in being electronically implemented, as the Blanes experience shows.

- *Discretional rules*: These, also, are a matter of design, and *discretionality* may be handled either as an heuristic problem (with the classical AI–type conventional tools), or discretional intervention of human staff can be

[2]This convention, however, shifts the referential problem to the admission process. Different items may require different requirements for acceptance into the auction house; appropriate guarantees on quality, delivery, refunding etc. have to be devised in addition to a sound and lucid identity preserving convention. Note that this is not an exotic form of addressing the referential problem, for example, books and CD's are currently traded in Internet with no apparent problems whenever there is an appropriate catalogue and commitments to sell and buy are dully enforced.

carefully intertwined with automated processes; situations that are really not that different from the ones in the Blanes electronic auction.

Therefore, it would seem that the implementation is feasible as long as:

(R1) The *referential* problem is properly addressed,

(R2) Adequate choices are made on the *delegability* of certain functions to more or less autonomous programs.

The referential problem, (R1), is an *ontological* problem, but as I implied in the foregoing argument, it has two distinct facets. One is a *theoretical* decision on what we take to be a (formal) entity in our domain of interaction (discourse) and whether or not it adequately represents the relevant features of a real world entity. The other is the *empirical* problem of how we can tell what constitutes a relevant feature of a real–world entity and how one can *tell* if it is adequately represented or not. The theoretical facet is a classical theory–construction problem that I will address in this chapter. The empirical facet is the same problem that underlies Electronic Commerce and one for which ample discussion on its existing and still emerging solutions is available from that community; I will comment on that in Chapter 8.

The delegability issue of (R2), on the other hand, is a *deontological* problem. It is, in essence, the fundamental problem of *agent* design, I will have a few things to say about its theoretical aspects here, and will comment on the empirical ones also in Chapter 8.

But notice that in addressing the feasibility issue, two crucial modifications have subtly crept into the web–based description of the auctioning conventions with respect to the Blanes description.

(M1) All interactions are now computer–mediated, and consequently accomplished and registered through an exchange of messages.

(M2) Only computer–based transactions can be taken to constitute a shared commitment.

And it is precisely these two subtle modifications that will allow me to formulate the **Dialogical Stance**.

I claim that:

> *Because* all interactions can be tagged by illocutions, and all observable commitments will be traceable to an illocution, agents can be thought of as entities who *engage in dialogue* and through dialogue *coordinate actions.*

In order to present my position properly I need to establish some distinctions.

4.1.1 Intuitions on dialogues

Dialogical Processes

I will first characterize a **dialogical process** and then develop the other components of the *dialogical stance*.

Notion 4.1 *A **Dialogical Process** must satisfy the following conditions:*

1. [Multiplicity]. *There must be two or more* participants.
2. [Internality]. *Participants hold* beliefs.
3. [Milieu]. *Participants exchange* illocutions.
4. [Sociability]. *Illocutory exchanges are subject to a common* interaction protocol.
5. [Situatedness]. *Participant's beliefs may* change because *of the dialogical exchange.*

Consequently, a dialogue participant will be a type of agent, who holds some sort of *dynamic* "beliefs". These can be true beliefs, opinions, desires, goals, commitments, obligations, crude propositions or simple formulas ..., for the moment such ontological distinctions are irrelevant, but I do require that there be some possibility of changing those beliefs. Neither do I commit, yet, to any special type of dynamicity, it can be deduction or pure reactiveness. The ontological content of those beliefs and the dynamic component of the belief base, nevertheless, do depend on the following requirement: a dialogical agent has to have the faculty of expressing and receiving *illocutions*. I require these exchanges to have a minimal illocutory structure (in Austin[11] or Searle's [150] terms) in order to distinguish a dialogue from a simple message–passing scheme; but I still do not commit to the exact structure and the fine distinctions of illocutions. Finally, I want to be able to impose restrictions on the sequences of *valid propositional exchanges*, and for that I will need some notion of a shared protocol.

That these notions are not vacuous I will prove by ostention, with the mention of a few intuitive examples, that they are fruitful is argued in this chapter with a dialogical version of the fish market and in Chapter 9, where I present a dialogical version of negotiation. That they are not excessive I will now show.

Examples of non–dialogical processes. My characterization of dialogical processes excludes soliloquies and classical (monological) argumentation, by virtue of the *multiplicity* condition. Similarly, by the *situatedness* condition, it would exclude any interaction convention that lacks situated elements such as an extensible set of beliefs, bounded rationality or extendible language. It also excludes unstructured exchanges (e.g. "pointless disputes") by the *sociability* condition. The characterization may also exclude any *intentionally–opaque* interaction depending on the notions of illocution and protocol one adopts. Thus, for instance, distributed computation in which concurrent processes exchange messages can be construed as dialogical processes provided the messages are taken to have illocutionary content. However, it may be preferable to adopt a more strict distinction between message and illocution. And if so, one can take as dialogical only those distributed systems in which autonomous processes communicate with the avowed intention to coordinate themselves, to learn or to argue through those interactions.

Examples of dialogical processes. The characterization in Notion 4.1 is more general than the ones usually adopted in Computational Dialectics. Those are naturally centered around the deliberative process, while I would prefer to handle argumentative dialogues *and* other forms of dialogue as well. Thus, in Computational Dialectics characterizations, the commitment bases are usually propositional, their dynamics are usually (refutationally) inferential and the protocols are usually quite deterministic, although each of these elements may be individually vulnerated for different argumentative purposes.(see for example [73, 77, 131, 179]). While these *dialectical* restrictions can be expressed within my proposal, I do not commit to any. Learning by exchanging facts or truth–labeled sentences, as in Federated Learning or by conflict identification as in Belief Revision [117] can be easily represented as dialogical processes in which the commitment bases are proper knowledge bases or belief systems, and dialogical interactions are regulated by a question–answer–delegation–validation protocol. Likewise other forms of action coordination, and in particular negotiation, can readily be expressed in these terms as will be shown in Chapter 9.

Other Dialogical Intuitions

With the above examples in mind, it may be convenient to discuss some additional intuitions.

Notion 4.2 *A* ***dialogical agent*** *will be any entity that can express illocutions —in a shared illocutory language— and react to them according to a shared interaction protocol.*

Notion 4.3 *A* ***dialogical protocol*** *is a prescriptive indication of how successive illocutions can be exchanged between dialogical agents.*

Notion 4.4 *A* ***dialogue*** *is a sequence of illocutions exchanged by dialogical agents according to a shared protocol within a dialogical process.*

I try to keep my notion of an individual dialogical agent as *theory–neutral* as possible, that is why I remain uncommitted to any *rationality* notion, or to any specific *intentional stance*; although I will have to commit to a given extent whenever I specify a particular dialogical process. I take this parsimonious attitude because I prefer to confront the reactive–deliberative debate only in those terms that allow me to argue in favor of either position on purely *empirical* *grounds*, while still being able to present a fully formalizable stance that can take any specific implementation needed. The cost I am paying is that I do need to impose a few concrete restrictions on the social aspects of the system of two or more interacting agents. Thus, I adopt a liberal notion of illocution to be able to distinguish as many illocutory features as needed (force, direction,... [151]) but I commit to one specific notion of illocution, again, only when the agreed protocol requires such a commitment. And, again, I require only a notion of sequential validity on a protocol to be able to resort to alternative formalizations of protocols.

I want to admit software agents as dialogical agents. People too. I do not require any form of actual *understanding*, but I do require these dialogical agents to engage in dialogue according to the protocol conventions, and to share at least a common language, even when a shared meaning is not a requirement[3]. This characterization is explicit about what Wooldridge calls the *social* and the *situated* nature of agents, and implicit notions of *proactiveness* and *persistence* are needed to satisfy a protocol, it is therefore at least as rich as the *weak* notion of agency, as expressed in [190]. This notion of dialogical agent can encompass the *stronger* notions of agents as well. Note, for example, that although for my purposes, the only *required* perception faculty is communication with other agents, dialogical agents may have other (non–dialogical) perception faculties, or not (cf. Chapter 2, Sec.2.2).

I should also make a few comments on the relationship between dialogues and illocutions. Notion 4.4 gives a *material* characterization of dialogue. It entails three rather important assumptions. First, the idea that a dialogue is apprehensible *post-facto* as a collection of illocutions ordered by the time of utterance. This will permit an objective substrate which is analogous to a proof in proof-theory, or the transcript of an interview in psychotherapy. The second entailment is more fundamental. It recognizes that isolated illocutions are not necessarily intelligible on their own, they may need to be taken in the context of a full dialogue to reveal their true content[4]. The third entailment involves the notion of protocol. I want to distinguish free–flowing conversation from true dialogue. As opposed to free–flowing conversation, in dialogue some conventional restrictions on meaning, flow and purpose are shared and acknowledged by the participants, and those restrictions will be embedded in a protocol. In Notion 4.3, I chose a sequential definition of protocol for simplicity, and to keep the definitions close to the natural notion of structured conversation. Thus the *potentially* alternative flows of a conversation —between any two participants— in the protocol, will always result in a single linearly ordered sequence of illocutions in the *actual* dialogue at the moment of performance or execution. Note however the intended vagueness, at this point, of the deontological component in this notion of Protocol. I will eventually have to commit to the inclusion of

[3]I grant this is a questionable position. As a radical (and jocular) example of its downside, see [143, v44–64], where "romans" and "greeks" are able to follow through a highly protocolized gesticular dialogical process without ever sharing any common meaning.

[4]This, I understand, is also something that Flores [52, 186]holds with respect to what he calls "conversations".

rules of behavior that participants are supposed to follow when they engage in a dialogue within the Fishmarket. It may be argued that existing conventional notions of protocol (distributed–systems–like, planning, process–law, etc.) already have clearly established all the elements that are relevant, and have available adequate tools to address whatever needs dialogical processes may have. Yes. On these issues as well, I remain committedly uncommitted.

Intentionality in dialogues

In Notion 4.2, not only do I commit to a shared communication language, but I also insist in forcing some syntactic relation between illocutions that are received by the agent and some form of reaction. Note, in addition, that whereas I am not requiring any special deliberative process here in this external repercussion of illocutions, in the *situatedness requirement* (of Notion 4.1) I established a *causal* relationship between perceived illocutions and internal changes. Although I try to remain detached, I am forcing here an intentional stance. This is not gratuitous, since from a casuistic perspective one can argue that the *point* of an argument, the *goal* of an action, the *issues* of a negotiation, or the *topic* of a lesson —all of these *teleological* aspects— is what explains the overall development of a dialogical exchange, or justifies each illocutory utterance among disputing rational agents. There is also a taxonomical argument: nitid, relevant differences can be easily ascribed to dialogical processes that have different *purposes* [118]. Thus, for example, a learning dialogue deals with truth–labeled beliefs, while a coordination dialogue deals with actions (or more properly *commitments to act*). Analogously, an argumentative exchange usually requires an inferential truth–conditional dynamics, while a negotiational one may rely on utility–based reasoning that may be non–inferential [154].

I am not requiring that the intentional content of a dialogical process has to be unique and permanent. Most dialogical processes involve several subprocesses that may be of themselves fully acceptable single–purpose dialogues. And as a dialogical exchange proceeds, new belief situations may induce a shift of interest, goals or intentions.

The acknowledgment of a purported finality in dialogue does not imply that agents *ought* to be intentional theories (or construed as such). It means that the dialogical protocols and the specific illocutions will involve differences for different types of dialogical exchanges. And as long as participating agents have to comply with a protocol, intentionality is reifiable through the sequence of illocutions of that agent. Thus, the (material) dialogue of a negotiation will be quite different in structure and illocutory content from that of an argumentative one. True BDI theories may be the best choice for modeling agents in some circumstances, while in others a mixed or even a crude reactive architecture will *empirically* prove to be more adequate.

Beyond Dialogical Processes

One can demand more properties to a dialogical process to better characterize other relevant features. An important added *epistemic* requirement is to account for the belief revision process in participants. It then becomes convenient to formalize the notion of belief, illocution and belief revision. This gives us a dialogical *system*.

Notion 4.5 *A* ***dialogical system*** *is a dialogical process in which:*

1. [Multiplicity]. *There must be two or more* participants.
2. [Internality (+)]. *Participants have a "belief base" $\mathcal{B}$, composed of formulas in a formal language, $L_{\mathcal{B}}$, with an inferential component ($\vdash_{\mathcal{B}}$)*[5].
3. [Milieu(+)]. *Participants exchange* illocutions *in a communication language $\mathcal{C}(L_{\mathcal{B}})$ that includes the symbols of $L_{\mathcal{B}}$.*
4. [Sociability]. *Illocutory exchanges are subject to a common* interaction protocol.
5. [Situatedness(+)]. *Participant's belief bases are $\vdash_{\mathcal{B}}$-updated when an illocution is received, and illocutions are uttered according to $\vdash_{\mathcal{B}}$ and the protocol conventions.*

This is a refinement of Notion 4.1 in the sense all dialogical *systems* are also dialogical *processes*. The differences reside in the fact that dialogical systems are *formal*. Thus in a dialogical system, each participant's beliefs, knowledge, intentions ($\mathcal{B}$) are to be subject to an inferential process ($\vdash_{\mathcal{B}}$) by which, the participant can *utter* an illocutory formula (φ) if the shared protocol allows it, when the protocol allows it, an only if it is backed by the participants belief base and inferential system ($\mathcal{B} \vdash_{\mathcal{B}} \varphi$). And whenever a participant *hears* an illocution, the illocution is processed by the participant's inferential system into its belief base (i.e., $\mathcal{B}_{t+1} = Cl_{\vdash_{\mathcal{B}}}(\mathcal{B}_t \cup \varphi)$)[6].

Again, these requirements may need to be further specified to produce actual dialogical systems. For instance, to produce **classical dialectics** ([73, 137]), one would require two participants (`proponent` and `opponent`), *classical syllogistics*, with a *refutational protocol* in which the illocutory operators would be: `assert`, `question`, `prove`, `admit`.

Another example is the dialogical system for argumentation based negotiation that appears in Chapter 9. In it, there is a formal deductive component, but also *rhetorical* elements are included in the form of *appeals* (in the form of *threats* and *enticements* and their supporting arguments).

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[5] I presume no special properties on $\vdash_{\mathcal{B}}$ not completeness, nor correctness, nor monotonicity, no nothing in particular, I am even willing to accept human reasoners if they conform to, say, syllogistic-dialectic conventions.

[6] The expression,

$$Cl_{\vdash_{\mathcal{B}}}(\mathcal{B}_t \cup \varphi)$$

denotes the $\vdash_{\mathcal{B}}$ *inferential closure* of the original belief base extended by φ.

Emotional, strategic, tactical features may also be required for specific dialogical processes and systems, however most of these will be outside of this work's focus. Nevertheless, for an appropriate description of the fish market I will need two significant ontological additions that will be incorporated in the illocutory language: illocutions will need to make reference to time and location. With that I will be able to *contextualize* the meaning of illocutions in order to simplify protocol description and some of the belief–revision conventions.

Dialogical Stances for Multi Agent Systems

Agents in a multi agent system can engage in dialogue. They usually do. But the dialogues they are usually involved in will generally involve *actions*, and not only propositions, or arguments. Most of these actions will be tagged by an illocution, and will correspond to the perlocutory content of the illocution. However, sometimes that perlocutory content may involve the actual performance of an action or a series of actions that take place *outside* of the MAS [7]. Note also that the point of conversing about actions is either to justify a certain state of affairs, or as is most common in multi agent systems, to *coordinate*, so that a state of the world obtains. Finally, note also that actions are usually concomitant with other types of beliefs, so that a dialogical system that involves actions also involves propositions, intentions, desires and so on.

By recognizing that agents coordinate actions, if I also require agents to account for the corresponding belief revision mechanisms, these mechanisms will have to encompass reasoning about actions. Actions differ from propositions in many respects, the most significant one is that actions are not true or false, but successful or otherwise. An action may fail in several ways, not only for being unsatisfactory for the intended recipient, but also for the performer of the action failing to perform, by never communicating its termination, by not terminating on time, etc. Different options to formalize actions are available. One is to take advantage of the rich distinctions and developments of planning (for example [68, 1, 168]. Another is to fall upon speech–theoretic formalisms, such as Singh's or Belnap's [160, 16]. A third one will be to adopt a "conversational" view [186, 14]. The three options are probably satisfactory. I will again remain uncommitted and recognize only that actions should be treated differently than propositions.

With all these elements, the dialogical stance that I advanced at the beginning of this section can be reformulated in two slightly different forms. The first allows for non-formal agents, the second one requires participating agents to use a formal language and justify illocutions and belief revisions.

Notion 4.6 ***[Weak Dialogical Stance]*** *A* multi agent system *is a* ***dialogical***

[7]Think of the case when a buyer agent declares its intention to pay, and then asserts that a given code corresponds to an actual electronic transference of funds, in between these two illocutory moves, other actions —perhaps several— may have taken place: the agent contacted its bank (or its owner did), a request for funds was issued and when the bank granted the funding, a transference was made to the auction house who perhaps only then acknowledges the original illocution.

process *where dialogical agents coordinate actions subject to a shared interaction protocol.*

Notion 4.7 ***[Strong Dialogical Stance]*** *A* multi agent system *is a* ***dialogical system*** *where dialogical agents coordinate actions subject to a shared interaction protocol.*

An abstract, and rather superficial, example of a strong dialogical stance is given in the next Chapter where a *layered* dialogical version of the bidding rounds is formalized. A more concrete —and far more detailed— weak stance is used in the following two sections to describe the Fishmarket.

4.2 An overview of the Fishmarket Institution

4.2.1 The idea of *Institution*

An auction —the *process* of trading fish by auction, I mean— is a dialogical process. Participants exchange illocutions and react to them following a protocol. But notice that in Blanes, whenever there is an auction some things may change, but many remain the same. Every day there is new fish. Buyers (and sellers) may vary from day to day, as well as their eagerness to buy or the money they bring along. But everyone knows that, every day, any fish that is brought in will be sold, and paid for. Everyone knows that neither the way the Llotja staff is *suppossed* to behave, nor the fact that pushing a button of the mineing machine means "mine!" change. Every one knows *because* those are the auctioning conventions that the llotja as an *institution* is there to uphold.

An institution, in everyday terms, is not merely a place, an organization or a set of employees, it is quite more. It is both a place and a group of people that perform certain tasks. It is a way of categorizing a fragment of reality (boxes of such and such types of fish, auctioneer, seller, credit lines, payments,...). And it is also a set of conventions on how participants are supposed to act on that fragment of reality (tag boxes, cry price quotations, push button,... *when* such and such things happen)[8]. An institution, thus, involves *ontological* and *deontologial* aspects. And, consequently, when an auction takes place within that institution a *dialogical process* takes place, but it is a dialogical process in which the *meaning* of illocutions, the *protocol* for the exchange of those illocutions and the *effects* and *preconditions* of those illocutions are all *upheld* by the institution.

In the next few pages I will present the Fishmarket, an idealized version of the fish market institution. It will constitute an *agent based institution* in which dialogical processes will take place among agents. Each auction event will produce one dialogue, but all dialogues will have to comply with the *institutional conventions* I shall describe. In order to make this description coherent, and hopefully more clear, I will introduce three types of theoretical constructs:

1. the dialogical framework,

[8] See D. N. North comments on this [121, pp 3–10].

2. the performative structure, and
3. the rules of individual behavior.

The first one is *ontological* since it defines the entities that constitute the virtual world of the Fishmarket, while the last two are *deontological* in as much as they correspond to the intended effects of the dialogical exchanges and the conventions according to which participating agents are assumed to behave within that world.

I will sketch the basic intuitions on these concepts now, and immediately afterwards I will give a quick overview of the dialogical processes the Fishmarket institutionalizes[9].

Context: The dialogical framework

To organize the description of Fishmarket I will first define a *Dialogical Framework*. The idea is to put into a single theoretical construct all those *contextual* elements that need to be shared by all the participants.

Such a shared convention involves at least a shared ontology and shared communication conventions.

What the ontological commitments are or ought to be is not a trivial question. I will take a *nominalistic* view and assume that by choosing a language I will commit to those entities that are mentioned in the language. And my choice of language will be given by the type of interactions I want the participating agents to be able to engage in.

Thus, I will start by defining who the participants are and a communication language $\mathcal{L}$ that will be shared by participating agents. $\mathcal{L}$ will involve a set of illocutory particles $\mathcal{I}$ to build illocutions whose propositional content will be expressed in an object language L. This object language will be introduced gradually as I develop the intervening dialogical processes.

Social Interactions: the Performative Structure

In order to describe a specific dialogical process, (recall Notion 4.1), one needs to commit to a specific interaction protocol that regulates the way illocutions are supposed to be exchanged. But because the true consequences of illocutions and the true justification for uttering one or other depends on the situation that prevails at the moment of utterance, aspects of time, location antecedent illocutions and expected ones need to be made explicit to a certain degree. To capture these elements I will resort to various devices.

1. I will define protocols for agent roles, so that it will be understood that every agent that plays that role is supposed to follow that protocol.
2. I will specify protocols as finite state machines with single initial and possibly multiple terminal states, whose arcs are labeled by illocutions. The

[9] These intuitions are developed further in the Chapter 10 of this dissertation.

states in these protocols will include *commitment bases* for participating staff agents. In these commitment bases the *preconditions* and the *intended effects* of illocutions are reflected.

3. I could specify (atomic) protocols that involve only two agent roles and then join all of those protocols that are performed concurrently at the same location into a *scene protocol*[10]. The Fishmarket, though, is simple enough to allow the unambiguous presentation of various such dialogues as "scene protocols" directly.

4. Scenes are joined by a similar amalgamation process into one *Performative Structure* that will represent the protocol of the whole dialogical process[11].

Rules for individual behavior

Depending on the convention adopted for the description of the dialogical protocol, the resulting dialogical process may be more or less undetermined in the sense that potential outcomes or situations may or may not be contemplated in that description. This is a convenient feature because it allows flexibility of design both of the institution and of participating agents. For example: the Fishmarket protocol is fully undetermined with respect to coalition between participating buyers, because that is something that I think happens "outside" of the market, although one can make one's own agents resistant to coalition or proclive to it.

By putting deontological constraints into the protocol description, and eventually into its computational implementation, one makes such constraints "structural". Everyone is uniformly and unavoidably bound to the rules up to the degree that the rules are determined by the protocol. However, one may also subscribe to the policy of making all, or some of the rules of behavior an individual responsibility by stating them in a prescriptive or normative way.

I think it is convenient to have both resources at hand, and that design reasons can be adduced for choosing a certain balance between the two.

Coding deontological elements into the protocol should make it easier to enforce the norms, and allows for a more reactive behavior of participants. It also restricts flexibility. For example, in the current implementation of the Fishmarket, FM96.5, we chose to "hard–wire" all the staff restrictions in the protocol code and as such was reflected in the code of the staff agents which are thus inflexible and efficient. In the next chapter I show the opposite alternative: how to specify "soft–wired" staff agents. I take some of the rules of behavior I mention in this section as a specification for the internal theories of deliberative staff agents whose actual implementation may take a given theory as input, and thus change their behavior whenever these rules are changed.

A convenient outcome of having explicit rules of behavior is that the elusive notion of *role* can be stated in terms of a theory:

[10]Causal and temporal precedence of subdialogues and illocutions, as well as their simultaneousness or alternativity may need to be properly accounted for in this amalgamation process.

[11]I explain these notions of scene and Performative Structure in the next paragraphs

Notion 4.8 *A role is the set of rules of behavior that an agent is supposed to comply with.*

Another one is that they can be easier to express, explain, verify and update than some protocols.

In Section 4.3.4 I will give some examples of explicit norms for staff and for external agents.

4.2.2 Main dialogical processes of the Fishmarket

Let's get a global but superficial view of the Fishmarket institution by examining the more obvious aspects of participant's interactions.

In the Fishmarket there are two classes of agents: *external* agents (buyers and sellers) and *internal* agents (staff). Sellers bring goods to an auction and buyers bring money. Through the dialogical process that constitutes an auction, goods and money change hands. But sellers and buyers never talk to each other in the Fishmarket, they interact exclusively with Fishmarket staff. Let's examine their interactions separately.

Dialogues involving a Seller

Any seller $\mathbf{s_i}$ is involved only in two dialogical processes. It will deposit its goods in the auction house and receive whatever is paid for them. Thus the seller needs to establish at least two dialogues, both with auction house staff. One to deposit goods, another one to get paid. The seller needs not to interact with anyone else, since the rest of the auction house staff sees to it that every deposited good is sold and that all purchased goods are properly delivered (or removed) from the auction room.

The two seller–staff interactions are asynchronous, and can be performed by two different staff members (a *seller admitter* **sa**, and a *seller manager*, **sm**). However, note that the second dialogue presupposes the first, since $\mathbf{s_i}$ will only get any payment for goods it had previously properly deposited. Thus the first dialogical process establishes commitments that are reflected (or presupposed) in the second one. Note also that at least in principle, these dialogical processes may be repeated in two different ways:

- The same seller and different goods. A seller may introduce goods at different times during an auction. The same seller may also collect payment once, for all the goods or at different times.
- Different sellers. Each depositing goods and getting paid at different times.

This repeatability is worth capturing, I will use the notion of **scene**, together with those of *role*, *location* and *displacement* to facilitate accounting for it.

Notion 4.9 (Scene) *A dialogical process that happens in a specific* location *and involves a cast of participant* roles *that may be instantiated by different participants, will be called a* ***scene****.*

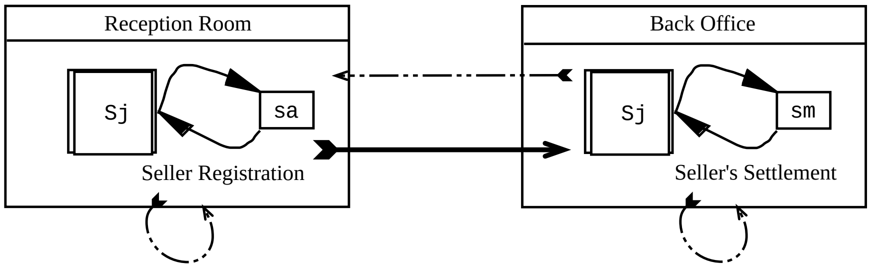

Figure 4.1: Superficial Performative Structure for sellers interactions. Note *necessary* and *potential* sequencing of scenes for a given seller indicated by solid and dashed arrows (resp.)

This is a direct theatrical analogy introduced mainly for descriptive reasons. The *script* of the scene is re–played, in different circumstances, by possibly different actual actors who, nevertheless, play the same characters or established roles. The notion of scene is evidently subsumed by that of a (cyclic) dialogical process, the script of the scene *is* the dialogical protocol, the actors are the participants, and characters correspond to roles. The notion of scene, however, allows me to *name* parts of a dialogical process that are repeated under certain circumstances and *indicate* a precedence relationship between these subdialogical processes. Moreover, the intuition of scenes conveniently suggests a certain persistence of locations and participants, in the sense that when a scene is taking place, participants are intended to be in the same location, at least while their presence is needed by the scene's script. Once the scene protocol dictates it, participating agents may or ought to change locations and start enacting another scene. In the Fishmarket, buyers and sellers will have to *move* from scene to scene and staff agents *stay* in a permanent location, taking care of new sellers, new buyers or the old ones, who may come back with new goods or bad news[12].

Note that by playing a scene, the Fishmarket world changes. New goods become available for auction, or money is available to pay for goods, or someone gets paid or charged. Note also that some scenes can only take place if certain situations of the Fishmarket world prevail, (e.g. unless a seller has brought in some fish, there can be no auction; a seller gets paid only if at least one of its goods was sold), Thus there are temporal and causal dependencies between scenes that may need to be made explicit. Finally note that the concurrent play (and replay) of scenes is a feature that is naturally needed to depict the Fishmarket, since for example, a buyer may want to update its credit while bidding is going on, or a seller may leave the market as soon as its goods are all sold, while other goods may still remain to be auctioned. These ideas are

[12]The persistence of place and the identity of agents is not a trivial issue and the notion of scene has, in this respect, some undesirable entailments. Illocutory exchanges among immobile staff members will require a means for communication between two locations, or the postulation of virtual locations. And if scenes are to be replayed by the *same* staff members (an unnecessary anthropomorphization perhaps) performance may be hampered by waiting queues that avatars or unfolding staff agents would avoid. I will touch upon these issues again in the next pages.

captured in the following description.

Notion 4.10 (Performative Structure) *A set of scenes whose temporal and causal precedence is indicated as a (possibly cyclic) graph of execution is called a* ***performative structure****.*

The performative structure, thus, depicts temporal, causal and locative relationships between scenes (and their inherent (sub) dialogical processes) but it doesn't capture neither the actual conventions for exchanging illocutions, nor the finer relationship among the participants' beliefs and the intervening illocutions. The first aspect will be captured by the interaction protocol, the second will be reifiable from the protocol and the (explicit) *rules of behavior*.

Figure 4.1 captures the *performative structure* of the seller interactions[13],

Dialogues involving a Buyer

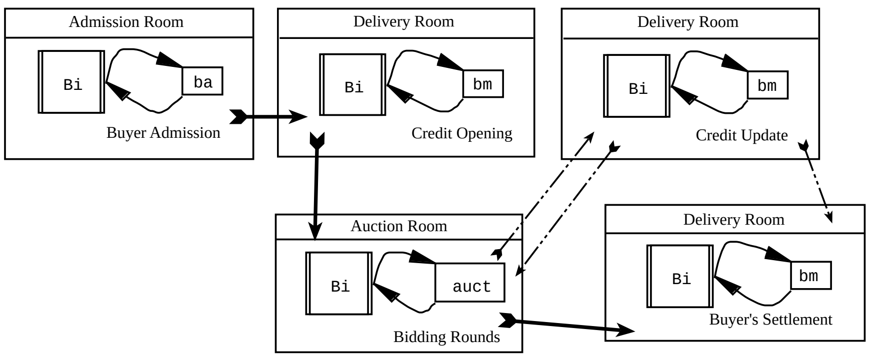

Figure 4.2: Superficial Performative Structure for buyers interactions. Solid arrows indicate the sequence in which scenes are to be performed by a given buyer, dashed arrows indicate potential replay of scenes.

Buyers play a more active role in an auction. They bid. But before bidding, a buyer $\mathbf{b_i}$ needs to register and open an appropriate account and credit line, and after bidding $\mathbf{b_i}$ may need to update the credit line (to be able to cover future purchases), settle its accounts, and remove the goods it has paid for.

These interactions can be schematized in the following *performative structure* (Figure 4.2) in which three staff members and three locations are involved: a *buyer admitter*, **ba**, who holds office in a buyers *Admission Room*; a *buyer manager*, **bm**, who works in the buyers' *Delivery Room*; and an *auctioneer*

[13] An agent **a** who happens to be a seller s_j will be said to "enter" the sellers' *Reception Room* to register its goods in the *Seller Registration* scene, where a dialogical process between the *seller* and the **seller admitter** (that is, between s_j and **sa**) takes place. Then the seller would "exit" that room and eventually "enter" the *Back Office* to receive its earnings through a *Sellers' Settlement* scene, and finally "leave" the market.

auct who presides over the *Auction Room*. Temporal and causal precedence is schematically described as well.

As for the sellers' interactions, a buyer's protocol and buyer's rules of behavior will eventually need to be specified to properly define the dialogical processes involved.

Dialogues involving Staff and overall Performative Structure

In Blanes, the market supervisor played a rather active role given the discretional character of many market conventions, specially those concerning the auctioneer's role. In the Fishmarket it will be possible to simplify these supervisory interactions by taking away from the auction house staff most discretional interventions and incorporating them into the protocol and the contents of illocutions. The few staff–staff interactions left from the fish market are essentially those involved in the initialization and updating of the auction catalogue and in the *Credit Validation Scene*[14]. However, given the virtual nature of an electronic auction house an *Activation* and a *Closing Scene* are now needed.

One can join all the previous performative structures —seller, buyer and staff— into a single diagram (Figure 4.3) that gives a synthetic representation of the *performance* of an auction in the Fishmarket .

4.3 Fishmarket

Here I present only a "formalizable" version of the Fishmarket institution, $\mathcal{FM}$, and not a fully formal description. Notice, however, that I will introduce some notational conventions that will be used here and in the following chapters in an attempt to simplify descriptions, and notice also that as I introduce the concepts I give intuitive semantics and pragmatics. Notice as well, that one partial formalization of $\mathcal{FM}$ (of possibly many better ones) is presented in the next chapter and a complementary one in Chapter 10 as a *dialogical institution*. Finally, notice that I also intend to build a computational version of the Fishmarket —an *agent mediated auction house*— and that is done as FM96.5 in Chapter 6. The intended relationship between the fish market, Fishmarket, $\mathcal{FM}$ and FM96.5 is expressed in Figure 4.4.

4.3.1 Auctions and Institutions

Let's first make a fundamental distinction. In the *world* there are buyers, sellers, goods and money and institutions like the fish market and FM96.5. Within an institution (like Fishmarket or fish market) there are *representations* of goods

[14]In this scene the auctioneer checks with the buyer manager whether a potential purchaser has enough credit to buy an item at the current price quotation or not, the buyer manager will either charge the buyer that price if the buyer is solvent, or fine the buyer otherwise and if the buyer is so insolvent as to not even have credit to pay the fine, it is expelled out of the auction house. Note that none of the staff members "leaves" the rooms where they usually hold office.

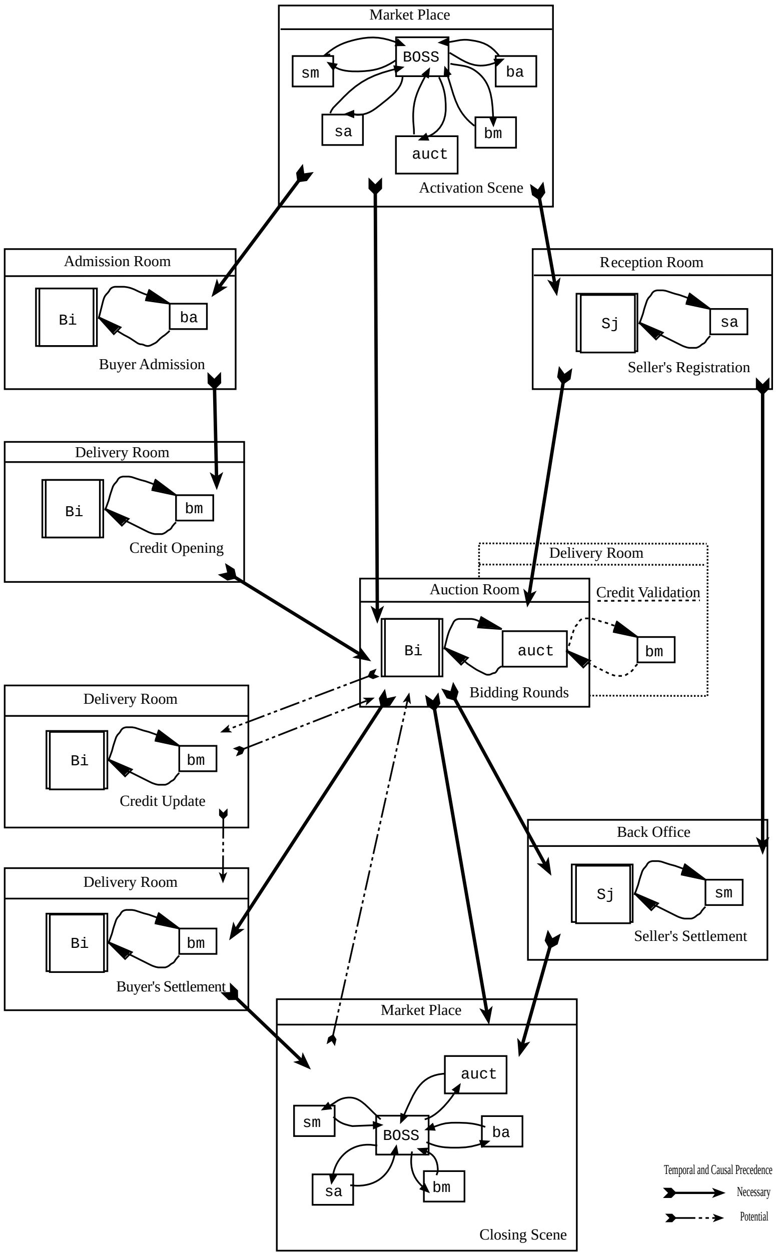

Figure 4.3: Superficial Performative Structure for the Fishmarket. Solid arrows indicate the sequence in which scenes are to be performed by an individual external participant, dashed arrows indicate potential replay of scenes.

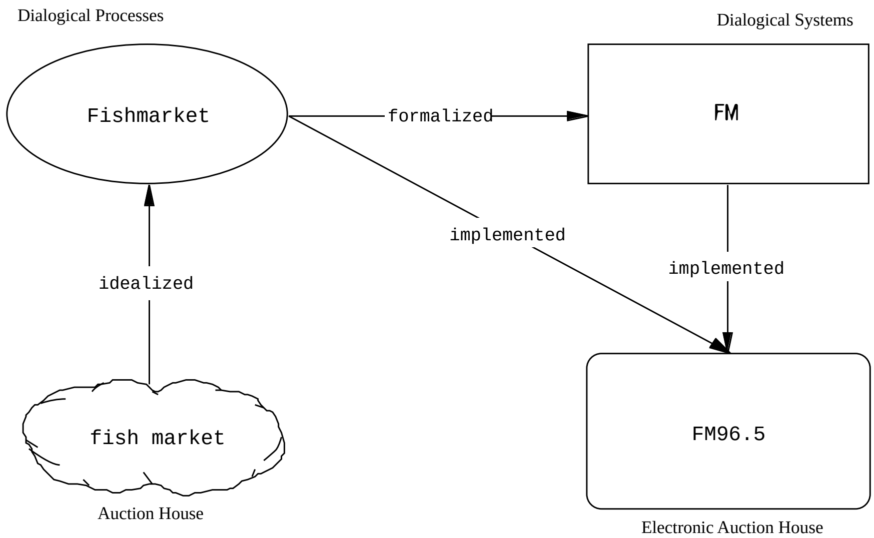

Figure 4.4: Auctions and Institutions

and sellers and money. *However* within the institution —and through illocutory exchanges— commitments are shared and obligations are adopted in such a way that whatever is agreed within the institution on those representations is to be carried over to the actual goods and money and participants in the world.

An auction, then, is a process through which a collection of goods that originally belonged to some sellers end up (mostly) in the hands of a group of buyers. In between these two extremes, there is a dialogical process in which each transformation of the initial conditions is to be made according to the auctioning conditions that the institution upholds.

To make the exchange of goods possible, participants engage in a dialogical process that is subject to an explicit set of conventions that an institution oversees and enforces through its staff. Given an initial set of conditions of property, resources, and presence, the auction starts and proceeds, gradually, until a final set of conditions are reached. In principle, at each stage in this process, the prevailing conditions can only change into resulting conditions that are consistent with the conventions that the institution upholds. An *auction*, therefore, is characterized by its participants, its initial conditions and their evolution in time (all of which belong to the actual world). An *institution* is characterized by its dialogical framework, performative structure and rules of behavior. In the case of the fish market or Fishmarket the institution is then characterized by its specific auctioning conventions.[15]

[15]It is in this sense that I mean that an auction A is *characterized* by a set of agents $\mathcal{A}$, a set of goods $\mathcal{G}$, a set of initial $\mathcal{E}_\prime$ and terminating $\mathcal{E}_\omega$ conditions whereby $\mathcal{E}_\prime$ is transformed into $\mathcal{E}_\omega$ through a dialogical process that satisfies the explicit auctioning conventions upheld by the institution. I should say that "the auction A is **performed** in $\mathcal{FM}$" (according to the

4.3.2 The dialogical framework of the Fishmarket

Communication Language and Market Ontology

The auctioning process will involve buyers and sellers who buy and sell goods through the mediation of auction house staff under some explicit auctioning conditions. This entails quite a rich ontology that needs to be reflected in the shared communication language $\mathcal{L}$ I will start developing here.

Following the standard practice in model theoretic construction, I will present a collection of language symbols (constants, functions, predicates,....) and the conventions to assemble these into formulas whose intended meaning is defined somewhat abstractly[16]. The actual meaning of these symbols and terms and formulas would depend on the entities that intervene in the actual auction session[17].

Participants and Illocutions In an auction, participants will be people or programs. In the Fishmarket institution, participants will be represented by agent constants that will have an associated role. *External agents* are buyers and sellers. *Internal* agents are those that perform roles associated with the staffing functions of the auction house.

Definition 4.1 *Let,* **Agents** *be a set of agent names, and*
Roles$=\{\mathbf{boss}, \mathbf{auct}, \mathbf{bm}, \mathbf{ba}, \mathbf{sa}, \mathbf{sm}, , \mathbf{b}, \mathbf{s}\}$
be a set of role names denoting market boss, auctioneer, buyer manager, buyer admitter, seller admitter, seller manager, buyer *and* seller *respectively. A*

auctioning conventions of the Fishmarket). Formally, $\mathcal{FM} \models A$, where

$$A = \langle \mathcal{A}, \mathcal{G}, \langle \mathcal{E}_0 \ldots \mathcal{E}_\omega \rangle \rangle.$$

[16]Abusing language I will say that a symbol is in $\mathcal{L}$ to mean that it is in the *signature* of $\mathcal{L}$.

[17]Recall that the Fishmarket is an abstract (theoretical) entity whose components are intended to correspond with real–world entities. Whereas agent id's and agent roles belong to the *Fishmarket–world theory* and will be represented by symbols in $\mathcal{L}$ —as are the types of goods and the fact that goods may have a reserve price, for example— a particular set of participants and a specific collection of goods to be sold, and the prices they get, will belong to the *real world*. Actual participants and goods and money will give signification to the dialogical exchanges that are made among real–world entities according to the Fishmarket conventions *if* they do conform to those conventions. Participating agents will be programs or people using a software interface to interact among each other, and goods may be actual boxes of fish or virtual boxes of fish, or whatever other good they may decide to trade. A specific, actual, auction will be characterized by those agents that participate in it, the goods they bring in, and the conditions they impose on them from the start and the changes that become as the auction proceeds. Therefore, actual participants and goods may change from auction to auction but they have to exist in the *real world*, while agent id's, agent roles, reserve prices are staple of the Fishmarket institution and are either constants or variables, or functions, or action symbols in L. In model–theoretic terms, a specific auction would then be a *model* of the Fishmarket *theory*, and the parameters of $\mathcal{L}$ would be *interpreted* in that model. I resist the impulse to carry this reflection further here, but the keen reader would notice that something akin to Dignum's approach in for example, [43] is needed to take that intuition to a complete formalization.

*set of **participants** in the Fishmarket* π *is a mapping:*

π : **Agents** $\rightarrow$ **Roles** *such that,*

$$(\forall \alpha, \beta \in \textbf{Agents})((\pi(\alpha) = \pi(\beta)) \wedge \pi(\alpha) \in \mathit{Roles} \setminus \{\mathbf{b}, \mathbf{s}\}), \rightarrow (\alpha = \beta)$$

I.e., each agent has a unique role, and all internal *roles are satisfied by exactly one agent.*

Abusing language, I will refer to internal *participating agents by their role (**auct,bm,ba,sa,sm,mb**), and* external *participating agents by their (indexed) role as well (buyers will be* $B = \{b_i\}_{i \in I}$*, and sellers will be* $S = \{s_j\}_{j \in J}$*)).* **staff** $\in \mathcal{L}$ *will denote the internal agents*[18]*. I.e.,*

$$\textbf{staff} = \{\textbf{auct}, \textbf{bm}, \textbf{ba}, \textbf{sa}, \textbf{sm}, \textbf{mb}\},$$

Since $\mathcal{L}$ is a *dialogical* language it will involve illocutory particles.

Definition 4.2 *The following **illocutory particles** are in* $\mathcal{L}$*:*

$$\mathcal{I} = \{\texttt{assert}, \texttt{notassert}, \texttt{request}, \texttt{declare}, \texttt{offer}, \texttt{deny}, \texttt{accept}, \texttt{command}\}$$

These illocutory particles will produce illocutions whose propositional content will be given by terms in a language L. For Fishmarket, it is enough that L be a typed first order language with equality. The exact nature of this language L is gradually given below, but assuming it is well defined and that we have an underlying set of ordered instants T (to time–tag illocutions[19]), we can define illocutions in $\mathcal{L}$ as follows:

Definition 4.3 *Given a set of participants* π*, an **illocution in** $\mathcal{L}$ is a formula of the form:*

[18] In FM, sellers will be identified by proper (boat) names:

$$S^{FM} = \{MARBLAVA, NURIA, MAIRETA, \ldots\},$$

and buyers by proper names:

$$B^{FM} = \{JOAN, PERE, MARTINEZ, \ldots\}$$

[19] All that is needed to properly describe the Fishmarket, in terms of time, is that T be a discrete acyclic forward branching order in which instants correspond to the sequential moments of utterance of illocutions according to the protocol. This model can be projected on any dense linear order that represents actual time of illocution (density is used to split concurrency). However the actual formalization is complex and is not attempted in this dissertation, but a few remarks on the **notation** are pertinent: an indexical "t_{now}" is intended whenever a simple t is written. Likewise, t' and $'t$ a *successor* and *predecessor* of t are actual indexals that point to " a next opportunity of illocution" and "the immediately past opportunity of illocution", which in the dense linear order model are referentially opaque. Intervals (such as the waiting period between rounds Δ_{rounds}) are easy to visualize in the dense linear order model, but are no longer that intuitive in the illocutory sequencing topology of time. Notice that whenever there is no ambiguity, direct mention to time is omitted in the illocutions.

$\iota(\alpha, \beta : \varphi; \tau)$
where $\iota \in \mathcal{I}$; $\alpha, \in \mathcal{A}$;$\beta \in \mathcal{P}(\mathcal{A})$; $\varphi \in L$ and $\tau \in T$
α is said to be the speaker, *β the* receptors *of the illocution ι, φ the (propositional) content of the illocution and τ is said to be the* time of utterance[20].

These are examples of Illocutions in the Fishmarket:

1. `request`$(b, bm : enter(DR); t)$ which is intended to mean that a buyer b would like to enter the Delivery Room, and at time t (*now*) requests the buyer manager's permission to enter. Such illocution presumes some utterance pre–conditions (that b is not in the delivery room, for example) and when uttered, will have an effect or produce some commitments (in this case it changes the occupancy of the delivery room and creates a pending task on the buyer manager who will have to take care of whatever business that buyer bring to him: open or update credit, or settle its account).

2. `offer`$(auct, all : tosell(g, p); t)$ denotes an offer made by the auctioneer to *all* external agents present at that moment (t) in the Auction Hall of a good g at price p[21]. The functional expression $tosell(g, p)$ is intended to represent, in this case, an action verb, *sell*, and whose arguments indicate the (direct) object g and the circumstantial condition (price) p[22]. Implicit in its semantics are the institutional assumptions on how the sale is actually performed (e.g., a good is to be deposited with the auction house, and if adjudicated to a buyer it will be delivered by the auction house to the purchaser, or whatever).

3. `assert`$(b, auct : bid; t')$ which inserted in the protocol after an illocution in time t (like the `offer` above) means that it is an intended sequent (of the `offer`) in the protocol. It denotes its acceptance by buyer b. The term *bid* denotes the *commitments to act* implicit in accepting the offer (i.e., the buyer will carry on with all the illocutionary exchanges required by the protocol afterwards, and will honor the commitments implicit in each of its illocutions).

4. `command`$(auct, b, moveout(AH); t)$ buyer b is moved out of the auction hall by the auctioneer (who has authority over every one present in that location). In this case, the preconditions are the presence of b in AH, and the postconditions its absence in AH, and its presence (at time t) in DR

[20]**Notation:** Some illocutions will be addressed to "all agents present in a room", that will be expressed with the symbol *all*. Most illocutions will have a single receptor, thus instead of $\{b\}$ I will simply write b. Likewise, since most of the illocutions I will write in this chapter are time–indifferent, I will omit the use of t.

[21]Note that I take this illocution as a collective speech act whose pragmatics involve both simultaneity and presence. An alternative approach would be to take it as a collection of illocutions, one for each external agent who is supposed to be in the room. The pragmatics may be quite different, and the implementation should be careful in paying attention to the subtle issues involved.

[22]These arguments, will be constants (a price, the identifier of a good) or terms (e.g. $p_{'t}(g) - \Phi_{price}$, indicating that the price that is offered is the previous minus a price decrement)

(because a buyer must always pass through the delivery room and clear its account before leaving the market).

5. With declare$(sa, auct : newlot(AG); t)$ the seller admitter passes the auctioneer a new lot of goods to be auctioned. It actually enables the auctioneer to make public a new part of the auction catalogue. The functional term *newlot* produces the default values for the "available goods" AG. AG is the collection of those goods that have been registered for sale (by possibly many sellers) and not yet being put up for auction, when the auctioneer receives those goods it labels them UG, "unsold goods". The illocution declare$(auct, all : present(UG); u)$, $(u > t)$ then, establishes the public commitment to auction the goods in UG.

Symbols that represent staff and market–related entities In the object language, L different symbols —actually, parameters that will stand for properties, activities, actions, locations and a diversity of parametric conditions— will be needed to formally characterize an auction house, its protocol and rules of behavior. Thus $\mathcal{L}$ will need to be rich enough to express these. Such is the purpose of the following definitions.

Definition 4.4 (Market–related parameters) *The following symbols are in* L*:*

- *Bidding–related parameters:*
  - $\Phi_{price} \in I\!R$ *(Price step. The difference between two successive price quotes in a bidding round.)*
  - $\Delta_{rounds} \in T$ *(Latency Period, or time allowed between two successive rounds.)*
  - $\Delta_{quotations} \in T$ *(Bidding window of opportunity; that is, the waiting period between two successive price quotations).*
  - $\Pi_{sanction} \in I\!R$ *(Sanction factor. Applied to an unsupported bid.)*
  - $\Pi_{re-bid} \in I\!R$ *(Price update factor, applied when an anomalous condition (a collision, an unsupported bid) forces an item to be re–bid.)*
  - $\Sigma_{Col} \in I\!N$ *(Maximum number of tolerated successive collisions.)*
- *Parameters that affect accounting processes:*
  - $\Pi_{spremium} \in I\!R$ *(Seller premium factor).*
  - $\Pi_{bpremium} \in I\!R$ *(Buyer premium factor)*[23].

[23]This parameter is included here only for completion purposes although I do not use it in any expression. In most selling auctions, the buyer's premium (normally taxes and commission) is discounted from the sale price as part of the seller's premium, but in buying auctions and some selling auctions (Sotheby's, for example) it is charged on top of the sale price. The accounting is straightforward anyway.

- $ahincome : T \rightarrow I\!R$ *(accumulated auction house income at time t)*

- *Parameters that refer to locations:*
  - RR *(sellers' registration room),* AR *(buyers' admission room),* AH *(auction hall),* BO *(sellers' back–office),* DR*(buyers' delivery room).*
  - $room \in \{RR, AR, AH, BO, DR\}$
  - *outside (to indicate that an external agent leaves the market.)*
  - $O_\lambda \subseteq \mathcal{A}$ *(Occupants of* $\lambda \in room$*)*

Good descriptors Market participants will talk about goods, that in the Fishmarket will be individual *items* ($g \in G$) that belong to different *good types*, $\widehat{G} = \{\hat{g}_k\}_{k \in K}$.

Each good is inscribed into an auction catalogue CAT and passes through different stages during an auction. First it is registered by its seller with the seller admitter who inscribes it into a temporary catalogue of "available goods", it is passed on to the auctioneer who sets its status as *unsold*, then it is put up for auction and is either *sold* or *withdrawn*.

As the good changes status, new or different information is attached to it: a catalogue number, a *starting price* ($p_0(g)$), a *reserve price*, ($p_{rsv}(g)$), a *sale price*, ($p_\omega(g)$), and a *current* price at time t, ($p_t(g)$) or *price quote*, its *seller* and the actual *buyer* if there is ever one and finally, other good–related parameters for tracking and analysis purposes: *incidents* (such as collisions and expulsions), *time stamps* for incidents, and registration, sale and withdrawal events.

An important aspect of the auctioning conventions is to define when that information becomes known and to whom, and as such is reflected in the illocutory protocol and state obligations of the social interactions.

Definition 4.5 (The auction catalogue) *Let* $G = \{g_m\}_{m \in M}$ *be a set of good identifiers and* T *a model of time, and let* B *and* S *be the buyers and sellers in an auction. Then,* CAT*, the* ***auction catalogue*** *is the following function:*

$$CAT : (G \times T) \rightarrow G \times \widehat{G} \times S \times (B \cup \{\perp, \pm\}) \times I\!R^4 \times T^3 \times INCI,$$

such that:

$CAT_t(g)_1 =$	$g \in G$	*(g's* catalogue number*)*
$CAT_t(g)_2 =$	$\hat{g} \in \widehat{G}$	*(the* type *of good g)*
$CAT_t(g)_3 =$	$seller(g) \in S$	*(the* seller *of g)*
$CAT_t(g)_4 =$	$buyer(g) \in B \cup \{\perp, \pm\}$	*(the buyer, if any, of g*
$CAT_t(g)_5 =$	$p_{rsv}(g) \in I\!R$	*(*reserve price *of g)*
$CAT_t(g)_6 =$	$p_0(g) \in I\!R$	*(*starting *price for g)*
$CAT_t(g)_7 =$	$p_t(g) \in I\!R$	*(price at time t)*
$CAT_t(g)_8 =$	$p_\omega(g) \in I\!R$	*(g's* final *price)*
$CAT_t(g)_9 =$	$t_0(g) \in T$	*(*registration *time)*
$CAT_t(g)_{10} =$	$t_\omega(g) \in T$	*(*sale/withdrawal *time)*
$CAT_t(g)_{11} =$	$incdt_t(g) = \{\langle t; i\rangle : t \in T \wedge i \in INCI\}$	*(incidents on g)*

Where:

- $\widehat{G} = \{\hat{g}_k\}_{k \in K}$ *is a set of* good types[24].
- $\perp, \pm$ *denote that the good was* left unsold *or* withdrawn *and is to be returned to the seller.*
- $INCI = \{\langle collision(n); g; \bar{b}; p(t)\rangle, \langle tie-break; b : \bar{b}\rangle$ $\langle fine; b; \Pi_{sanction} \times p_t(g)\rangle, \langle expulsion : b : cred(b)\rangle\}$

  is a list of incidents *associated with good* g.

Starting and *reserve prices* (resp., $p_0(g)$ and $p_{rsv}(g)$) are set by the sellers themselves in the process of introducing the goods to the market, but it could as well be chosen to define these as functions that depend on other variables and are set according to other conventions. Recall that in the Blanes fish market, the starting price was the last sale price times the price update factor and there was no reserve price.

Other *default values* are set by the seller manager. Values are updated by the auctioneer and the buyer and seller managers as the auction proceeds. Thus the following definitions:

Seller–related parameters Sellers will require parameters that describe their possessions, their financial dealings, and the different actions they have to accomplish or request to be accomplished for them. Some of this information is already kept in $CAT_t(g)$, it is organized and complemented in the seller's account.

The *seller account* reflects the evolution in time of the possessions and income of the seller by listing the value at time t of a seller's goods. Recall that a seller may enter the registration room repeatedly, but each time it enters the registration room, the seller registers what we refer to as a *lot of goods* which will get (from the seller admitter) the same reception time–stamp.

Definition 4.6 (Lots and newlots) *Given the set of goods* G *and a seller* s *in* S,

$$\textbf{deflot} = \{CAT_t(g)_2, CAT_t(g)_3, CAT_t(g)_5, CAT_t(g)_6 : g \in G \wedge seller(g) = s\},$$

and

$$\textbf{anewlot} = \{CAT_t(g) : g \in G \wedge (\exists s, t)(\forall g)(seller(g) = s \wedge t_\alpha(g) = t) \wedge \Psi\},$$

[24] In FM, $\widehat{G}$ will consist of a finite number of types of fish, that are well known in advance and in principle do not change.

$$\widehat{G} = \{COD, ANCHOVY, SQUID, SARDINE, PRAWNS, \ldots\}.$$

$CAT_t(g)_i$	Content	Set by	When	Known to	When	Known to all
CAT_1	g	**sa**	newlot	All	present(lot)	-
CAT_2	$\hat{g}$	**s,sa**	register	**auct**	newlot	present(lot)
CAT_3	$seller(g)$	**s,sa**	register	**auct**	newlot	present(lot)
CAT_4	$buyer(g)$	**auct**	cr-val/ re-dec.	**bm**	credit-val.	adj./w,
CAT_5	$p_{rsv}(g)$	**s,sa**	register	**auct**	newlot	withdrawn
CAT_6	$p_0(g)$	**s,sa**	register	**auct**	newlot	new-good
CAT_7	$p_t(g)$	**auct**	newgood/rebid	All	offer	-
CAT_8	$p_\omega(g)$	**auct**	cr-val/ re-dec.	**bm**	credit-val.	adj./w.
CAT_9	$t_0(g)$	**sa**	register	**auct**	newlot	present(lot)
CAT_{10}	$t_\omega(g)$	**auct**	cr-val/ re-dec.	**bm**	credit-val.	adj./w.
CAT_{11}	$incdt(g)$	**auct**	coll/cr.val	All	tie/rebid	-

Table 4.1: Market Information on Goods

where[25]

$$\begin{array}{rl} \Psi & : \; cat(g) = \hat{g} \oplus min\{x \in I\!N : \hat{g} \oplus x \notin CAT\} \\ \wedge & buyer(g) = \perp \\ \wedge & p_t(g) = p_{min}(g) = p_{max(g)} = p_0(g) \\ \wedge & p_\omega(g) = 0 \\ \wedge & t_0(g) = t_\alpha(g) \\ \wedge & t_\omega(g) = \omega \end{array}$$

That is, **deflot** will denote the default information that a seller provides of a non–empty set of goods it intends to register at time t_α. And **anewlot** will denote the complete default information of all the goods in one seller's lot that the seller manager will pass to the auctioneer.

The standard conventions in the Fishmarket are summarized in Table 4.1 that also reflects the previous definitions. In the tournament environment (Chapter 7) $CAT_t(g)$ is extended and other default setting alternatives are discussed.

Definition 4.7 (Basic seller–related parameters) *For s in S, let*

$$goods(s) = \{g \in G : seller(g) = s\},$$

be the set of **goods** of seller s. *And let*

$$Lots(s) = \{H \in \mathcal{P}(G) : (\forall g \in H)(\exists t)(seller(g) = s \wedge t_0(g) = t\},$$

*be the **lots** of goods seller s registers in the auction house.*

Let

$$incm_t(s) = \sum_{\{g \in goods(s) : t_\omega(g) \leq t\}} (1 - \Pi_{spremium}) p_\omega(g),$$

*be the **income** of s by time* t[26].

[25]**Notation:** The expression $A \oplus B$ indicates that an ordered set B is *appended* to an ordered set A and the ordering is extended in the natural way. The expression $1 \uparrow A$ denotes the *first element* of the ordered set A, and $1 \downarrow A$ denotes the ordered set resulting from the *elimination of the first element* of the ordered set A.

[26]In some auction houses, buyer's premium involves flat fees and a step functions for commissions and taxes instead of the simple constant we chose.

Definition 4.8 (Seller–account) *Given s in S, whose registered goods and income, by time t, are $goods(s)$ and $incm_t(s)$, let,*

$$selleraccount_t(s) = \{\langle u, g_u, k, K\rangle : (u = t_\omega(g_u) \wedge u \leq t) \wedge (g_u \in goods(s)) \wedge (k = p_\omega(g_u)) \wedge (K = incm_t(s))\}$$

which consists of a time ordered sequence of the goods sold, their sale price and the accumulated income up to time t, for that seller.

There should be some sort of consistency between all these functions. That can be expressed as a semantic property of the symbols or as part of the social conventions and the individual rules of behavior.

Note, for example, that in order to guarantee that both $incm_t$ and $selleraccount_t$ are well–defined functions, the default value for $p_\omega(g)$ and $t_\omega(g)$ are set, at the moment of registration, to 0 and ω (infinite) respectively. And one can define the rule for defining the next price quotation (when no bids are received) by the following conditional expression involving the price of a good at time t, its price at the next bidding opportunity (at time $t + \Delta_{quotations}$) and the price step Φ_{price} by[27]:

$$p_{t+\Delta_{quotations}}(g) := (p_t - \Phi_{price}(g)) : (p_t - \Phi_{price}(g) \geq p_{rsv}(g)) : \textbf{withdrawn}, \tag{4.1}$$

meaning that if the price was $p_t(g)$ in a given bidding opportunity (at time t), then the next price (at time t plus the waiting period between quotations) has to be $p_t(g)$ minus the price step, unless the reserve price is reached in which case the good is labeled as withdrawn[28].

Buyer–related parameters Buyers will need a few parameters associated with their credit —their available resources— and their purchases. In addition, since fines and commissions may be charged, parameters referring to these concepts will be included in L as well. Most buyer related parameters will be reflected in the buyer's account, which in a manner similar to that of the seller's reflects the evolution of the auction as it involves the buyer.

The following definitions capture the obvious underlying intuitions.

[27]**Notation:** I use Iverson's notation for function specification, where:

$$\varphi := \alpha : COND : \omega$$

states that φ gets value α if $COND$ holds, and it gets ω otherwise [82].

Notation: It may result convenient to abbreviate expressions that refer to the final conditions of a good, a buyer or a seller during an auction. I use $t_\omega(g)$ to refer to the moment the g is sold, $p_\omega(g)$ its final price, etc. Note that context will make it clear when ω is otherwise used to denote the first infinite ordinal.

[28]Recall that the value of a withdrawn or unsold good is set to 0 at the moment of registration of the good. In a more realistic commercial environment, a withdrawn good might conceivably involve some cost for the seller, while an unsold one might even oblige the auction house to pay the seller some economic compensation. Recall that a good is left unsold only when an auction is suspended for extraordinary circumstances.

Definition 4.9 (Buyer–related parameters) *Buyers require the following parameters*

- $bundle_t(b) = \{g \in G : buyer(g) = b \wedge t_\omega(g) \leq t\}$ *(the* bundle *of goods b has acquired by time t)*
- $cred_t(b) \in I\!R$ *(*credit *of b at time t)*
- $buyeraccount_t(b) = \{\langle u; tr, k, K\rangle : u \leq t \wedge tr \in TRNSCT \wedge k = amt(tr) \wedge K = cred_t(b)\}$ *(the buyer account of b at time t)*

Where $amt(tr)$ is the function given by:

$$amt(tr) = \begin{cases} 0 & if \quad collision \\ \Pi_{sanction} \times p_t(g) & if \quad fine(b) \\ p_\omega(g) & if \quad purchase(b, g, p_t(g))^{29} \\ cred_{'t}(b) & if \quad expulsion(b) \\ -d & if \quad deposit(d) \end{cases}$$

Action Terms in the Fishmarket Illocutions in $\mathcal{L}$ will involve *propositional* content that is expressed as a typed *action term* in L. These terms will be formed by a niladic, unary on n-ary symbol followed by the corresponding arguments that should belong to a certain type domain. Actions then, will require some symbols in the signature of L whose intended pragmatics are that they denote either the fact that a precondition to an action about to be invoked in an illocution is existent or that a postcontition should hold after the illocution that contains it is uttered[30].

The following action symbols are needed in illocutions used in the Fishmarket:

Definition 4.10 (Action terms in L) *:*

1. *Actions related with the presentation of goods:*
   - *availablegoods (demand a lot of goods for auction)*
   - *$newlot(\bar{g})$ (a lot of goods —with default values— is made available for auction)*

[29] Recall that I am *not* using $\Pi_{bpremium}$ to determine the cost of a transaction to a buyer, if I were, the purchase transaction would be reflected by:$amt(tr) = (1 + \Pi_{bpremium}) \times p_\omega(g)$

[30] Action related parameters, thus, correspond to verbs that syntactically will be *expressed* like functions or atomic formulas, although their semantics is a bit different. In the examples of individual rules included at the end of this chapter, rule conditions (that involve action terms) can be read as to hold true or not in a given state of the auction, in classical Tarski–like satisfiability semantics. I.e., actions will be semantically represented by a change in the commitment bases of listening agents. Thus, for example, when a buyer *enter*–s or *exit*–s a room, the set of buyers present in that room (which is part of the commitment base) will be updated accordingly by the staff member who is in charge of that room. Or, more formally, forcing the classical semantics on these performatives, if it is true that illocution $declare(s, auct : exitto(BO); t)$ is performed in auction A at time t, then the atomic formula $s \in O_{AH}$ will be true in the auction A at time t'.

- *moregoods (demand of additional available goods)*
- *nomoregoods (empty lot is transferred)*
- *lastgoods (demand of available goods in non-standard closing)*
- $lastlot(\bar{g})$ *(a final lot of goods for non-standard closing)*
- $present(\bar{g})$ *(a description a a new lot to be auctioned)*
- $entered(O_{AH}, CAT)$ *(prevalent occupancy conditions in the Auction Hall and auction catalogue)*
- $tosell(g, s, p)$ *(ready to sell a good g from seller s at price p., i.e. price quotation.)*
- *bid (*mineing *call to a price quotation.)*
- $sold(g, b, p, t)$ *(adjudication of good g to buyer b for price p at time t).*

2. *Admission and registration of external agents:*
   - $register(\bar{g})$ *(a new lot of goods* $\bar{g}$ *is brought in for registration and auctioning)*
   - $register(reason)$ *(reason for denial of registration to a seller)*
   - *registration (a new buyer attempts to register for an auction)*
   - $registration(reason)$ *(reason for denying registration to a buyer)*
3. *Incident tagging:*
   - $valid(b)$ *(credit of buyer b is good and is being charged)*
   - $fine(b, \kappa)$ *(buyer b will be fined for an amount* κ*)*
   - $fined(b, \kappa)$ *(buyer b is being fined for an amount* κ*)*
   - $expell(b)$ *(buyer b ought to be expelled)*
   - $expelled(b)$ *(buyer b is being expelled or was expelled)*
   - *invalid (last bid was declared invalid)*
   - $collision(n, g, \bar{b}, p)$ *(the nth. successive collision on good g was produced at price p by the group of buyers* $\bar{b}$*)*
   - $tiebreak(b, \bar{b}$ *(a tie–break among the group* $\bar{b}$ *was awarded to b)*
4. *Settlements for external agents:*
   - $opencredit(\kappa)$ *(sets up a buyer account with starting credit* κ*)*
   - $updatecredit(\kappa)$ *(increase the amount of credit by* κ *monetary units)*
   - *settleaccount (initiates settlement procedures for a buyer)*
   - $currentaccount(\alpha)$ *(Slip* α *reflects the current status of that agent's account)*
   - $finalsettlement(\alpha)$ *(Issuing of a final account settlement for the external agent)*

5. *Auction Management actions:*
   - $openauction$ *(ready to start bidding rounds)*
   - $endoflot$ *(prepare for another lot or auction closing)*
   - $endofauction$ *(standard termination of auction will start)*
   - $forceclose$ *(unstandard condition to close a room)*
   - $finishup$ *(terminate pending tasks without starting new ones)*

6. *location management actions:*
   - $activate(\lambda)$ *(room λ is being opened by a staff member)*
   - $ready(\lambda)$ *(room λ is ready to operate)*
   - $open(\lambda)$ *(room λ is open to market activities)*
   - $close(\lambda)$ *(room λ is being closed by the staff member in charge)*
   - $closed(\lambda)$ *(room λ has been closed)*
   - $inactive$ *(a staff member in charge of a location is now inactive)*

7. *Occupancy and movement actions:*
   - $enter(\lambda)$ *(voluntary displacement into a room λ)*
   - $exitto(\lambda)$ *(voluntary displacement from a room into a location λ)*
   - $outto(\lambda)$ *(forced displacement from a room into a location λ)*
   - $occupants(AH)$ *(a description of current occupancy of the AH)*
   - $notentered(\rho)$ *(justification of a denied entrance)*

4.3.3 Social Interactions: Performative Structure

The ten scenes included in the Performative Structure of the Fishmarket (Fig 4.3) will be given their protocols below. The only ones that will be discussed in full detail, for illustrative purposes, are those that correspond to the *bidding rounds* and the *credit validation* scenes. For the rest, only a protocol diagram and a few comments are given.

Two general remarks, though, may result useful at this point. One concerns the protocol diagrams, the other the commitment bases, or more properly, the market obligations at each scene.

Remark 1: The symbolism of the diagrams (as presented for example in Figure 4.5) can be interpreted as follows:

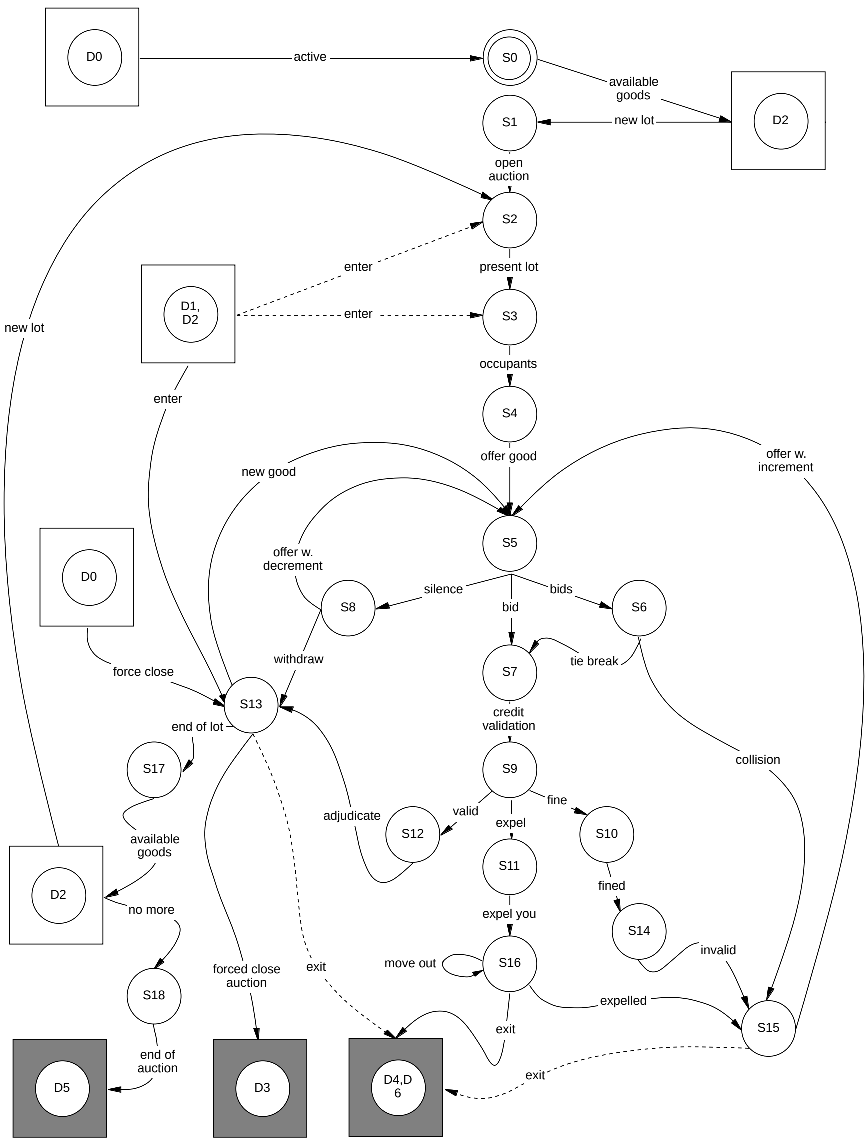

Figure 4.5: The Fishmarket bidding rounds scene

- Scenes involve different states (represented by circles) and possibly subordinate scenes (represented by boxes). Initial states are represented by a double circle, final states by a textured circle or box. Each scene must have one initial state and at least one final state for each participant type. Correspondence is made between final and initial states in subordinated diagrams.

- States and scenes are interconnected by directed lines. These lines represent an illocution or a set of equivalent illocutions uttered either by different individual agents of the same type (e.g. some buyers), or uttered by one agent to a few other agents (e.g. the auctioneer to all buyers present).

- Solid lines represent forced trajectories for the dialogical process, and dashed lines represent potential trajectories. Arrows indicate precedence.

- When two or more arrow–heads arrive to the same state or scene, they are considered independent sufficient conditions for the activation of the state or scene.

- All outgoing arrows are mutually exclusive. However, in some states, different trajectories may be followed concurrently by different participants (each participant a single trajectory).

- State and illocution labels are local to each diagram (i.e., they are not univocal for the whole Fishmarket dialogical process). Arc labels are chosen to evoke the propositional content of the corresponding illocution to facilitate reading.

- Failures are not denoted in the diagrams. The general convention is that unallowed illocutions are ignored (return to the original state without any changes in the shared commitments), additional specific conventions are stated when needed.

Remark 2: States, in the protocol diagrams, are used to make reference to the commitment bases of participants. Recall that state conditions determine the content of illocutions, and are affected by incoming illocutions because the auctioning process is a dialogical process. Agents are supposed to utter their illocutions in the Fishmarket if and when the state they are in guarantees that utterance, and are to respond to uttered illocutions in strictly the fashion dictated by the auctioning conventions. Is it necessary to keep track of all the beliefs and commitments of all participating agents to account for interactions then? Fortunately not, for two reasons. First, in the Fishmarket the only *significant* commitments are those that the auction house (as an institution) and external agents share. Individual commitments of buyers and sellers are not involved in the accomplishment of the ultimate purpose of the auction dialogical process. Second, shared market obligations in the Fishmarket are rather simple to describe and to handle. These obligations are all reflected in the seller accounts and in the buyer accounts, and can be made explicit with elegant economy by

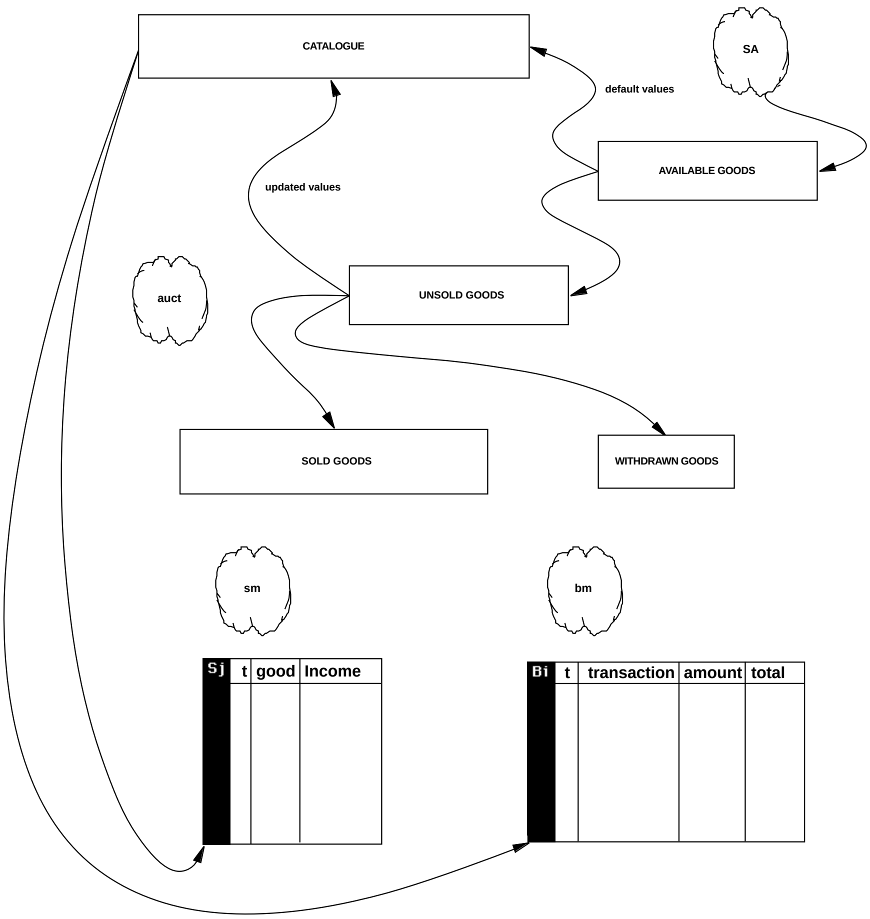

Figure 4.6: Fishmarket Institutional Obligations

making reference to the way the auction catalogue evolves and keeping track of bidding incidents and their effects in the two accounts. A few *instrumental* commitments, though, are also necessary to manage the auction process properly, fortunately these are quite simple as well: occupancy of locations, staff pending tasks, collision count and a list of expelled buyers.

The overall flow can be grasped from Figure 4.6

The auction catalogue, as we saw before, is an ordered list that is spasmodicaly filled by the seller admitter (who actually creates a temporary list of "available goods" AG, which is passed to the auctioneer; at that moment the seller admitter updates de catalogue with that information) and updated gradually by the auctioneer. The seller account is created by the seller admitter, and updated by both the seller admitter and the seller manager. The buyer account involves also the buyer admitter (create and update) and the buyer manager (updates).

Occupancy of the room where each staff agent is located and its own pending tasks are both responsibility of that same staff agent. The fact that each staff agent stays in one location greatly facilitates this aspect. Occupancy is updated whenever an external agent moves in or out of a location. Pending tasks for the auctioneer are the unsold goods in the catalogue. Entrance creates a pending task (in a queue) for admitters and managers which may need to be qualified as the dialogue proceeds and is released on reaching an *exit* or *moveout* state. The auctioneer interrupts pending tasks in the Registration Room (when requesting more goods to auction) and in the Delivery Room when validating credit [31].

Bidding Rounds Scene

This is the most characteristic dialogical process in the Fishmarket and it is also the most complex. Figure 4.5 gives a schematic description of the whole scene protocol. However, this dialogue may be easier to analyze as five supplementary subdialogues (Fig. 4.7):

1. a preparatory phase (from scenes D0 and D1 to state S4).
2. the bidding round proper (the cycles from state S4 to states S13 and S15)
3. the credit validation scene (S7, to S10–12)
4. the new lot cycle (from state S17 to S2 and S18), and
5. a closing phase (state S18 to D5)

I will discuss each one separately.

Auction Preparation Phase Assuming the auctioneer is already active and the Auction Hall (AH) open, the bidding rounds start with the request of the

[31] This interruption is needed because we have a single agent for each staff role, if the identity–stability convention adopted involved avatars or multiple agents queueing would be addressed otherwise.

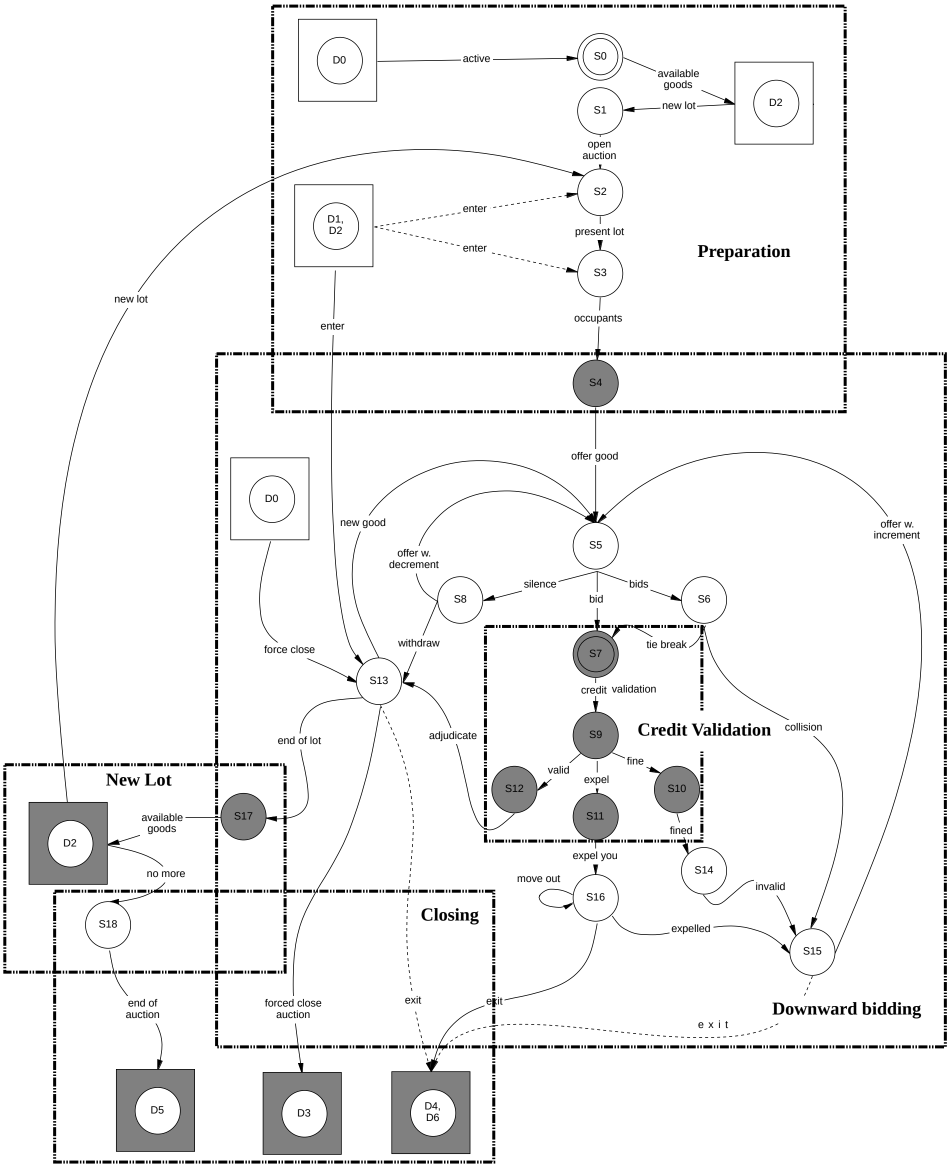

Figure 4.7: Schematic decomposition of the bidding rounds scene

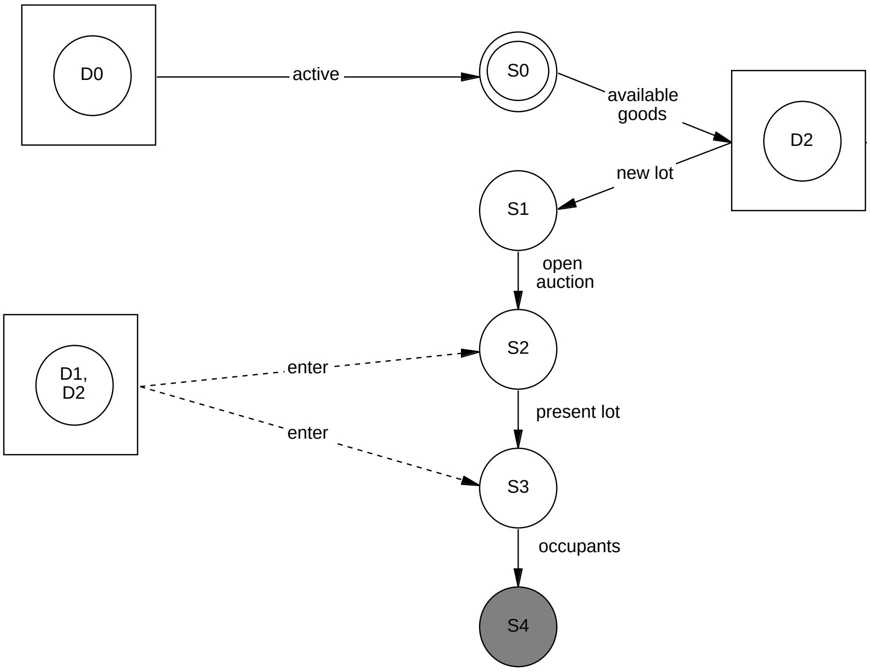

Figure 4.8: Protocol of the Preparation Phase of the Bidding Rounds

auctioneer to the seller manager of a lot of goods to auction. When the auctioneer gets a new lot (S1), if enough buyers are present, it opens the auction, gives those participating buyers (and sellers) information about the available goods and the occupancy of the room and prepares to start a bidding round by choosing a good to be offered for sale (S4). Sellers and buyers may enter the Bidding Room once the auction is open (and while no bidding is taking place).

Definition 4.11 (Illocutions in the BR-Preparation scene) *The following illocutions are exchanged in the BR-preparation subscene:*

$request(b, auct : enter(AH))$
$request(s, auct : enter(AH))$
$accept(auct, ext : entered(O_{AH}, CAT_t); t)$
$deny(auct, all : entered(reason))$
$request(auct, sa : availablegoods)$
$declare(sa, auct : newlot(AG))$
$declare(auct, all : openauction)$
$declare(auct, all : present(UG))$
$declare(auct, all : occupants(AH))$

Definition 4.12 (Obligations in the BR-Preparation scene) *The auctioneer updates the following obligation sets:*

In S1:

$$UG := AG$$

$$Pending_{auct} := UG$$

In S4 when a new good is about to be offered:

$$g := 1 \uparrow UG$$

$$p_t(g) := p_0(g)$$

In S1, S2, S3 (whenever a new participant enters)

$$O_{AH} := O_{AH} \cup \{b\}$$

$$O_{AH} := O_{AH} \cup \{s\}$$

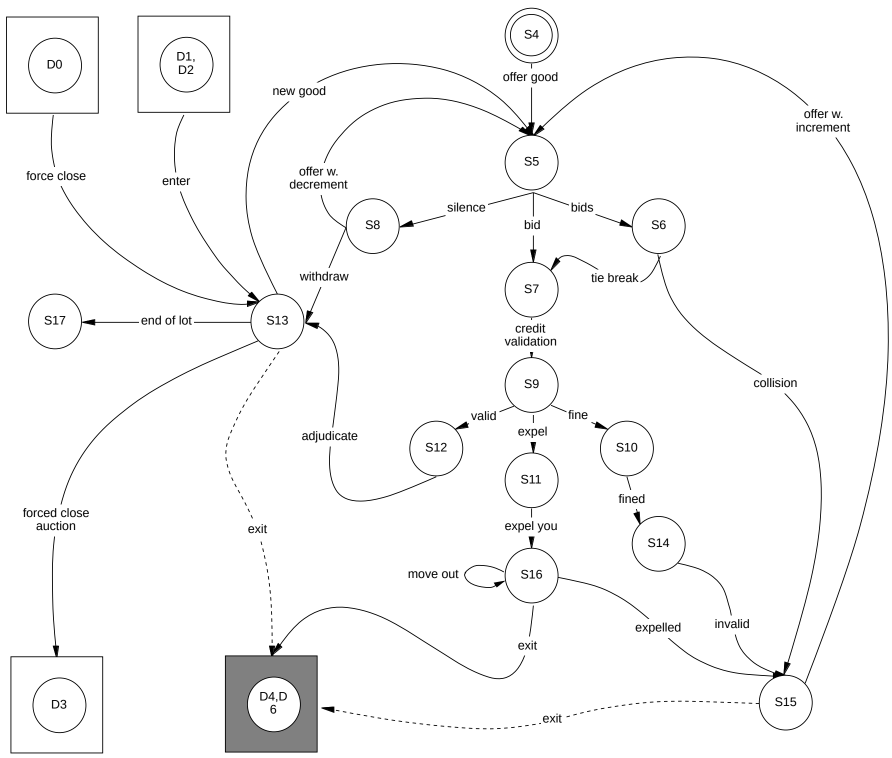

Figure 4.9: Protocol of the (downward) bidding round

Fishmarket Downward Bidding protocol We assume a starting group of buyers is in the bidding room, that a non-empty lot of goods has been presented (S3), and information about buyers present and historical prices (if any) has been made available to any new entering buyers (S4).

The auctioneer chooses a good to be sold (with its starting price) and makes an opening offer (S4). Then waits to hear bids (S5).

If no bids come after a waiting period (of length $\Delta_{quotations}$), a new smaller offer is made unless the reserve price is reached (S8). In this later case, the good is withdrawn and a new good is to be chosen for auction (S13).

If multiple bids are received in the allotted time, the auctioneer simply prepares to declare a collision and rebid the item at a higher price (S15). However with automated agents, it is not impossible to have a coincidence in heuristics that might result in an infinite ascending cycle. To counter this possibility we institute a tie-breaking criteria in which if a maximum of successive collisions Σ_{Col} is reached, one of the colliding bidders is chosen at random as a single bidder and its credit is then validated (S6). No checking is made to see if all colliding bids are valid or not. This is the same convention used in Blanes, and we thought it worth preserving since it is a manner of allowing bidders to reveal their valuations thus helping other buyers to react in a downward bidding auction (abuses are unlikely since a non–colliding malicious bid can be expensive).[32].

If a single–bid situation is reached, the *credit Validation Scene* (Section 4.3.3) is activated. As a result of that dialogue, two outcomes are possible, either the good is adjudicated, or not.

If the good is adjudicated the auctioneer declares the good sold and chooses another good (S13, again). If the good is not adjudicated it is because either a collision or an invalid bid happened. In that case, the auctioneer qualifies the type of incident and re–bids the good with a price increment (S15). Note that if an invalid bid happens, the Fishmarket charges a fine to the insolvent buyer, and if the buyer is unable to pay the fine, it is expelled out of the market. All these actions are tagged by illocutions uttered in this scene. Proper handling of the corresponding obligations (updating of the good information functions, buyer and seller accounts, updating of the set of room occupants) is made in the credit validation scene and in states S14–16.

When the good is adjudicated, the *auctioneer* is supposed to auction another good, it chooses the first one left in the catalogue of unsold goods (S13), but in case this catalogue is empty, the auctioneer declares the end of a lot and prepares to request the *buyer admitter* for another lot of goods (S17). If there are no more goods available, the auction is closed.

Buyers can enter the auction hall whenever there is no bidding going on. They have to enter from the delivery room that grants them an automatic admittance status. They get updated information on the market when registering and when a new lot is presented.

Buyers may also leave the auction room whenever there is no bidding going on. They just notify their intention to the auctioneer and are allowed out at the earliest opportunity (S13, S15, S16)[33].

[32]Note, however, that since colliding bids may be invalid, this tie–breaking convention is not good enough to guarantee a natural termination. Although, if fines are positive and buyer resources bounded, the process terminates when enough fines accumulate on the insistent insolvent buyers.

[33]This “locking” the bidding room while bidding is going on is not the convention in Blanes,

Occupancy updates are made public when a new good is up for auction (S2).

Sellers can enter and leave the room at the same moments that buyers do, but they have no opportunity to utter any illocution. They can hear all broadcasted illocutions, though.

Buyers and sellers are forced out of the room at closing time (D3, S11).

All invalid illocutions are taken as failures and return the utterer to the state where the invalid utterance was made[34].

Definition 4.13 (Illocutions in the BR-Bidding) *The illocutions used in the bidding round proper are the following:*

$offer(auct, all : tosell(g, p))$
$assert(b, auct : bid)$
$notassert(b, auct : bid)$
$declare(auct, all \cup \{bm\} : sold(g, b, p, t_\omega))$
$declare(auct, \{b, bm, ba\} : expelled(b))$
$command(auct, b, outto(DR))$
$declare(auct, all : expelled(b))$
$declare(auct, b : fined(b, \kappa)$
$declare(auct, all : invalidbid)$
$declare(auct, all : collision(g, \bar{b}, p)$
$declare(auct, all : tiebreak(\bar{b}, b))$
$declare(auct, all : endoflot)$
$request(b, auct : exitto(DR))$
$request(s, auct : exitto(BO))$

Definition 4.14 (Obligations in the BR-Bidding scene) *The auctioneer updates the following obligation sets:*

In S5, the set $\bar{b}$ of potential buyers is built during the waiting period. Its cardinality determines what action is taken next.

$$\bar{b} = \{b_i : assert(b_i, auct : bid; t + \Delta_{quotes})\}$$

In S6 when a collision happens

$$colls := colls + 1$$

If $colls < \Sigma_{col}$, a collision will be declared, and registered as an incident (recall that the incidents set is updated by the auctioneer):

$$incidents(g) := incidents(g) \oplus \langle t; collision(coll); g, \bar{b}, p_t(g)\rangle$$

However, if $colls = \Sigma_{col}$ the auctioneer is supposed to break the tie by choosing b from $\bar{b}$:

$$b := random(\bar{b}),$$

---

but it is used in a virtual auction house to guarantee *fairness* conditions.

[34] Other failures are taken as invalid illocutions or exit form the market when no recovery is achievable.

$$colls := 0$$

and consign the tie–breaking incident:

$$incidents(g) := incidents(g) \oplus \langle t; tie - break; b; \bar{b} \rangle$$

In S8 when a good is offered again with a decrement

$$p_t(g) := p_t(g) - \Phi_{price}$$

In S8 when a good is withdrawn:

$$WG := WG \cup \{g\}$$

$$UG := 1 \downarrow UG$$

$$p_\omega(g) := withdrawn$$

$$Pending_{auct} := UG$$

In S12, the auctioneer updates final information on g, and its pending tasks:

$$p_\omega(g) := p_t(g)$$

$$t_\omega(g) := t$$

$$buyer(g) := b$$

$$bundle(b) := bundle(b) \cup \{g\}$$

$$SG := SG \oplus g$$

$$UG := 1 \downarrow UG$$

$$Pend_{auct} := UG$$

In S13 when a new good is offered ($UG \neq \emptyset$)

$$g := 1 \uparrow UG$$

$$p_t(g) := p_0(g)$$

In S14 when a buyer is being fined:

$$incidents(g) := incidents(g) \oplus \langle t; fine; b, \Pi_{sanction} \times p_t(g) \rangle$$

In S15 when a good is re–bid with an increment

$$p_{t'}(g) := \Pi_{re-bid} \times p_t(g)$$

In S16 when a buyer is expelled:

$$O_{AH} := O_{AH} \setminus \{b\}$$

$$incidents(g) := incidents(g) \oplus \langle t; expulsion; b; credit(b) \rangle$$

In S13 (whenever a new participant enters)

$$O_{AH} := O_{AH} \cup \{b\}$$

$$O_{AH} := O_{AH} \cup \{s\}$$

In S13, S15 and S16 (whenever a participant leaves)

$$O_{AH} := O_{AH} \setminus \{b\}$$

$$O_{AH} := O_{AH} \setminus \{s\}$$

The buyer admitter is responsible for updating the unelegible buyers set in S16:

$$UB := UB \cup \{b\}$$

And, finally, buyer manager and seller manager update accounts in S13.

The buyer manager should update the purchase of a good, when that good is adjudicated (S13) (although the credit line is affected already in S9) in the buyer account, and the house income:

$$BA(b) := BA(b) \oplus \langle t; purchase : b, g, p_\omega(g); credit(b) - p_\omega(g) \rangle$$

$$ahincome := ahincome + (\Pi_{spremium} \times p_\omega(g))$$

The seller manager will reflect the transaction in the seller account as well:

$$SA(s) := SA(s) \oplus \langle t_\omega(g); g; p_\omega(g); p_\omega(g) - (\Pi_{spremium} \times p_\omega(g)) \rangle$$

Credit Validation Protocol (Figure 4.10) .

This scene involves two staff members: the auctioneer and the buyer manager who, without leaving their respective rooms exchange the following messages[35]:

Definition 4.15 (Illocutions in the Credit validation scene) *The following illocutions are uttered in the credit validation scene:*

$request(auct, bm : credit - status(b, p_t); t + \Delta_{quotations})$
$assert(bm, auct : valid(b))$
$assert(bm, auct : fined(b, fine))$
$request(bm, auct : expel(b))$

[35] I have kept the intuition of a physical location as far as I could, but it fails here. This intuition is convenient for descriptive and prescriptive purposes, however dialogues involving two staff members are necessary to coordinate the market, and the choice was either to force a move of at least one of the staff members, or to enable some sort a virtual location, the second option is the one I chose. One can think of this situation as if staff members would interact through a closed–circuit channel.

Behind these apparently frivolous metaphors lies the elusive problem of agent identity. It has proven convenient to preserve agent identity associating one agent with a collection of tasks and a physical location. The costs have been reflected in performance efficiency and some queuing complications in implementation, but ontological parsimony was intended (really). But now these *virtual locations* need to be postulated

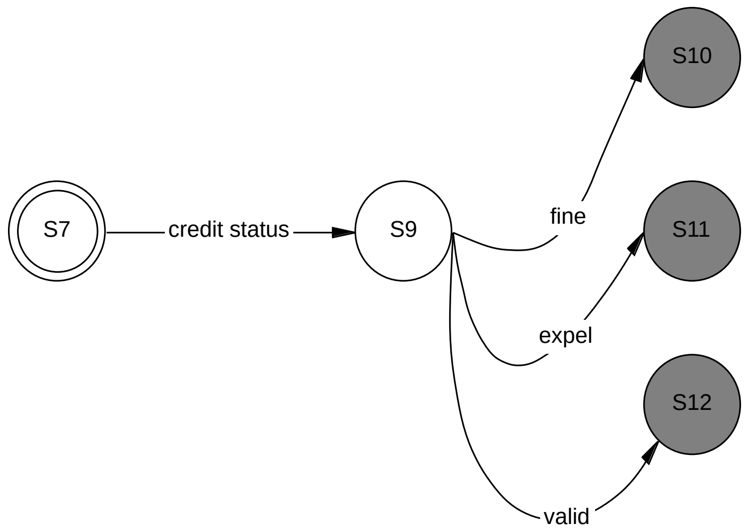

Figure 4.10: Protocol of the Credit Validation Scene

If a single bid is received, the auctioneer request a position on a potential buyer's resources. It does that through the illocution:

$$request(auct, bm : credit - status(b, p_t); t + \Delta_{quotations})$$

The buyer manager acts on that request (S9) by examining the credit line of the potential buyer charging the transaction costs to the buyer's account. The manager then may answer *valid*, *fine* or *expel*. The auctioneer reacts as expected in the continuation of the bidding round (S10–12).

State Obligations can be summarized as follows:

Definition 4.16 (States in the Credit validation scene) .
In S9 the buyer manager inspects and updates, bs account, as follows:

- *If the buyer has enough credit to pay $p_t(g)$ monetary units for good g, the buyer manager charges the full price $p_t(g)$:*

  $$credit(b) := credit(b) - p_t(g)$$

  This transaction, and the corresponding auction house income, are registered in the buyer account and the house account when the good is adjudicated by the auctioneer (state S13).

- *If the buyer does not have enough money to pay for the good, but enough to pay for the fine, the fine is charged and the buyer account and house income updated:*

$$credit(b) := credit(b) - (\Pi_{sanction} \times p_t(g))$$
$$BA(b) := BA(b) \oplus \langle t; fine : b, g, p; credit(b) - (\Pi_{sanction} \times p_t(g))\rangle$$

$$ahincome := ahincome + (\Pi_{sanction} \times p_t(g))$$

- *If the buyer has no money to even pay for the fine, it will be expelled and its remaining credit taken over by the auction house:*

$$ahincome := ahincome + credit(b)$$
$$credit(b) := 0$$
$$BA(b) := BA(b) \oplus \langle t; expell : b, g, p; 0\rangle$$

New Lots of Goods In the Fishmarket we decided to reproduce the possibility of admitting goods while the auction is in progress. Thus when the auctioneer runs out of goods to auction, it has to check with the buyer admitter to see if more goods are available for sale. The buyer admitter makes these available (in the order these arrive) if there are any. If not, it will constitute a closing condition.

Definition 4.17 (Illocutions in the New Lots scene) *:*
$request(auct, sa : moregoods; t)$
$declare(sa, auct : newlot(CAT_t); t')$
$declare(sa, auct : nomoregoods; t')$

Definition 4.18 (States in the New Lots scene) .

- *The initial state of this sub–scene, (S13 in the bidding rounds scene), is*

$$UG := \emptyset$$

.

- *In D2, the seller admitter checks its AG catalogue, if it is not empty, it will update CAT before taking care of any other pending sellers:*

$$CAT_t := AG$$
$$AG := \emptyset$$

If AG is empty, the seller admitter checks to see if any sellers are waiting to enter the room. If so, takes care of the first of these, updates AG with the **anewlot** *information and responds to the auctioneer as before. Then proceeds to take care of any other waiting and incoming sellers. That is,* *If* $Pend_{sa} \neq \emptyset$,

$$s := 1 \uparrow Pend_{sa}$$

$$AG := anewlot$$

$$CAT_t := AG$$

$$AG := \emptyset$$

$$Pend_{sa} := 1 \downarrow Pend_{sa}$$

However, if no sellers are waiting to register and AG is empty, it will declare that to the auctioneer and prepare to close its room.

- *If a new lot is available, the auctioneer goes to S2 in the Bidding Rounds scene protocol with the updated catalogue and list of unsold goods received from the buyer admitter. Thus it updates the list of auctionable goods and pending tasks accordingly:*

$$UG := CAT_t(g)$$

$$Pending_{auct} := UG$$

Note that this is a rather flexible convention, since the rules of behavior of the buyer admitter may be such that admission of goods is restricted in different ways, for instance that new goods can be entered all at the start, and they may or may not be made known to buyers then, or only lot by lot. Lots can be organized according to different criteria because it is up to the buyer admitter to let the auctioneer know if there are new lots. The buyer admitter also controls the moment an auction is closed by withholding the no–more–goods illocution as long as it wants or needs.

Bidding Rounds Closing Protocol (Figure 4.11) This is the standard closing convention for an auction. Once the last good has been sold, and no new goods are available at the admission room (S18), the auctioneer declares the auction finished and notifies the rest of the staff that the auction is over. Actual closing of all the rooms starts then as explained in subsection 4.3.3. Note that in this standard closing, the registration room is being closed by the seller admitter while the auctioneer declares the auction closed.

Definition 4.19 (Standard closing illocutions) .

$declare(auct, all : endofauction; t)$
$request(auct, ba : close; t')$
$command(auct, b : exitto(DR); t'')$
$command(auct, s : exitto(BO); t''')$
$request(auct, sm : finishup; t'''')$

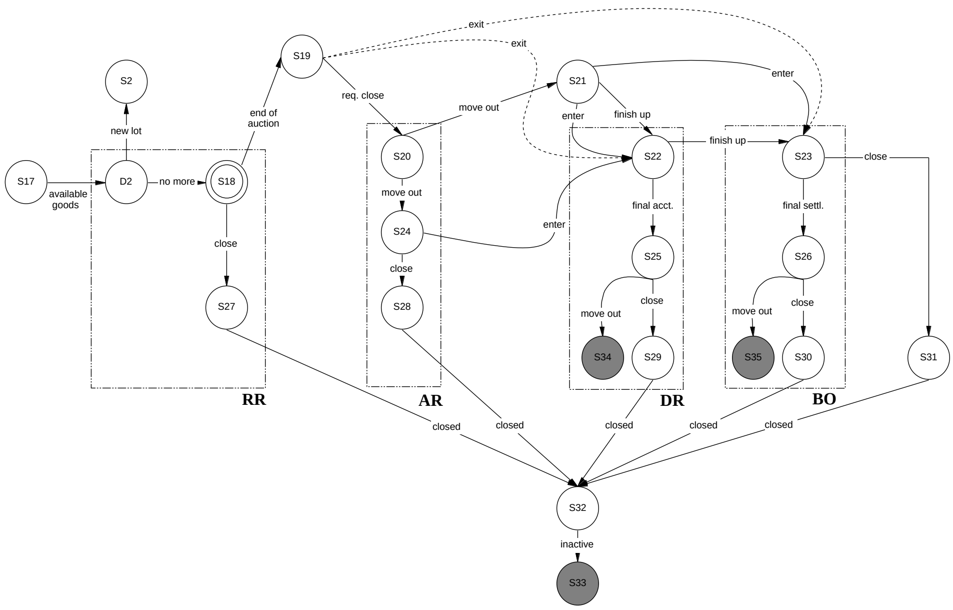

Figure 4.11: Protocol for closing the bidding rounds scene

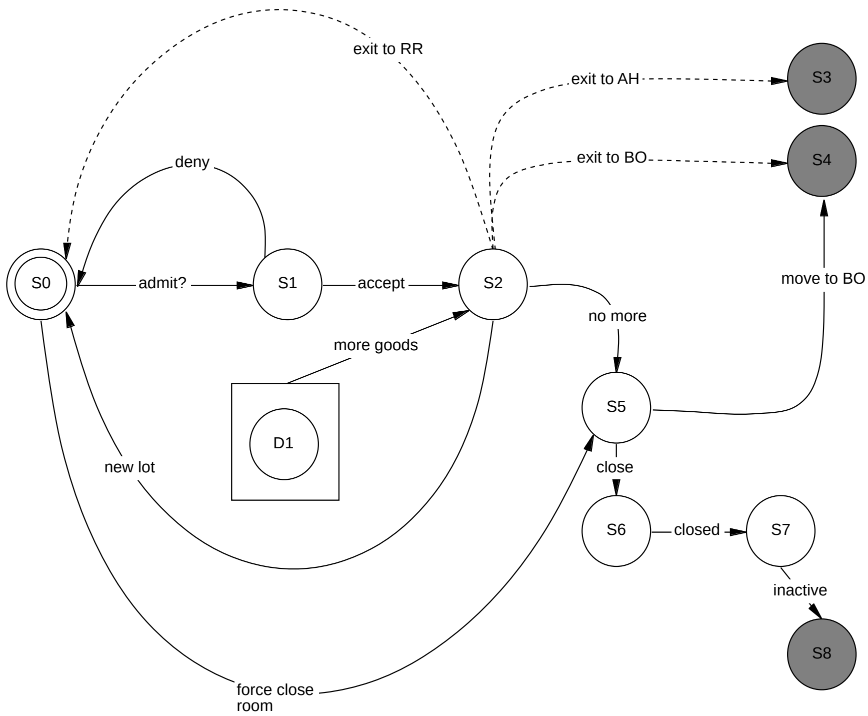

Figure 4.12: Protocols of the Sellers' Registration Room Scenes

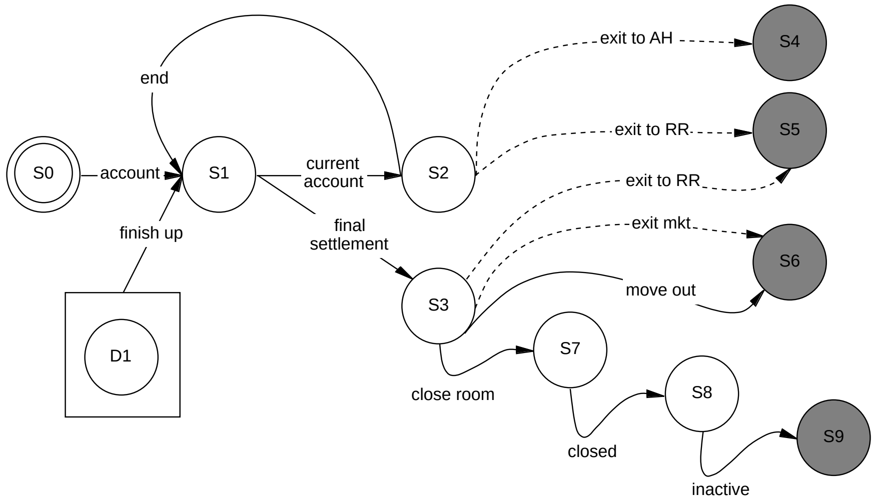

Figure 4.13: Protocols of the Sellers' Back Office Scenes

Seller Registration and Seller Settlement Scenes

Seller Registration (Figure 4.12). Sellers register a lot of goods by entering the Registration room and listing the goods in the lot. They are then allowed to enter the auction hall, or the back office. The seller admitter updates AG and the auction catalogue with that new lot of goods, setting at that point the default values for each good.

This scene can be repeated as long as the auction is open, but additional or different requirements may easily be adopted. For instance one can require that registration of goods be done only once for each seller and that registration be done prior to a certain time by simply inhibiting the seller's re–registration cycle and adding a filtering time or repeatability condition in the initial state of the registration scene.

The diagram also shows the closing and forced closing processes.

Definition 4.20 (Illocutions in the Registration Room) *:*

$request(s, sa, register(lot))$
$accept(sa, s, registration(anewlot)))$
$deny(sa, s, registration(reason)))$
$request(s, sa, exitto(room)$
$request(auct, sa, moregoods)$
$declare(sa, auct, newlot(AG)))$
$declare(sa, auct, nomoregoods)$
$command(boss, sa, forceclose)$
$command(sa, all, outto(BO))$
$declare(sa, boss, closeroom(RR))$
$declare(boss, sa, closed(room))$
$declare(sa, boss, inactive)$

Where, anewlot is the completed default information that is inscribed in the catalogue, from the information given by s in lot, and

$$room \in \{BO, AH, RR\}.$$

Seller's Settlement (Figure 4.13). Once a good that was registered by a seller has been auctioned, that buyer can request a settlement. If the good was sold, the corresponding payment is made. If the good was withdrawn it is returned.

The seller manager settles all standing accounts with the seller when it enters the room. But if all the goods a seller has registered have not been auctioned by the time the seller enters the back office, only a partial settlement is performed by the seller manager.

After a partial settlement of its account, the seller may enter the auction room, or stay in the back office until the auction is over. A seller may re–enter the Reception room with more goods (if multiple registration is allowed), after a partial or a final settlement, but it cannot leave the market unless all its registered goods have been settled.

Order of arrival into the room is also the convention here for standing settlements, however, since these settlements are not necessarily final, when a seller has had a settlement and decides to remain in the room, it is put at the end of the standing settlements queue.

Settlements may be an empty sales slip. This happens because a seller may re–enter the back office in an interval in which none of its goods have been auctioned.

If an auction is forced to close by the market boss, some goods may be left un–auctioned. In this case, the seller manager should acknowledge it in the final settlements slip. Notice also that in a forced closure, all sellers are moved into the back office by the seller admitter and the auctioneer.

When the auction is over, all sellers are forced out of the market once their accounts are settled.

Definition 4.21 (Illocutions in the Back Office scenes) *:*

$request(s, sm, enter(BO))$
$declare(sm, s, finalsettlement(SA))$
$declare(sm, s, currentaccount(SA))$
$request(s, sm, exitto(room))$
$command(sm, s, outto(outside)$
$request(auct, sm, finishup)$
$declare(sm, boss, closeroom)$
$declare(boss, sm, closed(room))$
$declare(sm, boss, inactive)$
Where, $room \in \{AH, RR, outside\}$

Buyer's Admission and Credit Management Scenes

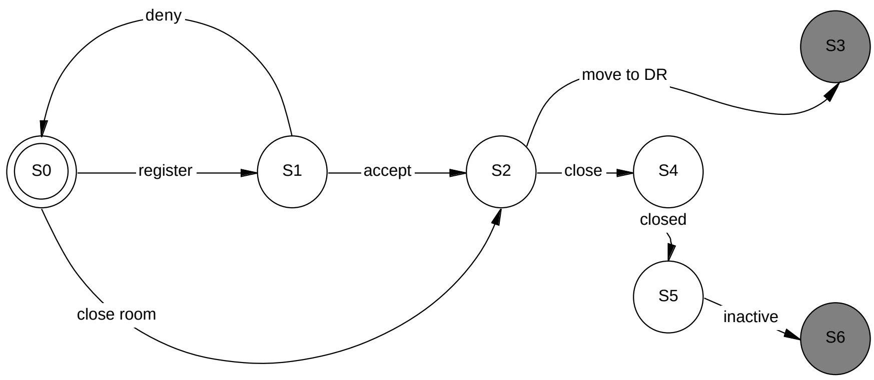

Figure 4.14: Protocol of the Buyer Admission Room scenes

When the Admission Room is open a buyer can enter by signing in with an opening credit line. It is then automatically sent to the delivery room to register its credit, unless it had been previously expelled from the market, in which case it is denied entrance to the market.

Definition 4.22 (Illocutions in the Buyer Admission scene) *:*
$request(b, bm : register)$
$accept(bm, b : registration)$
$deny(bm, b : registration(reason))$
$command(bm, b : outo(DR))$
$request(auct, bm, close)$
$declare(bm, boss, closeroom)$
$declare(boss, bm, closed(room))$
$declare(bm, boss, inactive)$
Where, $room \in \{AR, DR\}$

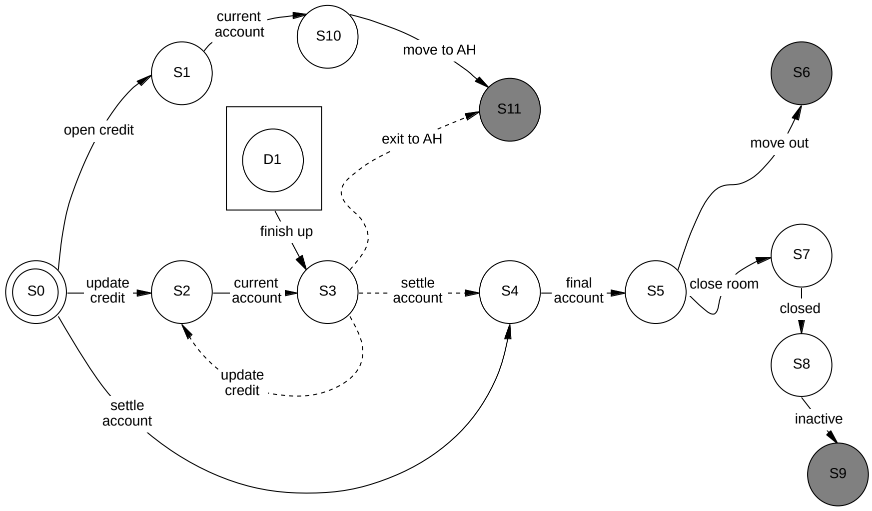

Figure 4.15: Protocols of the Delivery Room scenes

Credit Opening and Update

In the Fishmarket, a credit line is opened with a simple declaration of intention by the buyer. The buyer manager reflects all transactions in this credit line without any further intervention of the buyer.

Once a credit line is established, the buyer is forced into the auction room. At that moment all available public information is passed to it.

When a buyer wants to update its credit line, it has to enter the delivery room and request an update for the amount it wants to be added to its current account. It may then re-enter the auction room or remain in the delivery room.

Buyers' Settlements

A buyer may leave the auction hall when no bidding is taking place, but to leave the market it has first to settle its account. To do that it has to enter the Delivery room and request a settlement. Its purchases are delivered to the buyer and its current credit line is reintegrated to it.

Recall that all adjudications and fines are directly charged to the credit line, thus a settlement process amounts to simply issuing an account statement to the buyer (listing purchases and remaining credit) liberating the remaining credit, and setting all buyer accounts to zero[36]. A buyer may re–enter the market any time, but it would then need to open a new account.

Note that the three types of dialogues that may take place between the buyer manager and a buyer in the Delivery Room are all initiated by the buyer (See

[36]The issuing of the sales slip should amount to the actual delivery of goods and cash devolution if the system were properly grounded.

Figure 4.15). The buyer has to indicate which of the three processes is to be initiated with its first illocution.

The buyer manager, as all staff agents, takes care of all dialogical processes sequentially one after another responding to incoming requests in the order of entry of buyers to the room. Note also that buyers cannot leave the delivery room unless the buyer manager allows them to exit or forces them out.

Definition 4.23 (Illocutions in the Delivery Room scenes) *:*

$request(b, bm : opencredit(k))$
$declare(bm, b : currentaccount(BA))$
$command(bm, b : moveto(AH))$
$request(b, bm : updatecredit(k)$
$request(b, bm : exitto(AH))$
$request(b, bm : settleaccount)$
$declare(sm, s, finalaccount(SA))$
$command(bm, b, outto(outside)$
$request(auct, bm, finishup)$
$declare(bm, boss, closeroom)$
$declare(boss, bm, closed(room))$
$declare(bm, boss, inactive)$

Where, $room \in \{AH, AR, DR\}$

The buyer admission and settlement conventions just described are rather artificial and can be easily turned into more realistic ones. In Chapter 7 slightly different Buyer Admission and Buyer Settlement conventions are adopted.

Market Activation Scene

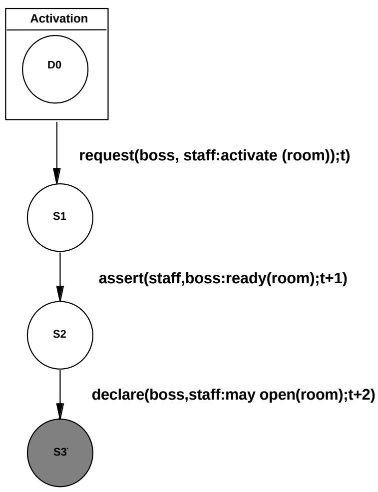

Figure 4.16: Protocol for the Market Place Activation

The market boss *activates* staff who open their corresponding locations and notify their success to the boss. The boss then enables each of them to act and communicates all staff members the fact that they are all ready. At that moment they become operational and can start interacting with external agents.

This can be formalized as follows:

Definition 4.24 (Illocutions of the Activation Scene) *The* market boss *initiates the market activity by "commissioning" staff members to their corresponding rooms.*

$\{\mathtt{command}(boss, \beta : activate(\lambda); t) : \beta \in \mathbf{staff}, \lambda \in \mathbf{rooms} and \langle \beta, \lambda \rangle \in SL\}$

and enters state (S1). Each one becomes operational (S3) only when it has acknowledged the proper opening of the room to the market boss *(S2)*

$$\mathtt{assert}(\beta, boss : ready(\lambda); t'), for \langle \beta, \lambda \rangle \in SL$$

and receives the authorization to open (together with a copy of the corresponding authorizations to the rest of the staff members):

$$\{\mathtt{declare}(boss, \beta : open(\lambda); t'') : \beta \in \mathbf{staff}, \lambda \in \mathbf{rooms}\},$$

Any other illocution —including a silent illocution— are taken as failures *and all agents return to the initial state.*

Definition 4.25 (States of the Activation Scene) *There are four sequential states that correspond to successful achievement of the transition illocutions. Failures in this scene are all subsumed as a transition to the initial state D0.*

1. *In D0 the market boss is active and all staff agents are supposed to be accessible by the boss*[37]*.*
2. *In state S1, the belief base of each staff member is initialized as follows:*
    - *The auction catalogue, CAT and the derived sets of available withdrawn, unsold and sold goods, are also set to empty.*

      $$CAT := AG := WG := UG := SG := \emptyset$$

    - *Likewise the rest of the market commitments (Seller and buyer accounts, and instrumental variables like auction house income, unelegible sellers, pending tasks...)*
3. *Room occupancy is set to empty, as well, in S2.*

$$(\forall \lambda \in \mathbf{room}) O_\lambda = \emptyset$$

[37] The market boss will be a program, probably supervised by a human staff member, who may have to run some code to set up an actual electronic auction (including the code or interfaces that will perform staff duties. In addition, there may exist some activation triggering conditions (for example, time, date and external agents pre-registration) and possibly also a few initial preconditions (e.g. enough external agents are ready and able to participate) that need to be satisfied for D0 to be properly activated. All this is assumed by the phrase "*the market boss is active*".

Market Closing Scenes

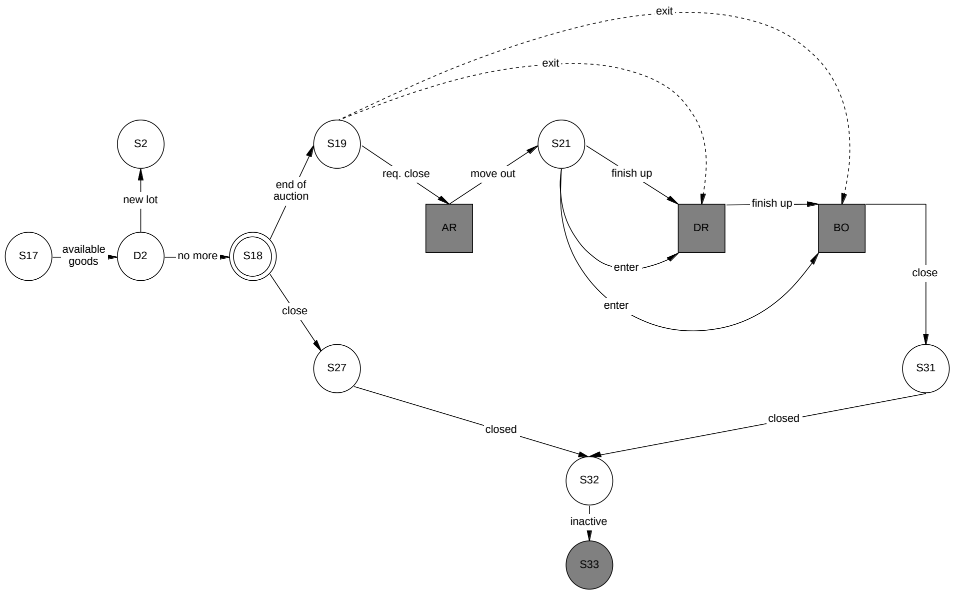

Figure 4.17: Standard Closing Protocol (AH view).

Standard Closing: Recall that auctions will normally end when all goods that were available to be sold have been sold or withdrawn from the auction. This normal closing process (as depicted in Fig 4.17) is initiated once the auctioneer declares an auction closed:

$$\texttt{declare}(auct, all : closeauction(A); t)$$

The utterance of this illocution presupposes that the seller admitter has closed the registration room. The closing actions propagate from the auction hall to the rest of the market locations. The auctioneer requests first the buyer admitter to close the admission room, moves out of the auction hall any remaining buyers or sellers and requests the other two staff members to finish up any pending settlements before closing the auction room. Buyers and sellers exit the market through their settlements dialogues. Consequently the buyer manager and the seller manager may need to finish settling accounts, to let external agents log out, before they can close their rooms. Closing a room supposes that the internal agent responsible for that room notifies the boss who acknowledges the closing by declaring the agent inactive.

Forced Closing: It can occur by direct command of the market boss (for example when not enough buyers are present, or when in a market tournament not enough money is available to buy any more goods, or when a catastrophic event occurs). In that case, new admissions and registrations are immediately inhibited, and in a manner similar to that of the standard closing, the current bidding round is ended and settlements are finished. However, in this case, it is likely that some goods are still to be auctioned. These are left tagged as "unsold" ($\perp$) and returned to their seller by the seller manager as part of the final settlement.

Definition 4.26 (Forced closing illocutions) .

$command(boss, sm : forceclosing; t)$
$command(sm, all : exitto(BO); t')$
$command(boss, auct : forceclosing; t')$
$request(auct, sm : lastgoods; t'')$
$declare(sm, auct : lastlot(AG); t''')$
$declare(auct, all : forcedcloseauction; t'')$
$request(auct, ba : close; t')$
$command(auct, b : exitto(DR); t'')$
$command(auct, s : exitto(BO); t''')$
$request(auct, sm : finishup; t'''')$

Figure 4.18 pictures the two forms of closing in the five market locations.

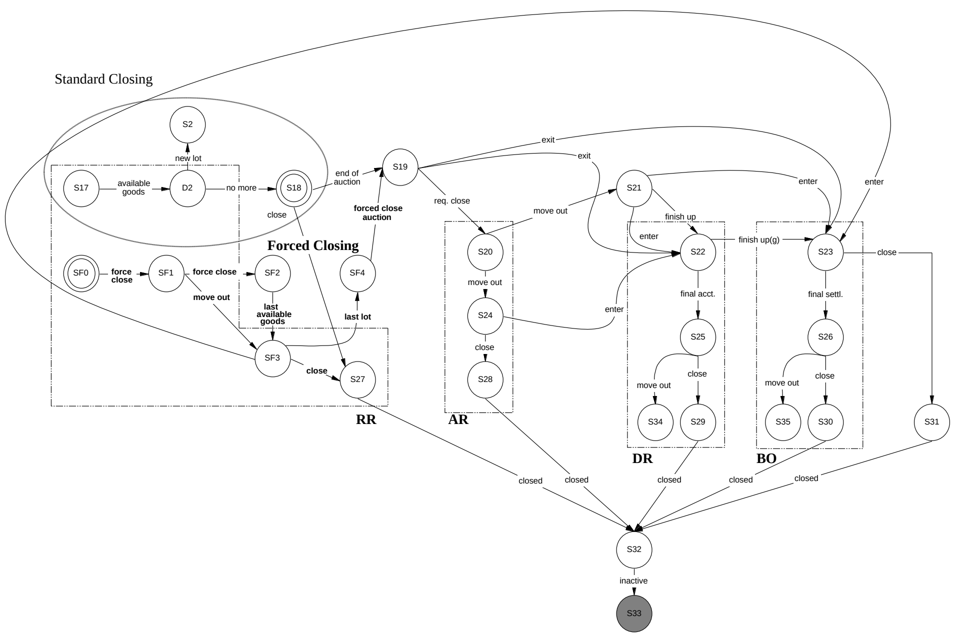

Figure 4.18: Closing protocols.

4.3.4 Rules of behavior

The above stated protocols happen to enforce a collection of individual rules of behavior that I will illustrate with a few examples, all of which can be thought of as *structural rules.*

Staff behavior

Examples of Rules for the Buyer Manager These three rules govern the buyer manager's behavior in the credit validation scene:

Rule 13 *(***valid$_{\mathbf{bm}}$***)*

$$\begin{array}{ll} IF & request(auct, bm, creditstatus(b, p_t(g)), t) \\ AND & credit_t(b) \geq p_t(g) \\ THEN & credit_{t'}(b) := credit_t(b) - p_t(g) \\ AND & assert(bm, auct : valid; t') \end{array}$$

Meaning that when the buyer manager is requested to check on the credit status of a buyer b (at time t), it will check to see if b has enough money to purchase that good. If so, the buyer's credit is updated and at the first opportunity (time t'), it will answer back to the auctioneer that the credit is good.

The effect on the buyer account should be

$$BA(b) := BA(b) \oplus \langle t_\omega(g); purchase : b, g, p_\omega(g); credit_{t_\omega(g)}(b)\rangle,$$

but note that this update of the buyer account is not registered until the auctioneer declares the good sold.

If the buyer does not have enough credit, it will be fined (and charged for that) or, if its credit does not cover the fine, expelled (and whatever credit remained taken over by the auction house).

Rule 14 *(***fine$_{\mathbf{bm}}$***)*

$$\begin{array}{ll} IF & request(auct, bm, creditstatus(b, p_t(g)), t) \\ AND & \neg(credit_t(b) \geq p_t(g)) \\ AND & credit_t(b) \geq (\Pi_{sanction})p_t(g) \\ THEN & credit_{t'}(b) := credit_t(b) - (\Pi_{sanction})p_t(g) \\ AND & ahincome := ahincome + (\Pi_{sanction})p_t(g) \\ AND & assert(bm, auct : fine(b); t') \end{array}$$

Rule 15 *(***expel$_{\mathbf{bm}}$***)*

$$\begin{array}{ll} IF & request(auct, bm, creditstatus(b, p_t(g)), t) \\ AND & \neg(credit_t(b) \geq p_t(g)) \\ AND & \neg(credit_t(b) \geq (\Pi_{sanction})p_t(g)) \\ THEN & ahincome := ahincome + credit_t(b) \\ AND & credit_{t'}(b) := 0 \\ AND & request(bm, auct : expel(b); t') \end{array}$$

Thus, in the first case, the expected result in the buyer's account is:

$$BA(b) := BA(b) \oplus \langle t'; fine : b, g, p_t(g); credit(b) - (\Pi_{sanction} p_t(g))\rangle$$

While in the expulsion case, the effect on the buyer account should be

$$BA(b) := BA(b) \oplus \langle t''; expel : b, g, p_t(g); 0)\rangle,$$

where the time stamp t'' reflects the fact that it is the auctioneer who should expel the buyer.

Finally, recall that the buyer manager has to update the buyer account and the house income when a good is sold, but only after the auctioneer declares that good sold, thus the following rule:

Rule 16 *(***adjudicate$_{\mathbf{bm}}$***)*

$$\begin{array}{ll} IF & declare(auct, all, sold(g, buyer(g), p_\omega(g)); t) \\ THEN & ahincome := ahincome + (\Pi_{spremium} \times p_\omega(g)) \end{array}$$

And the effect on the buyer's account should be:

$$BA(b) := BA(b) \oplus \langle t; purchase : b, g, p_\omega(g); credit(b) - p_\omega(g)\rangle$$

Some Rules for the Auctioneer As an illustration of the auctioneer's rules of behavior, let's consider the outcomes of the credit validation scene. Recall that there were three possible responses coming from the buyer manager: *fine*, *expel* and *valid*. Here are the intended auctioneer reactions:

Rule 17 *(***fine$_{\mathbf{auct}}$***)*

$$\begin{array}{ll} IF & assert(bm, auct : fine(b); t) \\ THEN & declare(auct, b : fined(b, (\Pi_{sanction}) p_t(g)); t') \end{array}$$

When the auctioneer learns that a potential buyer was fined, it first informs the buyer (previous rule), and then declares the bid *invalid* to all present.

Rule 18 *(***invalid$_{\mathbf{auct}}$***)*

$$\begin{array}{ll} IF & declare(auct, b : fined(b, (\Pi_{sanction}) p_t(g)); t) \\ THEN & declare(auct, all : invalidbid; t') \end{array}$$

However, when the buyer manager requests an expulsion, the auctioneer first notifies the insolvent buyer and also the buyer admitter (so that the expelled buyer is not allowed into the market again).

Rule 19 *(***expel$_{\mathbf{auct}}$***)*

$$\begin{array}{ll} IF & request(bm, auct : expel(b); t) \\ THEN & declare(auct, \{b, ba\} : expelled(b); t') \end{array}$$

And once a buyer has been notified of the expulsion the auctioneer makes sure the insolvent buyer is out, and then notifies all present that an expulsion took place. The following two rules formalize that.

Rule 20 *(*$\mathbf{expelled_{auct}}$*)*

$$\begin{array}{ll} IF & declare(auct, b : expelled(b); t) \\ AND & b \notin O_{AH} \\ THEN & declare(auct, all : expelled(b); t') \end{array}$$

Rule 21 *(*$\mathbf{expelled'_{auct}}$*)*

$$\begin{array}{ll} IF & declare(auct, b : expelled(b); t) \\ AND & b \in O_{AH} \\ THEN & command(auct, b : outto(DR); t') \\ AND & O_{AH} := O_{AH} \setminus \{b\} \\ AND & declare(auct, all : expelled(b); t'') \end{array}$$

Finally whenever there has been an invalid bid or an expulsion, the auctioneer should offer the same good for sale but at a higher price that is proportionally increased by factor Π_{re-bid}. Notice, that the auctioneer should also wait Δ_{rounds} before making the new offer. Two rules specify this behavior:

Rule 22 *(*$\mathbf{re-bid_{invl}}$*)*

$$\begin{array}{ll} IF & declare(auct, all : invalidbid; t) \\ THEN & p_{t+\Delta_{rounds}}(g) := (1 + \Pi_{re-bid})p_t(g) \\ AND & offer(auct, all : tosell(g, p_{t+\Delta_{rounds}}(g)); t + \Delta_{rounds}) \end{array}$$

Rule 23 *(*$\mathbf{re-bid_{expl}}$*)*

$$\begin{array}{ll} IF & declare(auct, all : expelled(b); t) \\ THEN & p_{t+\Delta_{rounds}}(g) := (1 + \Pi_{re-bid})p_t(g) \\ AND & offer(auct, all : tosell(g, p_{t+\Delta_{rounds}}(g)); t + \Delta_{rounds}) \end{array}$$

The third possible outcome of the credit validation scene is that the good should be adjudicated. The corresponding auctioneer actions are triggered by the declaration of the buyer manager of an existing good credit status:

Rule 24 *(*$\mathbf{adjudicate_{auct}}$*)*

$$\begin{array}{ll} IF & assert(bm, auct : valid(b), t) \\ THEN & credit_{t'}(b) := credit_t(b) - p_t(g) \\ AND & buyer(g) := b \\ AND & bundle(b) := bundle(b) \cup \{g\} \\ AND & p_\omega(g) := p_t(g) \\ AND & t_\omega(g) := t \\ AND & (SG := SG \oplus g) \\ AND & (UG := 1 \downarrow UG) \\ AND & (Pend_{auct} := UG) \\ AND & declare(auct, all, sold(g, buyer(g), p_\omega(g), t_\omega(g); t') \end{array}$$

That is, when the credit validation of a potential buyer is declared *valid* by the buyer manager, the auctioneer will update good g information ($CAT_t(g)$), and update sold and unsold goods lists and the auctioneer's pending tasks, before declaring the good sold.

Once the good is adjudicated, the auctioneer will try to offer a new good. If it still has any unsold goods, it will choose the first available one. But before offering it, it has to update its public commitment bases and use appropriate default values in the offering, as shown in the following rule:

Rule 25 *(*$\mathbf{newgood_{auct}}$*)*

$$
\begin{array}{ll}
IF & declare(auct, all, sold(g, buyer(g), p_\omega(g), t_\omega(g), t) \\
AND & UG \neq \emptyset \\
THEN & (g := 1 \uparrow UG) \\
AND & p_{t+\Delta_{rounds}}(g) := p_0(g) \\
AND & (Pend_{auct} := 1 \downarrow UG) \\
AND & offer(auct, all : tosell(g, p_{t+\Delta_{rounds}}(g)); t + \Delta_{rounds})
\end{array}
$$

Obligations, thus, should be:

$$g := 1 \uparrow UG : UG \neq \emptyset : \mathbf{newlot}$$

$$Pend_{auct} := \Delta_{rounds} \oplus Pend_{auct}$$

But if no unsold good is left in the auctioneer's list, then the auctioneer will ask the seller admitter for more goods to auction:

Rule 26 *(*$\mathbf{newgood_{auct}}$*)*

$$
\begin{array}{ll}
IF & declare(auct, all, sold(g, buyer(g), p_\omega(g), t_\omega(g), t) \\
AND & \neg(UG \neq \emptyset) \\
THEN & request(auct, sa : moregoods; t')
\end{array}
$$

And if more goods are available, (because the seller admitter tells so to the auctioneer), the lot is presented to those present in the Auction Hall, occupancy information is made public, and the first good of the new lot is offered after the stipulated waiting period. All that can be coded in a similar fashion by the proper rules.

Example of a seller's behavior rule

Whenever a good is sold, a seller may request an update of its account. Such an update should reflect that specific sale only if the seller that requests the update was the original owner of the good. The account statement is final only if all of that seller's goods have been sold.

Thus, an account request produces, either the current account:

Rule 27 *(***adjudicate$_{\text{seller}}$***)*

IF $declare(auct, all, sold(g, buyer(g), p_\omega(g), t_\omega(g)), t)$
AND $s_j = seller(g)$
AND $request(s_j, sm : account; u)$
AND $u > t$
AND $(\exists h \in goods(s_j))(u \langle t_\omega(h))$
$THEN$ $declare(sm, s_j : currentacct(SA); u')$

Or the corresponding reaction to the sale of the last good:

Rule 28 *(***adjudicate$'_{\text{seller}}$***)*

IF $declare(auct, all, sold(g, buyer(g), p_\omega(g), t_\omega(g)), t)$
AND $s_j = seller(g)$
AND $request(s_j, sm : account; u)$
AND $u > t$
AND $(\forall h \in goods(s_j))(u \geq t_\omega(h))$
$THEN$ $declare(sm, s_j : finalacct(SA); u')$

Where s_j's account should reflect the fact that each good was sold, and the corresponding income, by the expressions:

$$\langle t_\omega(g); soldg, b, p_\omega(g); incm_{`t_\omega(g)}(s_j) + (p_\omega(g) \times (1 - \Pi_{spremium}))\rangle \in SA(s_j)$$

Example of a buyer's behavior rule

Analogously, a buyer's account should reflect its own purchases:

Rule 29 *(***adjudicate$_{\text{b}}$***)*

IF $declare(auct, all, sold(g, buyer(g), p_\omega(g), t_\omega(g)), t)$
AND $b_i = buyer(g)$
AND $request(b_i, bm : settleaccount; u)$
AND $u > t$
$THEN$ $declare(sm, b_i : finalacct(BA(b)); u')$

The effects should be kept in $BA(b)$, thus for all $g \in bundle_u(b_i)$,

$$\langle t_\omega(g); purchase : b_i, g, p_\omega(g); credit_{`t_\omega(g)}(b) - p_\omega(g)\rangle \in BA(b)$$

4.4 Discussion

The Fishmarket, as has been presented here, is evidently an *idealized* version of a fish market. Some significant differences should be perhaps discussed, and some comments made on a few subtle theoretical aspects:

Software agents Fishmarket is a proposal for implementing a *virtual marketplace* FM in which buyers and sellers can exchange actual goods over the Internet following auctioning conventions that are similar to those used in a real fish market. Fishmarket participants, then, are to be either software agents or humans interacting over a network through a proper interface. Thus the new institution intends to extend the types of interactions of the real fish market to accommodate other potential users without restricting the presence of the traditional buyers and sellers, although it modifies their interface conventions. Most other conventions have been kept as close to the Blanes practice as possible with some justifiable exceptions.

Buyers presence Since Fishmarket participants are to be either software agents or humans interacting over a network through a proper software user interface, the notion of *presence* is also a virtual one. Thus when the auctioneer addresses all agents present in the Auction Hall, it has to make sure that all virtual buyers do hear that same offer at the same time and have the same time to elaborate a response and submit it back to the auctioneer. Or more precisely yet, the auctioneer has to make sure it *hears every* virtual buyer bid on the same conditions for every buyer present. How one can make sure this happens will depend on implementational issues: the type of network, the livelihood of external agents, etc. But in order to guarantee that this is achievable, the Blanes bidding protocol *had to be modified* and buyers are not allowed to leave the auction hall between the moment a good is offered and it is either adjudicated, or ready to be re-offered. The set of buyers remains unchanged during a bidding round to make sure that the collective speech act of "multicasting a bid", is corresponded by a *fair* "listening" of *all* the individual responses. In Chapter 6, when the relevant implementational aspects are introduced, a more detailed discussion of this issue will be made.

Lots and quantity options One notable difference, between Blanes and Fishmarket is that in Fishmarket, buyers have no quantity option for a lot that contains various items of the same type. The modification obeys simple design reasons: the feature adds descriptional and behavioral complexity, while it does not require markedly different heuristics or architectural features from participating agents. The present Fishmarket protocol (and its implementations) could be modified to incorporate this feature, anyhow, if the goods to be traded would require such facility.

Referential simplicity No attempt has been made to reflect realistic aspects of credit, commissions and security. Again these may become relevant only in the scope of realistic use of the auction house and I will discuss related issues in Chapters 6 and 8.

Illocutory completeness Except for the silence period following an offer of a good, all other interactions are tagged by an illocution. And all illocutions comply with the rigid syntactic mold introduced in Definition 4.3. This procustean effort produces an apparently ridiculous side–effect of uniformizing illocutions into only four types: declarations, requests, commands and offers, of which the first type is the most abundant by far. In reality this declarative bias is a result of making the auctioning conventions a structural part of the protocol and having staff agents submit forcibly to it. The lack of discretionality makes staff react according to their role and thus inform of their accomplishments through a declaration, and occasionally demand an action from an agent. Offers could be also made into declarations, but I preferred to keep them distinct here to mark their likely evolution into more complex interactions in less structured trading scenarios. The subtle pragmatic issues of authority, canonical forms, etc. are obviated also because of the highly structured nature of the Fishmarket interactions, but an effort is made to recover them in the next chapter where more discretional staff agents are discussed. In Chapter 6 the same concerns weigh in the adoption of a richer interaction language such as KQML.

Properties of the auctioning convention The description I made of a downward bidding protocol can be implemented in different ways. The handling of collective speech acts —as suggested above— the management of time, concurrency and pending tasks may introduce complexities that are not evident in this descriptive level. Consequently, interesting properties of the bidding conventions that may depend on these aspects —such as fairness, or the reductibility of Dutch–auction to closed–bid auction— cannot be tested with this level of description. We will have to wait until the actual implementation to test some of these, as shown in Chapter 6.

Public Information As economists are well aware of, *when* information is made available in a trading process and *to whom*, may affect significantly the outcome of the process. The Fishmarket, as it stands, pretends to be as transparent as Blanes is. The default information release conventions are synthesized in Table 4.1, but these can easily be changed to produce more or less opacity. For the tournament generation tool (FM97.7) more flexibility has been incorporated in this aspect. I discuss that in Chapter 7

Institutional Aspects I left this comment last to stress its importance. The detailed specification of the Fishmarket we have just been through, makes evident the fact that an auction house imposes numerous restrictions on the participating agent's behavior. It, mostly, establishes a crisp distinction between what is obligatory and what is not, and thus takes away from the deliberation or negotiation processes of participants a considerable number of issues, concerns and problems that are assumed, addressed or solved by the auction house itself or have to be taken care of by participants in order for them to be allowed to participate in the auction process. This traditional role of an institution can be also played by an institution that is incarnated as a software code in a network. But new and sometimes subtle features then emerge as we perhaps began to vislumbrate in this last section. To me, the new fundamental question will have to do with trust. How can we ascribe trust to an electronic auction house, what are those technical features (not psychological, not promotional, not political) that increase the trust one can put into an automated institution, and what are those that may decrease that trust.

In the next two chapters I will pursue a specification and an implementation of the Fishmarket, and in Chapter 7 I will explore its behavior. But in the last three chapters of this dissertation I will come back to the ideas that nourish this chapter. I will first discuss some empirical aspects of agent mediated auction houses in Chapter 8, I will extend the dialogical ideas to argumentation based negotiation in Chapter 9 and in Chapter 10 I will propose a dialogical view on institutions.

Chapter 5

$\mathcal{FM}_{bid}$

"Truly now,
double thanks, triple thanks
that we've been formed,we've been given
our mouths, our faces,
we speak, we listen,
we wonder, we move,
our knowledge is good, we've understood
what is far and near
and we've seen what is great and small
under the sky, on the earth
Thanks to you we've been formed,
we've come to be made and modeled,
our grandmother, our grandfather,"

Popol Vuh. Part IV [1]

5.1 Introduction

In Chapter 4 I proposed to take a *dialogical stance* with respect to multi agent systems. There I focused on those external elements that made it possible to describe agent interactions as dialogues: the dialogical framework, the social interactions and the intended rules of behavior. In this chapter I will give a partial formalization of those ideas, but focusing in the *internal* structure of agents in which those rules of behavior are supposed to incarnate.

In this chapter I will take a *strong dialogical stance* and advance a formalization of the Fishmarket as a multi agent system in which all participants are *formal systems* that interact according to a formally specified interaction con-

[1] Popol Vuh. The Mayan Book of the Dawn of Life. Translated by Dennis Tedlock. —Rev. ed. "A Touchstone Book". Simon and Schuster, N.Y. 1996. p.147.

vention. To do that, I first define a formal scaffolding for the multi agent system and for each participating agent, and secondly, I specify its computational counterpart.

I present a "layered" or *multi–context* agent architecture —based on Giunchiglia's *context* logics [62][2]— in which an agent will be constituted by the composition of several units, each of which is in itself a logical theory. The distinguishing features of the proposal lie in the dialogical perspective. Thus, since these agents are supposed to be *dialogical* agents, I will require all of them to have a special communication theory, to handle the incoming and outgoing illocutions that tag all the interactions of these agents within the dialogical system. Within each agent, however, constitutive theories will interact among each other by the exchange of formulas that become intelligible through a convenient formal device, *bridge rules* (introduced by Giunchiglia), a sort of inference rule that permits translation of formulas from one theory's language to another's. Bridge rules, however, play the role of a restricted type of illocutions, and will suggest a view of this *internal* multi–context architecture as a dialogical system as well.

I will therefore assume that communicational exchanges always take place within a dialogical context in which some aspects of ontology and some social conventions for interaction need to be shared in order for the agents to be said to react rationally. So I give here a *first* formal version of the notion of a *dialogical framework* to capture these basic common ontological and communicational commitments[3]. Illocutions between agents will be formalized through a special kind of bridge rules between the multi–context agent theories, but also by internal bridge rules and axioms. This being a *dialogical system*, the speech act tenant that communicational exchanges *are* actions that modify the *internal state* of agents (i.e. their *perlocutory* effects) is therefore formalized through the inferential component of the internal theories and the bridge rules connecting them. The fact that each participating agent is supposed to follow certain rules of behavior when interacting within the fish market is also formalized through axioms and bridge rules of the agent's (*internal*) theories.

The proposal is illustrated through a type of dialogical agents that exhibit complex rational behavior when acting within a multi-agent system. Such rational behavior, here, is assumed to involve several kinds of *attitudes* beyond the essential communicational ones: informational, argumentative, motivational, etc. The idea is to integrate *available* formal accounts of such attitudes —which have been thoroughly studied and formalized elsewhere, e.g. [174, 97, 92, 28, 134, 16, 190, 160]— in the proposed *multi–context* architecture for the construction of agent models, and focus on the communicational and social attitudes of agents in order to define multi-agent systems within a *strong dialogical stance*. Consequently, the resulting *multi–context* agent architecture will assume a crisp separation between attitudes (each one modeled as a formal theory) and the relations among them (modeled as bridge rules that exchange

[2]This chapter is based on [120], which was previous to the matured ideas of chapters 4, 7 and 10. Further evolution of these ideas and applications can be found in [126].

[3]In Chapter 9 I give a different illustration, finally, in Chapter 10 I commit to a general abstract definition.

—or translate— formulas between theories). This attitudinal aggregation assumption is mostly academic since the multi–context architecture proposed here can be instantiated by any theories. In Chapter 7 I discuss two examples of actual agents for the fishmarket that are built according to this very same architecture but whose internal theories correspond to *on-line* and *off-line* deliberative units, and not to rational attitudes.

To formalize the computational representation of the mental states of the participating agents and their evolution over time as a result of the deliberative and dialogical activity of agents, I draw upon Dynamic Logic and propose CDDL, an extension to IIIA's Descriptive Dynamic Logic [156].

Summarizing, then, these are the explicit assumptions in this chapter:

(A1) Attitudes can be modeled as theories written in formal declarative languages.

(A2) Rational behavior of an agent is the result of explicit interactions between attitudes.

(A3) Bridge rules between theories are adequate to model such interactions.

(A4) Agents are social dialogical entities that are to be defined within a multi-agent system.

(A5) A dialogical framework is adequate to model the ontological grounding and communication conventions of agents.

(A6) Dynamic Logic is a satisfactory language for the specification of multi-agent systems.

I will illustrate how all this can be achieved by giving a formal specification of a slightly simplified version of the bidding round scene of the Fishmarket.

In this example of a strong dialogical stance I will characterize only three types of agents: auctioneer, admitter and buyer. I will indicate how their individual attitudes can be formalized and how these attitudes evolve as a consequence of the dialogical interactions between agents in a bidding round.

A bidding round (for this purposes) presupposes a collection of goods from which a specific item is to be auctioned to a group of potential buyers. The "auctioneer" receives from an admissions officer (the "admitter") the good, its starting price and the list of "buyers" that are going to be involved in that round, it then "opens" the bidding round and calls prices in a descending sequence until a buyer expresses his or her intention to purchase the good. If the potential buyer has a "valid" credit-status (something that the admitter tells the auctioneer) and there is only one standing offer at that price, then the auctioneer "adjudicates" the good and "closes" the bidding round. But if any of these two conditions fail, the auctioneer declares the bid invalid, rises the standing price and renews the descending price sequence until a new price is accepted by a single able buyer.

In Section 5.2, I will present the multi agent system model; in Section 5.3, I will illustrate how these dynamics of theory evolution can be conveniently specified and implemented using CDDL.

5.2 Agent Architecture and multi-agent systems

A *multi–context* dialogical agent architecture will be a computational entity in which different units, modeling attitudes, are formalized as theories expressed in possibly different languages. Each unit is provided with an initial theory, and a set of inference rules that are used in unit deductions to produce the theory of the unit. These unit-specific languages will contain predicates to represent notions such as *Believe*, *Commit*, *Know*, *Declare*, etc. Reification of formulas of other such languages, by means of *bridge rules*[4], will produce instances of those predicates over terms quoting formulas [62, 156][5]. An agent would then be the theory resulting from a set of unit-theories embedded one into each other by means of bridge rules. The bridge rules incoming to a given unit determine which formulas from other units will extend its theory; likewise, the outgoing connections determine which formulas of the given theory extend other theories.

Note that these languages, units and embeddings are to be tailored for each particular agent in order to express its distinctive features. It would seem desirable, in order to take full advantage of available developments, to keep those theories that formalize a specific attitude as abstract and context-independent as possible while still endowing agents with context-specific knowledge and communicational capabilities that allow them to interact successfully with other agents in a specific environment. On the other hand, this multi-context layering can be convenient for separation of other non-attitudinal features. For example, one theory may include what may be thought of as "off–line" deliberation, while another one may involve "reactive" or "on–line" deliberation,[6]. Similarly, one module may be used to represent general knowledge about trading, for example, while another one may include knowledge that is relevant for trading within an auction environment.

Here, once more, I will remain committedly uncommitted within a strong dialogical stance. The definition contemplates "pure dialogical" agents, i.e. agents that interact with other agents *exclusively* through illocutions. Consequently, illocutions may have an effect on the environment —for instance when new entities are admitted into the discourse— but they also have an effect on agent's states of mind —for example, a given agent's collection of obligations changes whenever another agent accepts a promise the first one makes. I will not go into detailing the actual contents of the agents' theories.

Thus, each agent will be endowed with a "communicational unit", and a

[4]The term *bridge rules* (following Giunchiglia *et al.*'s terminology [62]) denotes a special type of inference rules that have premises in one language and consequents in a possibly different one. See also [17].

[5]For instance, the statement that an auctioneer agent A knows the intention of buyer agent B_i to buy the good $cod\#24$ at price $3550pts$ could be represented as: $K(A, \lceil I(B_i, \lceil buy(cod\#24, 3550pts)\rceil)\rceil)$, where $\lceil buy(cod\#24, 3550pts)\rceil$ is a term "representing" the formula $buy(cod\#24, 3550pts)$, and $\lceil I(B_i, \lceil buy(cod\#24, 3550pts)\rceil)\rceil$ is a term "representing" $I(B_i, \lceil buy(cod\#24, 3550pts)\rceil)$.

[6]M. de Toro in [38] decides, on empirical grounds, to use exclusively domain–specific theories with this type of time–dependent heuristics in a multi–context architecture for buyers in the Fishmarket.

special kind of bridge rules will handle dialogical exchanges among agents. Such communication bridge rules will be expressed in an illocutionary language that will incorporate some basic context-specific elements and may evolve over time.

5.2.1 Dialogical Frameworks

The shared ontological grounding and illocutory elements that allow agents to interact are made explicit through a "dialogical framework"[7].

Definition 5.1 *Given a set* Agents *of agent names, a set* I *of illocutionary particles, and a set* Pred *of typed predicates, a* **Dialogical framework** *is a mapping* $DF = Agents \times Agents \to 2^I \times 2^{Pred}$.

Intuitively, then for each pair of agents α and β, $DF(\alpha,\beta)$ represents the illocutions and predicates that α can *utter* to β and the illocutions and predicates that α can *receive* from β.

Example: The fish market auction requires the next Dialogical framework DF_{FM} for the bidding round scene:

- Participating agents: *Auctioneer* (A), *Buyers* (B_i) and *Admissions intermediary* (Ad).
- $DF_{FM}(A, B_i) = DF_{FM}(B_i, A) = (\{declare, offer, accept\}, \{Open : auctionname, Close : auctionname, Sell : good \times price, Buy : good \times price, Sold : good \times price \times buyer, Collision : good \times price, UnsupportedBid : good \times price\}$
- $DF_{FM}(A, Ad) = DF_{FM}(Ad, A) = (\{declare, inquire\}, \{Open : auctionname, Close : auctionname, Admit : buyer \times auctionname, CreditStatus : buyer \times \{valid, invalid\}, Newgood : good\}$
- $DF_{FM}(B_i, Ad) = DF_{FM}(Ad, B_i) = (\{request, concede, deny\}, \{Admit : buyer \times auctionname, IncreaseCredit : buyer \times quantity\}$

As a matter of fact, in most dialogical frameworks the extension of predicates needs to be dynamic[8]. This dynamicity can be achieved in a rather straightforward manner by understanding specific illocutory particles such as *declare* as having effect over time on the extension of the predicates. In this formalism it is captured by the temporal evolution of languages in units.

It is important to note that in addition to the "ground formulas" that can be built with the dialogical framework elements, other more complex formulas

[7] The following definitions show a slightly different conception of Dialogical Framework than the one introduced in Chapter 4. Here I give each pair of agents a shared language, in the next chapters I will change this condition and have one single common language shared by every participant. I will also include additional elements into the dialogical framework (locations, social structure,metalanguage and time) cf. Chapter 10.

[8] For example, the availability of a new good, e.g. $declare(Ad, A, \lceil Newgood(cod\#25)\rceil, 16 : 35)$, introduces new terms, e.g. $cod\#25$, and will permit new dialogical exchanges between auctioneer and buyers later on, e.g. $declare(A, B_i, \lceil Sell(cod\#25, 1315pts)\rceil, 17 : 05)$.

may be present in the dialogical exchanges of agents. Formulas that may include operators of different kinds, such as K, B, $Commit$, $Intend$, etc. are going to be needed to express some of the agent's internal states and may eventually be communicated to other agents.

Thus, this multi–context agent architecture will expand the dialogical framework according to the specific unit–languages of particular agents. Hence, the following definition:

Definition 5.2 *Given a Dialogical framework $DF : Agents \times Agents \to 2^I \times 2^{Pred}$, the* **communication language at time** *t of agent $\alpha \in Agents$, noted by $L^t_{C_\alpha}$, is upper bounded by the following set of formulas:*

$$L^t_{C_\alpha} \subseteq \{\iota(\beta, \gamma, \sigma_t, t) | \iota \in I, \beta, \gamma \in Agents, \alpha = \beta \text{ or } \alpha = \gamma, t \in Time^9, \sigma_t \in \Sigma^t_\alpha\}$$

and the communication language is then:

$$L_{C_\alpha} = \bigcup \{L^t_{C_\alpha} | t \in Time\}$$

where $\Sigma^t_\alpha = \{\lceil\varphi\rceil | \varphi$ is generated by internal bridge rules and unit deductions inside agent α from formulas present at time $t-1\}^{10}$ and $\Sigma^0_\alpha = \bigcup\{Terms(DF(\beta,\gamma)) | \beta = \alpha$ or $\gamma = \alpha\}$. $Terms(DF(\beta,\gamma))$ represents the set of terms naming formulas constructed inside the communication unit of agent α without resource to any formula incoming by means of bridge rules.

5.2.2 Agent architecture

This notion of agent involves four constitutive elements:

1. *Unit names*: Identifiers that denote atomic attitudes.

2. *Languages*: Declarative and formal with a deductive component.

3. *Theories*: Sets of language, collection of formulas written in that language and a set of inference rules. Theories are attached to unit names.

4. *Bridge rules*: Mappings between language formulas.

Formally, an agent will be given by:

Definition 5.3 *An* **Agent Structure** *is a 4-tuple $A = (U, L, T, B)$, where:*

1. $U = \{u_k\}_{k \in K}$ is a set of unit identifiers.

[9] For our pourposes, it is enough to consider the set *Time* as a linear structure.

[10] Agents are assumed to be ideal reasoning agents that accomplish all their intended conclusions in one instant of time.

2. *$L = (\mathcal{L}, \Delta)$, is a pair containing a set of* finite *logical languages $\mathcal{L} = \{L_j\}_{j \in J}$, and a set of inference rules between pairs of languages $\Delta = \bigcup \{\Delta_{j_1,j_2} | j_1, j_2 \in J\}$, where $\Delta_{j_1,j_2} \subseteq 2^{L_{j_1}} \times L_{j_2}$. In particular, when $j_1 = j_2$, Δ_{j_1,j_2} denotes a set of inference rules of the corresponding language; otherwise it denotes a set of bridge rules between two different languages.*

3. *$T = (M_L, M_\Delta, M_\Sigma, M_\Omega)$ where*

   (a) M_L assigns a language to each unit identifier, i.e. $M_L : U \longrightarrow \mathcal{L}$.

   (b) M_Δ assigns a set of inference rules to each unit identifier, i.e. $M_\Delta : U \longrightarrow 2^\Delta$ such that if $M_L(u) = L_j$, for some $j \in J$, then $M_\Delta(u) \subseteq \Delta_{j,j}$

   (c) M_Σ assigns a concrete signature $M_\Sigma(u) = (Oper, Sort, Func)$ to the language $M_L(u)$ of each unit identifier u, such that $Func : Oper \rightarrow Sort$ gives a type in $Sort$ to each element in the alphabet $Oper$.

   (d) M_Ω assigns a set of formulas (initial unit theory) built upon M_Σ to each unit identifier, i.e. $M_\Omega : U \rightarrow \bigcup_{i \in J} 2^{L_j}$ such that if $M_L(u) = L_k$ then $M_\Omega(u) \subseteq L_k$.

4. *B is a mapping that assigns a (possibly empty) set of directed bridge rules to pairs of different units, i.e. $B : U \times U \longrightarrow 2^\Delta$, such that:*

   (i) if $u_1 \neq u_2$, $M_L(u_1) = L_i$ and $M_L(u_2) = L_j$ then $B(u_1, u_2) \subseteq \Delta_{i,j}$ [11].

   (ii) $B(u, u) = \emptyset$, for any $u \in U$

The class of all possible agents satisfying the structure above will be $\mathcal{A}$. An agent structure is said to be **Communicational** *with respect to a given dialogical framework, $DF : Agents \times Agents \rightarrow 2^I \times 2^{Pred}$, when it has a (unique) distinguished unit $C \in U$ for communication purposes, with its corresponding communication language $M_L(C) \in \{L^0_{C_\alpha} | \alpha \in Agents\}$.*

5.2.3 Multi-agent systems

Usually a multi-agent system is described as a computational system consisting of a collection of agents interacting concurrently within a context. Here it will additionally be required that they interact only through the exchange of formulas that conform to a given dialogical framework. Hence, the next definition:

Definition 5.4 *A* **multi-agent system** *is a 3-tuple $S = (DF, F, C)$, where*

1. *$DF : Agents \times Agents \rightarrow 2^I \times 2^{Pred}$ is a dialogical framework.*

[11] Notice that in this definition, even in the case where $u_1 \neq u_2$, $B(u_1, u_2)$ can be empty, denoting that unit u_1 has no (directed) link with the unit u_2. In this way, a unit u_1 is connected to a unit u_2 whenever $B(u_1, u_2) \neq \emptyset$.

2. $F : Agents \to \mathcal{A}$ *is a mapping from agent identifiers to Communicational agent structures following the agent structure of* Definition 5.3.

3. $C = \bigcup\{C_{\alpha,\beta} | \alpha, \beta \in Agents\}$ *where* $C_{\alpha,\beta} \subseteq 2^{L_{C_\alpha}} \times L_{C_\beta}$ *is a set of bridge rules between the communication languages of agents* α *and* β.

Note that, in general, this definition of a dialogical framework allows agents in a multi-agent system to have completely independent ontologies and communication languages. The necessary translations between different ontologies and illocutions can be modeled through bridge-rules[12]. When the ontologies and communication languages are shared between a pair of agents, their bridge rules may become the identity translation function.

5.2.4 Example

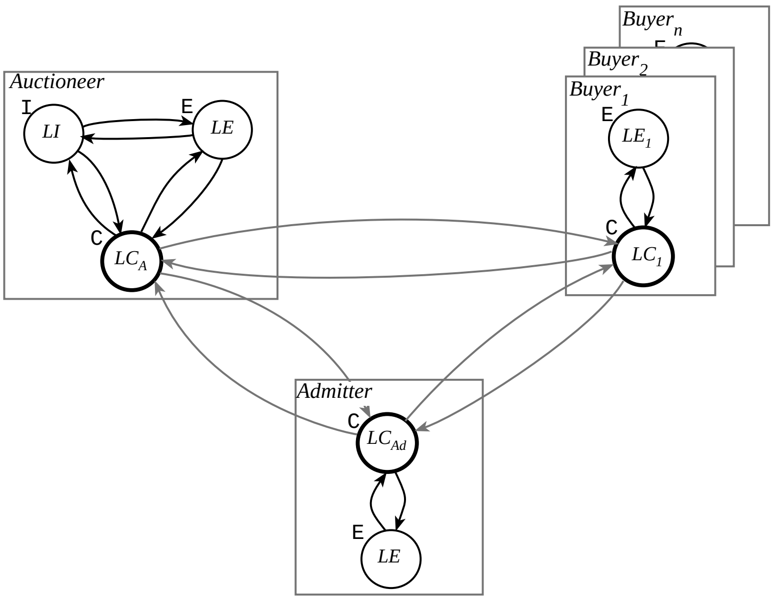

Figure 5.1: Fish Market specification. Arrows mean Bridge rules, balls mean units, squares mean agents, objects with thick lines are concurrent processes.

To have an actual bidding round, three interacting types of agents need to be present, and connected. This collective structure is represented in Figure 5.1, and definable as[13]:

[12] This generality is given up for simplicity in the next chapters.

[13] Here and in the rest, E stands for an epistemic unit, LE for an epistemic language, I for an intentional unit, LI for an intentional language. The details of which language, deductive system and initial theory are used, are omitted.

$$S_{FM} = (DF_{FM}, F_{FM}, C_{FM})$$

$$F_{FM}(A) = (\{C, E, I\}, (\{LC_A, LE_A, LI_A\}, \Delta_A), T_A, B_A)$$
$$F_{FM}(Ad) = (\{C, E\}, (\{LC_{Ad}, LE_{Ad}\}, \Delta_{Ad}), T_{Ad}, B_{Ad})$$
$$F_{FM}(B_i) = (\{C, E\}, (\{LC_i, LE_i\}, \Delta_{B_i}), T_A, B_{B_i})$$

In S_{FM} the only required bridge rule between any two agents α and β is the identity of common illocutory formulas:

$$C_{FM\,\alpha,\beta} = \left\{ \frac{\iota(\alpha,\beta,\sigma,\tau)}{\iota(\alpha,\beta,\sigma,\tau)} \right\}$$

Dialogical exchanges among agents follow a clearly established protocol in which not only are the successive illocutions dependent on the previous ones but also the agent ontologies are to be affected in a well understood way. Furthermore, in this agent model it might be possible to include abstract deliberative units, languages and theories (proposed, developed or tailored elsewhere), and keep context dependent elements confined to the communication unit and its outgoing and incoming bridge rules as much as possible. The following example illustrates how dialogical protocols and abstract intentional and epistemic reasoning may be brought together in a neatly layered architecture, in this case the *adjudication process* as performed by the auctioneer agent[14].

- The following are a sample of the kind of bridge rules that the auctioneer agent model includes in order to adjudicate goods only to willing and able buyers.

  Consider φ to be the formula $buy(g,p)$, i. e. the formula that states that a buyer is willing to buy a good g at price p. Then, the bridge rule schema presented below shows how the auctioneer should interpret a *declaration* of buyer B_i to buy at a given price, as an *intention* of B_i to buy. The schema says indeed that any declaration of a buyer is considered an intention of the buyer.

$$B_A(C, I) = \left\{ \ldots, \frac{declare(B_i, A, \lceil\varphi\rceil, t)}{I(B_i, \lceil\varphi\rceil, t)}, \ldots \right\}$$

- The auctioneer knows that a buyer is able to buy a good g if the admitter has declared the buyer's credit status "valid", and the good is for sale, i.e. the buyer has previously received an offer to buy that good.

[14] In this example, in order to make the decision, a temporal persistence modeling inside the epistemic unit is needed. Formulas inside units are not presented, so bridge rules have to be understood as schemas with all variables universally quantified.

$$B_A(C,E) = \left\{ \ldots, \frac{\begin{array}{c} declare(Ad, A, \lceil creditstatus(B_i, valid)\rceil, t')\wedge \\ declare(A, B_i, \lceil sell(g,p)\rceil, t) \wedge t < t' \end{array}}{Able(B_i, \lceil buy(g,p)\rceil, t')}, \ldots \right\}$$

- The auctioneer's epistemic theory is made aware of the previously declared intentions of other agents.

$$B_A(I,E) = \left\{ \ldots, \frac{I(\alpha, \lceil\varphi\rceil, t)}{K(A, \lceil I(\alpha, \lceil\varphi\rceil, t)\rceil, t)}, \ldots \right\}$$

- Finally, the auctioneer adjudicates the good to the buyer that showed the intention to buy and is able to do so.

$$B_A(E,C) = \left\{ \ldots, \frac{\begin{array}{c} K(A, \lceil I(B_i, \lceil buy(g,p)\rceil, t)\rceil, t')\wedge \\ Able(B_i, \lceil buy(g,p)\rceil, t') \wedge t < t' \end{array}}{\forall B_j \in Buyers.declare(A, B_j, \lceil sold(g,p,B_i)\rceil)\rceil, t')}, \ldots \right\}$$

5.3 CDDL. A MAS Specification language

I will define Concurrent Descriptive Dynamic Logic ($CDDL$) as a specification language for agent modeling. Here is a short reminder on Concurrent Dynamic Logic from which $CDDL$ is an extension.

5.3.1 A Reminder of Concurrent Propositional Dynamic Logic

Propositional Dynamic Logic [74] is a powerful program logic used as a meta-language to refer to computer programs. A program can be seen as a dynamic object, that is, an object capable of making the computer change state. Due to the state change, the truth values of the formulas describing the state also change.

The objective of the logic of programs is to create a logical basis to reason about computer programs. PDL achieves this by using modal logic as its basis to express changes in truth values due to changes of states. The universe of the Kripke structure is, in PDL, a universe of states. Each program has an associated accessibility relation such that a pair of states (s,t) is in that relation if and only if there is a computation of the program transforming the state s into the state t. Finally, as in modal logic, each formula is interpreted as a set of states. Note that since we conceive a program as a binary relation between initial and final states, we associate an accessibility relation to every program thus having a multi-modal language.

An important extension of PDL is Concurrent Propositional Dynamic Logic $CPDL$ where the concurrent executions of different programs is allowed [127]. For a detailed description of PDL and $CPDL$ c.f. [63, 74].

General Syntax for CPDL Given a set of propositional atomic variables Φ_0 and atomic programs Π_0, the set Φ of compound formulas and the set Π of compound programs of $CPDL$ are defined as [15]:

1. $\top \in \Phi$, $\bot \in \Phi$, $\Phi_0 \subseteq \Phi$,
2. if $A, B \in \Phi$ then $\neg A \in \Phi$ and $(A \vee B) \in \Phi$,
3. if $A \in \Phi$ and $\alpha \in \Pi$ then $\langle\alpha\rangle A$, $[\alpha]A \in \Phi$,
4. $\Pi_0 \subseteq \Pi$,
5. if $\alpha \in \Pi$ and $\beta \in \Pi$ then $(\alpha;\beta) \in \Pi$, $(\alpha \cup \beta) \in \Pi$, $(\alpha \cap \beta) \in \Pi$ and $\alpha^* \in \Pi$,
6. if $A \in \Phi$ then $A? \in \Pi$

$(\alpha;\beta)$, $(\alpha \cup \beta)$, $(\alpha \cap \beta)$, α^* stand respectively for sequential, undeterministic union, concurrent and iterative computations. Also, $\wedge, \rightarrow$ and $\leftrightarrow$ are abbreviations with the standard meaning.

General Semantics for CPDL The semantics of CPDL is defined relative to a structure M of the form $M = (S, \{R_\alpha\}, V)$, where S is a set of states, R_α a reachability relation on S for each program α, i.e. $R_\alpha \subseteq S \times 2^S$, and V an interpretation of formulas, saying in which states they are true, i.e. $V : \Phi \longrightarrow 2^S$. A significant difference between PDL and $CPDL$ is that the reachability relation in $CPDL$ is defined on pairs (s,T), where $T \subseteq S$, instead of pairs (s,t) with $t \in S$. This notion captures the intended meaning of the concurrency of operator $\cap$, that can lead the computation to one of a set of possible states, each one representing a possible concurrent computation. Hence, the reachability relation for compound programs is defined as:

$R_{\alpha;\beta} = R_\alpha \cdot R_\beta$
$R_{\alpha\cup\beta} = R_\alpha \cup R_\beta$
$R_{\alpha\cap\beta} = R_\alpha \otimes R_\beta$
$R_{\alpha^*} = R_\alpha^{(*)}$
$R_{A?} = \{(s,\{s\}) | s \in V(A)\}$

where

- $s(R{\cdot}Q)T$ iff there exists $U \subseteq S$ with sRU, and a collection $\{T_u | u \in U\}$ of subsets of T with uQT_u for all $u \in U$, such that $T = \bigcup_{u\in U} T_u$
- $R \otimes Q = \{(s, T \cup W) | sRT \text{ and } sQW\}$

[15]Notation: I will use p, q, ..., to denote atomic propositional variables; A, B, ... to denote arbitrary $CPDL$ formulas; α, β, ... to denote arbitrary programs.

- $R^{(*)} = \bigcup_{n \in N} R^{(n)}$, with $R^{(0)} = \{(s, \{s\}) | s \in S\}$ and $R^{(n+1)} = R^{(0)} \cup R \cdot R^{(n)}$

For notions of satisfiability the conventions are:

$M \models_s \langle\alpha\rangle A$ iff there exists $T \subseteq S$ with $sR_\alpha T$ and $T \subseteq V(A)$

$M \models_s [\alpha]A$ iff $sR_\alpha T$ implies $T \subseteq V(A)$

Since this interpretation of $\cap$ makes $[\alpha]$ and $\langle\alpha\rangle$ no longer interdefinable via $\neg$, both operators need to be independently axiomatized in $CPDL$.

Axiomatics for CPDL $CPDL$ is the smallest logic containing the schemata [63]:

(A1)	All instances of tautologies of the propositional calculus
(B-K)	$[\alpha](A \to B) \to ([\alpha]A \to [\alpha]B)$
(B-Comp)	$[\alpha;\beta]A \leftrightarrow [\alpha][\beta]A$
(B-Alt)	$[\alpha \cup \beta]A \leftrightarrow ([\alpha]A \wedge [\beta]A)$
(B-Comb)	$[\alpha \cap \beta]A \leftrightarrow (\langle\alpha\rangle\top \to [\beta]A) \vee (\langle\beta\rangle\top \to [\alpha]A)$
(B-Mix)	$[\alpha^*]A \to (A \wedge [\alpha][\alpha^*]A)$
(B-Ind)	$[\alpha^*](A \to [\alpha]A) \to (A \to [\alpha^*]A)$
(B-Test)	$[A?]B \leftrightarrow (A \to B)$
(D-K)	$[\alpha](A \to B) \to (\langle\alpha\rangle A \to \langle\alpha\rangle B)$
(D-Comp)	$\langle\alpha;\beta\rangle A \leftrightarrow \langle\alpha\rangle\langle\beta\rangle A$
(D-Alt)	$\langle\alpha \cup \beta\rangle A \leftrightarrow (\langle\alpha\rangle A \vee \langle\beta\rangle A)$
(D-Comb)	$\langle\alpha \cap \beta\rangle A \leftrightarrow (\langle\alpha\rangle A \wedge \langle\beta\rangle A)$
(D-Mix)	$\langle\alpha^*\rangle A \leftarrow (A \vee \langle\alpha\rangle\langle\alpha^*\rangle A)$
(D-Ind)	$[\alpha^*](\langle\alpha\rangle A \to A) \to (\langle\alpha^*\rangle A \to A)$
(D-Test)	$\langle A?\rangle B \leftrightarrow A \wedge B$
(B-D)	$[\alpha] \perp \vee \langle\alpha\rangle\top$

The set of theorems of $CPDL$, denoted by $\vdash_{CPDL}$, is defined as the set of axioms above plus the theorems that can be obtained from the following inference rules applied to other theorems:

(MP)	from $\vdash_{CPDL} A$ and $\vdash_{CPDL} A \to B$ infer $\vdash_{CPDL} B$	(Modus Ponens)
(G)	from $\vdash_{CPDL} A$ infer $\vdash_{CPDL} [\alpha]A$	(Generalization)

5.3.2 Concurrent Descriptive Dynamic Logic

This is a description of the logical tools needed to represent and reason about the computational dynamics of multi-agent systems. The modeling of such systems is accomplished through an extension of $CPDL$ and the formalization of the reasoning dynamics of reflective knowledge-based systems presented in [156]. This extension will be called *Concurrent Descriptive Dynamic Logic*, $CDDL$ for short, and consists of:

- A definition of a set of atomic formulas to represent quotings of the formulas present in a multi-agent system,

- A definition of two kinds of atomic programs, one to represent the computation of agents and another to represent the computation of bridge rules among agents, and
- A definition of the set of possible concurrent computations of multi-agent systems.

Although the ultimate goal is to faithfully describe the computational behavior of multi-agent systems by performing logical deduction in $CDDL$ theories, or in other words, to be able to check some properties of multi-agent systems by means of proofs in $CDDL$, here I only advance the main intuitions and their basic formalization.

To define $CDDL$ one needs to fix the set of atomic formulas and the set of atomic programs. Given an agent $A = (U, L, T, B)$, with $L = (\mathcal{L}, \Delta)$, the set of atomic formulas of $CDDL$ will be defined as the set of "quoted" formulas built upon the languages $\mathcal{L}$ in A and indexed by the Agent and the unit identifier. More formally,

Definition 5.5 *Given a Dialogical Framework $DF : Agents \times Agents \to 2^I \times 2^{Pred}$, and an agent structure $A = (U, L, (M_L, M_\Delta, M_\Sigma, M_\Omega), B)$ in a multi-agent system $\mathcal{S} = (DF, F, C)$, the set of* **atomic formulas** Φ_{0_A} *of agent structure A is defined as the following* finite *set:*

$$\Phi_{0_A} = \{\lceil\varphi\rceil_A^u \mid u \in U, \varphi \in M_L(u)\}$$

and the set of all atomic formulas in S is $\Phi_0 = \bigcup\{\Phi_{0_{F(\alpha)}} | \alpha \in Agents\}$.

The sets of formulas Φ_A and Φ are defined as usual. Given an agent structure A, the set of atomic programs Π_{0_A} can now be defined. Atomic $CDDL$ programs will represent deduction steps, inside agents and between agents. From this set of atomic programs the compound program π_A —denoting the control of execution of agent structure A— can be defined following the $CPDL$ rules for compound program generation.

Definition 5.6 *Given an agent structure $A = (U, L, (M_L, M_\Delta, M_\Sigma, M_\Omega), B)$, the set Π_{0_A} of* **atomic programs** *of agent structure A is defined as the following* finite *set: $\Pi_{0_A} = \{\lceil\Gamma \vdash_{kk} \varphi\rceil \mid (\Gamma, \varphi) \in M_\Delta(u_k)\} \cup \{\lceil\Gamma \vdash_{kl} \varphi\rceil \mid (\Gamma, \varphi) \in B(u_k, u_l)\}$, where $\lceil\Gamma \vdash_{kl} \varphi\rceil$ is an abbreviation for the quoting function applied to a deduction step.*

Having defined the quoting function for formulas, it can be extended to sets of formulas and deduction as follows:

Definition 5.7 *Let $\Gamma = \{\gamma_1, \ldots, \gamma_n\}$ be a set of formulas. Then, $\lceil\Gamma\rceil = set(\lceil\gamma_1\rceil, \ldots, \lceil\gamma_n\rceil)$ and $\lceil\Gamma \vdash_{kl} \varphi\rceil = proof(\lceil\Gamma\rceil, \lceil\varphi\rceil, \lceil k\rceil, \lceil l\rceil)$. Where set and $proof$ are names used to construct the term "naming" sets of formulas and proofs.*

It is clear then that the access to components of quoted formulas is possible by means of accessor functions. For example,

$$conseq(proof(\ulcorner\Gamma\urcorner, \ulcorner\varphi\urcorner, \ulcorner k\urcorner, \ulcorner l\urcorner)) = \ulcorner\varphi\urcorner.$$

The execution control for a particular agent structure A is then defined as a compound program built from this set of atomic programs. I will denote it Π_A.

Correspondingly, the execution control for a multi-agent system results from the CDDL-composition of agent's execution control programs and the programs associated with the bridge rules for communication among agents:

Definition 5.8 *Given a multi-agent system $S = (DF, F, C)$, the set of execution controls for agents* Agents $\Pi_A = \{\pi_{F(\alpha)} | \alpha \in Agents\}$, *and the programs associated to the bridge rules between agents* $\Pi_C = \{\pi_{C_{\alpha,\beta}} | \alpha, \beta \in Agents; C_{\alpha,\beta} \in C\}$, *where* $\pi_{C_{\alpha,\beta}} = \{\ulcorner\Gamma \vdash \varphi\urcorner | (\Gamma, \varphi) \in C_{\alpha,\beta}\}$, *the set of* **possible execution controls** *for S is defined as the compound programs that may result from applying the syntactic rules for $CPDL$, defined in Section 5.3.1, over the set of atomic programs* $\Pi_0 = \Pi_A \cup \Pi_C$.

The usual control program of multi-agent systems will consist of the concurrent execution of the programs associated to agents and bridge rules.

The particular semantics and axiomatics of $CDDL$ correspond to the expected behavior of the particular type of programs (inference rules).

5.3.3 Example

Here are some examples of *possible* execution controls for the agents in the fish market formalization. Actual differences in control specification would indicate alternative views of what amounts to be a deliberative cycle within an agent. In the case of the auctioneer for example, one can require the full deductive closure of its theories before any new illocution is uttered or heard by the auctioneer, while the admitter may have a more "reactive" behavior.

When a program α is an atomic program denoting a deductive step, or the undeterministic union of such atomic programs I will denote by α^c the compound program computing the deductive closure of program α as defined in [156].

$$\begin{array}{ll} \pi_A = \textbf{while} & \text{auction-open?}\ \textbf{do} \\ & \vdash^c_C; (R^c_{C\to E} \cap R^c_{C\to I}); ((\vdash^c_I \cap \vdash^c_E); R^c_{E\to I}; R^c_{I\to E})^c; (R^c_{E\to C} \cap R^c_{I\to C}) \\ \quad \textbf{end} & \end{array}$$

$$\pi_{Ad} = \textbf{while} \quad \text{auction-open?}\ \textbf{do}\ \vdash^c_C; R^c_{C\to E}; \vdash^c_E; R^c_{E\to C}\ \textbf{end}$$

where, in the context of each agent, $\vdash_i = \bigcup\{\alpha | \alpha \in M_\Delta(i)\}$, $R_{i\to j} = \bigcup\{\alpha | \alpha \in B(i,j)\}$. The meaning of **while** test? **do**...**end** is the standard in dynamic logic. π_{B_i} is analogous to π_{Ad}, so I omit it here.

Finally, one can make use of the expressive power of $CDDL$ to specify the concurrent execution of agents and bridge rules between pairs of agents. Given that in the fish market example we have $Agents = \{Ad, A, B_1, \ldots, B_n\}$, the global control of the fish market bidding rounds becomes simply:

$$\pi = \bigcap(\{\pi_\alpha | \alpha \in Agents\} \cup \{\pi_{C_{\alpha,\beta}} | \alpha, \beta \in Agents, \alpha \neq \beta\})$$

5.4 Closing remarks

In this chapter I presented a general framework for the modelization of agents and multi-agent systems. Two quite independent sources have inspired this theoretical framework: on one hand IIIA's work in reflective knowledge systems [156] and, on the other hand, my interest in Computational Dialectics but, in the background, there has been an honest intention to build actual real-world applications of multi-agent technologies.

Deep connections exist between the intuitions manifest in this multi–context model of dialogical agents with [17] as well as many points of contact with other BDI approaches that stress the speech–acts components of communication, for example: [43, 20, 168]. These connections I mention in Chapter 2.

The ideas of this chapter have been developed further by Carles Sierra, with N. Jennings and S. Parsons in [126]. There, the notion of unit is refined further and actual content for the units is proposed and developed. On the other hand, a more utilitarian approach was followed by M. de Toro in [38] to build trading agents on this multicontext architecture, but taking units to be on–line and off–line decision heuristics, rather than proper BDI attitudes. I report briefly on those agents in Chapter 7.

Finally, when this chapter was finished, Julian Padget made available to us [124], in which a $\pi - calculus$ formalism is used to specify the bidding protocol. The resulting specification is very clear and concise, and may perhaps result more useful than CDDL specifications if claims to the executability of the $\pi - calculus$ notation are sustained (cf. [129]).

Chapter 6

Implementing the Fishmarket

Facts are something like a common product of language and reality; they are reality pinned down by descriptive statements. They are like abstracts from a book; made in a language which is different from that of the original, and determined not only by the original book but nearly as much by the principles of selection and other methods of abstracting, and by the means of which the new language disposes.

Karl R. Popper[1]

In this chapter I discuss the way the Fishmarket Institution is implemented as an electronic auction house. First I present the general idea behind the implementation, then give a brief description of the different versions that have been developed at IIIA. In Section 6.2 I describe in more depth FM96.5, a stable version of the Fishmarket that closely matches the description of Chapter 4. Finally, I discuss the two main contributions that resulted from the implementation effort: the remote control devices and the implementation of *fair* downward bidding[2].

[1]Conjectures and Refutations: the growth of scientific knowledge. Harper, N.Y., 1963, p. 214

[2]This chapter is based on [139]. I would like to make a special acknowledgment to the coauthors of that paper, to Julian Padget who supervised much of the programming effort and instigated the discussion on bidding properties, and to Juan Antonio Rodríguez and Francisco Martín who did most of the actual programming.

6.1 Implementing an Electronic Auction house

6.1.1 Intentions and design premises

Recall that the fish market —and other similar price-fixing mechanisms— can be described as an institution in which buyers and sellers exchange goods according to explicit conventions for interaction[3]. These interactions can be represented as *scenes* in which participants exchange illocutions whose exchange protocol and effects are subject to explicit rules that are enforced by the institution. Several *scenes* may take place simultaneously, at different places, but with some causal continuity. Each scene involves various agents who are subject to the accepted market conventions, but they also have to adapt to whatever has happened and is happening at the auction house at that time.

As described in Chapter 4, the principal scene is the bidding round itself, in which buyers bid for boxes of fish that are presented by an auctioneer who calls prices in descending order —the downward bidding protocol. However, before those boxes of fish may be sold, fishermen have to deliver the fish to the fish market (in the *sellers' registration scene*) and buyers need to register for the market (at the *buyers' admission scene*). Likewise, once a box of fish is sold, the buyer should take it away by passing through a *buyers' settlements scene*, while sellers may collect their payments at the *sellers' settlements scene* once their lot has been sold.

One important aspect of the actual fish market —which can be transferred directly to the electronic version— is the presence of market intermediaries: the auctioneer, a market boss, a receptionist, a credit officer. These intermediaries interact with buyers and sellers on behalf of the fish market, and therefore have authority to request, acknowledge, dismiss or accept all the actions that sellers and buyers need to perform within the fish market. Furthermore, all those interactions between the market intermediaries and external agents (buyers and sellers) can in fact be associated with standardized illocutions, some of which are probably tacit in the actual fish market, but explicitable nonetheless in the computational model.

FM is designed to show the full complexity of those interactions while keeping as strong as possible a similarity with the ontological elements of the actual fish market. Hence, we have tried to identify computational agents in FM with either buyers or sellers or actual market intermediaries (we identify agents not with functions of intermediation, but with actual persons). Market information, such as the catalogue and the buyer and seller accounts, correspond to FM log inscriptions, and market instruments —boxes, remote control bidders— are implemented as FM objects and classes (goods record, buyer interface, ...). And, naturally, we mirror all actual fish market illocutions, tacit or explicit, with agent illocutions that are always explicit.

[3] Recall also that we use the (lower-case) expression *fish market* to refer to the actual, real-world, human-based trading institution, and the (upper-case) *Fishmarket* to denote the artificial, informal, multi-agent counterpart. Thus, FMXX refers to a particular implementation of the Fishmarket model of the fish market.

In spite of this healthy mimetic intention, a careful consideration was needed to represent computationally some aspects of physical reality. Activation and closing of the market involved evident differences between the actual market and its computational models. The appropriate implementation of collective speech acts also required subtle analysis. And the notions of presence, permanence and commitment involve adaptation as well.

The resulting environment, FM, is quite similar to the Fishmarket Institution as described in Chapter 4. It preserves enough realistic elements to evoke an actual fishmarket but it is also idealized enough to constitute an electronic auction house that is independent of the type of goods sold. The auctioning conventions are as complex as those of an actual fish market, but are far more flexible and can be changed rather easily. But it is not a *commercial* electronic auction house, yet, because some components that would be essential for public commercial use (low–level security; criptography; grounding of financial matters; convenient off–line registration, practicing and testing; etc.) have been left out on purpose. Partly because many of these components are already being developed by other players in the electronic commerce community, and partly because it wouldn't make sense to address others until a specific application with its own ideosincratic needs is at hand. Our main concern, therefore, was *auction–generic functionality* and we have been able to build an electronic auction house prototype that is *realistic* in the following sense:

- It has the full functionality of the Fishmarket institution,
- it preserves the distinctive characteristics of downward bidding,
- it is flexible enough to bring alternative conventions in a simple fashion,
- it has adequate performance and speed to allow for electronic bidding that is as vivacious as the real fish market, and
- it is robust enough to permit safe trading among heterogeneous agents of arbitrary complexity (including humans).

This design process reached a stable development around the prototype we called FM96.5, on top of which we are now in the process of adding functionality that goes beyond that of an auction house (and I report in the next Chapter), the efforts are described briefly in the next section.

6.1.2 Preliminary Implementations

In [112] we presented a prototype implementation of a simple version of the fish market. FM96.5 is a far more thorough implementation. In between we have addressed different aspects of the problem, and gone through the exercise of exploring specific technical or methodological issues as shown in Table 6.1.

FM96.0

The very first prototype of the Fishmarket was an unpretentious Netscape demonstrator. Although it was developed almost overnight as an exercise in Netscape virtuosity by Francisco Martín, it included the functionality that is present in most existing commercial internet–based auctions: an on–line catalogue, buyer registration (before the auction) and account settling after the auction, and a rough "dutch clock" screen that allowed real–time individual bidding for buyers logging in the page via Internet.

The purpose of this prototype was very modest, to explain what is meant by a downward bidding auction. It proved very motivating and drew the attention of two of IIIA's partners in the VIM Project with whom the other prototypes were jointly developed[4].

FM96.1

In this PVM prototype, whose main programmer was Maurizio Giordano (of the Instituto di Cibernetica, CNR), the implementation follows closely the intuitive description of the simplified bidding round given above in Chapter 5. The auctioneer and admitter are resident tasks in the main PVM daemon, while buyers can be spawned in any machine in the network and can be activated and de-activated manually or through programs. Buyers register and update their "credit line" with the admitter and can participate, if they wish to, in a bidding round. When the auctioneer opens a bidding round, participating buyers are "locked in" (hence, inhibiting buyers to participate in other scenes, such as updating their "credit lines") until the bidding round is over.

Actual llocutions, in the formal model, are represented as messages exchanged among the PVM software agents. Thus, for example, the auctioneer price quotations are sent to each buyer together with other good-associated information as a PVM message. Other market information corresponding to the illocutions exchanged by participating agents is presented in the corresponding screens of the different agents. Figure 6.1 gives a flavor of these interactions and message passing effects.

[4]The University of Bath, U.K., and the Instituto di Cibernetica, CNR: Napoli, Italy.

Version	Place	Basic Tool	Concerns	Advantages
FM96.0	IIIA	Netscape	Fast development	Demonstrability
FM96.1	IIIA-Naples	PVM	Synchronization, Bidding protocol	Proof of concept
FM96.2	IIIA-Bath	MPI/C	Open Network	Portability
FM96.3	IIIA-Bath	MPI/C	More agents, Market functionality	Isolated Contexts
FM96.4	IIIA-Bath	EU-Lisp/MPI	Agent interactions	Expressiveness
FM96.5	IIIA-Bath	JAVA	Modularity, concurrency, functionality, fairness, livelihood of protocol	Full functionality Robustness Expandability

Table 6.1: Implementations of the Fishmarket Environment

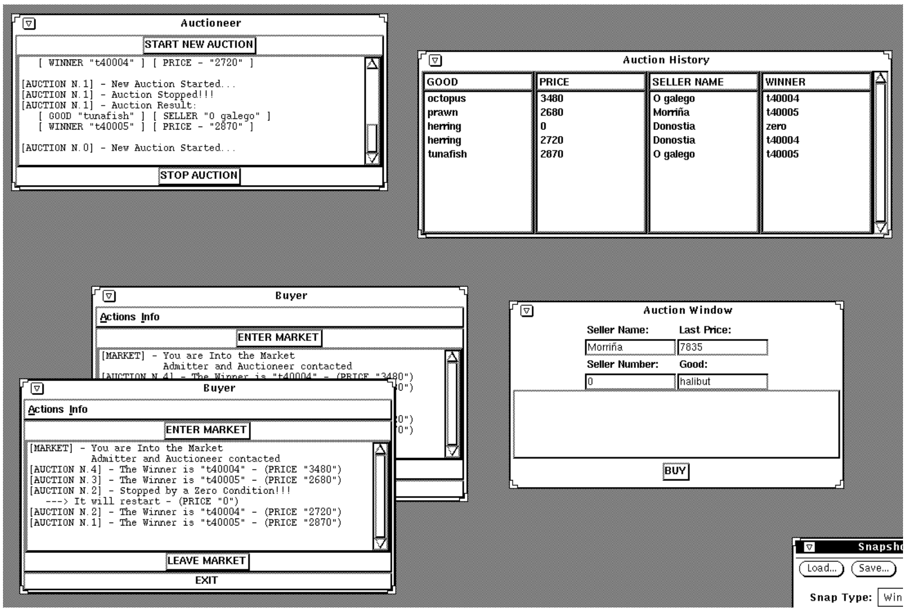

Figure 6.1: PVM prototype (FM96.1) snapshot

Several strategies were tried and tested to deal with collisions and unsupported bids. Synchronization of incoming bids and the corresponding waiting period was achieved through an intricate *pinging* mechanism in which the auctioneer daemon would make sure that all silent buyer daemons were alive before a new price quotation was broadcasted.

This PVM version is documented in [112].

The PVM experience proved fruitful in many ways. It constituted a convenient demonstrator of what was intended to be an agent–mediated auction house. But more significantly, it made clear some respects in which the computational implementation could affect the bidding protocol.

On occasions, the computational concerns affected positively the bidding convention. Sometimes, however, these concerns produced undesirable outcomes. For example, in order to guarantee "presence" of buyers in the auction hall, in the PVM implementation, the auctioneer kept a list of those buyers that were active at the beginning of the round, and checked on that list to see if everyone had a chance to bid. This process constituted a virtual "locking" of the auction hall. A locking that is not necessary in the real fish market, but that turns out to be very convenient and easily enforceable in an electronic one[5]. On the other hand, it became clear that unless a very clever implementation of the "wait for the first bid" action was achieved, the resulting bidding convention would appear to be the classical downward bidding, while in fact it could be provably

[5]It seemed unavoidable in PVM because of the "grouping facilities" of spawning processes in PVM, we decided to keep it in all subsequent versions because of its useful properties.

equivalent to a close–bid convention. The bidding mechanism implemented in FM96.1 does not preclude foot–dragging.

Activation and closing of the market, emerged also as essential scenes that needed careful consideration.

FM96.2, .3 and .4

The next efforts built systematically on the FM96.1 experience[6]. MPI was adopted to deal with communication and networking, and functionality was incrementally added on top of the FM96.1 simplistic round.

FM96.2 addressed the problem of having an open communication infrastructure in which agents could be developed and activated independently. In FM96.3 the basic bidding round coded in FM96.1 was extended to include the rest of the Fishmarket roles: buyer admitter and manager, sellers and seller admitter and buyer, with simple functionality but the complete communication capabilities that were built in FM96.2.

In FM96.4 the focus was on functionality. Hence, a careful design of each agent's capabilities and the overall market institution was addressed. Bath's recent experience with EU–Lisp interoperability was central to the analysis and implementation of the new version, and a concern with portability permeated the whole effort.

In these versions, the difficult implementational aspects that were perceived in FM96.1 were methodically confronted:

- Staff agents were given fixed and independent virtual locations. External agents were intended to move from one location to the next mimicking the real fish market.
- Time was given a systematic analysis. The waiting periods in the bidding rounds —-when many external agents are supposed to share the same time measurement—- were treated differently than the (logical) time that is used to perform actions and illocutions in a one–to–one exchange between a staff agent and an external agent.
- Downward bidding was carefully studied, and alternative ways of addressing the presence of buyers and simultaneity of bids explored and discarded until the current bidding protocol was adopted.
- Illocutions were made to correspond with messages that kept the potential pragmatic richness of a true illocutionary exchange.
- Action flow and communication flow were disected and harmonized.
- A first parametrization of the bidding protocol was considered, to facilitate the implementation of alternative conventions.

[6]These three prototypes were mostly due to Juan Antonio Rodríguez under the direction of Julian Padget, and with the collaboration of Andreas Kind and Julio García

Parallel to these efforts, FM96.5 was developed. Profiting from the analysis and the coding experiences of these three versions, the first release of FM96.5 was coded in JAVA in a matter of weeks, it has kept evolving marginally up to the end of 1997. In the following section it is described in detail.

6.2 FM96.5

FM96.5 was conceived from the beginning as a stable version, in which most design decisions would be fixed, and only improvements on performance and added functionality (that was upward–compatible) would be considered.

In this version we decided to address the underlying problems of identity and persistence of entities, subjective and objective time, and causation and effects of activity with a different set of computational tools. We decided to use a more expressive concurrent programming paradigm and more general and abstract computational constructs in the interest of achieving a realistic —i.e., robust, thorough, lively and sound— computational model, that would also be agent architecture neutral for external agents. In particular, three basic implementation decisions were adopted from the start:

- All agent interactions were to be performed on a *reliable* network[7] .
- Multithreading would be used to implement concurrency[8] ; and
- Object encapsulation and strong typing would allow for layering and modularization of the specification of agents and environment.

In this version we again chose to build internal agents that correspond with actual fish market intermediaries. Thus our agents should be able to perform several functions —sometimes even in different scenes— but should be able to manage precedence conditions and keep track of pending actions and obligations towards other agents. Although our emphasis in their construction has been functionality and performance, a certain degree of *layering* was brought to their design but no abstract reasoning was implemented[9].

The market boss, in FM96.5, thus, fulfills the prosaic function of a *name server* as well as the more anthropomorphic ones of auction supervisor and ultimate authority in the auction house. An auctioneer takes care of the bidding process. Other internal agents fulfill the other roles defined in the Fishmarket for them.

External agents may be agents of arbitrary complexity, even human users, but they participate in the fish market always and exclusively through a standardized communication *nomadic* interface. Buyers in this version are handled

[7]A network is said to be reliable if messages transmitted on it are never lost or duplicated, nor message sequencing altered (e.g. TCP/IP) [30].

[8]In fact we used Java *threads* with their priority operators —aware of their implicit limitations. Cf. [67].

[9]The term *layering* (as used in Chapter 5) is used to indicate that the internal architecture of agents involves various units that represent crisply differentiated attitudes.

through software incarnations of a *remote control device* which receives all the (significant) market illocutions, and transmits to the market only those illocutions that the buyer may express; always in a standardized form and only in scenes and moments when these illocutions are acceptable. Sellers, likewise, are always handled through similar nomadic interface-programs.

Three market activities deserve special comment for their treatment in FM96.5 has been significantly different from what we had done in previous versions: activation, closing and bidding rounds. Activation and closing are implemented as described in Chapter 4, bidding also follows the protocol described there, but it involved more complex implementational aspects.

In FM96.5, activation of the market is started by the market boss agent who *opens* the market place and establishes the identity of market intermediaries who are enabled by it to perform their intended functions [10]. Once these intermediaries are activated, buyers and sellers may start entering those *rooms* where they would conduct business, but always subject to the fish market behavior and illocutory constraints. In fact, as soon as the market intermediaries are activated, they set up an *agenda* of pending actions that will correspond to sequential or concurrent actions (threads) they have the obligation to perform. These agendas are constantly updated since obligations are fulfilled by the market agents and new actions may be inscribed in the agenda by a directive of the market boss —for example: *open a bidding round*—, by a request from an external agent —e.g. *update my credit line*— or by a delegation from another market intermediary —e.g. *check buyer's credit status*. In this way, activity is propagated to different scenes through events that are triggered sometimes by the market boss, sometimes by other market agents, but many times by sellers or buyers as well.

Market closing involves, also, some artificiality in FM96.5. The market boss may stop an auction through a *forced closing declaration*, whose triggering conditions are explicit, albeit varied. The market may also close through the standard closing procedure triggered by the auctioneer when the set of auctionable goods is exhausted. In both cases the implemented protocols are the same ones described in Chapter 4, but actual closing requires that all pending actions of market agents be properly terminated *computationally* as well. Depending on the prevalent situation of the market at the time of the closing declaration, the termination process may be more or less involved. In order to avoid anomalous conditions, some careful bookkeeping of delegation of execution control and of action flow had to be implemented[11].

Likewise, the implementation of the fish market's downward bidding protocol required considerable effort. In FM96.5, synchronization is achieved not within each price quotation —as in the actual fish market room— but within the sequence of price quotations that are needed to sell one good (the bidding

[10]In FM96.5 we still have a human *user* who triggers an activation command through which the market boss agent is spawned and starting conditions for an auction —including number of sellers, products and product characteristics— are passed.

[11]FM96.5 is not provably fault-tolerant, but significant security, integrity and failure-recovery features are built-in for that purpose.

round). By doing so, and thanks to the fact that a reliable network is assumed, fairness conditions are preserved. Thus, premature bids, foot-dragging, and spoofing are adequately avoided directly by the protocol implementation, while malicious suplantation and snooping are dealt with through the *ad-hoc* identity devices. Both elements are partially coded into the remote control devices, and complementarily in the auction house itself.

6.2.1 Design

For FM96.5 we had two complementary objectives in mind. First of all we wanted a robust, stable version of the fish market that we could expand or refine in a modular fashion in order to develop and test, systematically, our theoretical proposals on agent architecture, agent models, interaction protocols and structured environments. But we also wanted a realistic example of an electronic auction house that could eventually be developed into a commercially interesting product. Therefore, the guiding design principles had to do with transparency, modularity, reusability and standardization on one hand, and, on the other, robustness, functionality and performance. Evidently, the choice of tools and programming methodology was strongly determined by these principles.

First, there was the matter of computing paradigm: Illocutions can be regarded as the basic unit of analysis in the Fishmarket. In the actual-world fish market, these illocutions are performed by humans with some intention in mind and eventually change the state of the world in a way analogous to the way physical actions do. In the electronic Fishmarket, an agent performing an illocution can be computationally modelled as a *client* (speaker) contacting a *server* (receiver) and sending a *message* (illocution). In the same way, an agent listening to an illocution (message) can be seen as a server (receiver) waiting for incoming communication requests from a client, performing the necessary computation (which eventually changes the state of the world) and perhaps returning an answer to the client. Note that this client/server model is a computational model and is independent of the type of illocution. The fact that every illocution changes in some way or another the state of the receiver justifies this very convenient implementational simplification[12].

We decided not to use the distributed object paradigm for the implementation of staff agents[13]. In the actual fish market, buyers, sellers and market intermediaries utter illocutions that trigger actions on the hearers. But it is important to notice that the different behaviors exhibited by the hearers are

[12]Two technicalities may be worth noting. First, this simplification imposes processing costs: A cost is paid in the interpretation of the illocution on the server side —different illocutions trigger possibly different actions in the server— and another cost had to be paid at the client side in order to produce the utterance of the illocution. Second, a true client/server model usually implies an explicit response from the server to every request from a client. In FM96.5, for performance and transparency reasons, we actually build in a few illocution/action sequences in which servers give no explicit replies. But, these are all reifiable as true client/server interactions.

[13]It will be evident in the discussion of the external agents' *nomadic agent interfaces* that the distributed object approach is indeed quite useful for those devices.

exclusively determined by themselves as a response to incoming messages. From a computational point of view, all we need, then, is to bundle clients (*speakers*) messages and send them out, and it should be up to servers (*hearers*) to determine how to handle incoming messages. We see no benefit from endowing agents with the capability to invoke methods on remote objects since we do not intend that clients trigger actions on the servers' side but only that they *provoke* actions to be triggered. Therefore, we prefer the model of clients' illocutions triggering actions in the server, in contrast to clients invoking those actions directly.

And then there is the matter of concurrence: One of the main features of the fish market is that it is composed of several, isolated scenes whose activities happen in a concurrent way. But, notably, market intermediaries may be involved in tasks that happen simultaneously in different scenes. We modelled scenes as sets of distributed processes and gave to our market agents a multi-threaded architecture so they are capable of both servicing requests and delegating tasks concurrently. For instance, the buyers' manager may be active enrolling several buyers in its list of buyers while at the same time be involved in verifying whether a bid made in the current bidding round should be regarded as valid. Hence, we in fact model two levels of concurrence. On one hand, that corresponding to the concurrent activity of isolated scenes, modelled as a set of distributed processes. And on the other hand, the inner activity of each market agent, modelled as a multi-threaded process.

Consequently, action-flow in the Fishmarket is non-trivial. One should distinguish an agent-flow corresponding to buyers and sellers moving from scene to scene, and a communication-flow caused by illocutions exchanged between agents. In order to model the mobility of buyers and sellers, we designed our scenes as virtual scenes made up of processes that might physically be running at different sites but which are always virtually situated within the same scene. Buyers and sellers in FM96.5 have therefore the impression of moving between locations (e.g. from the admission room to the auction hall, from there to the delivery room and so on) in the same way human buyers and human sellers would in the actual fish market. As to the communication flow, we opted for standardizing the structure of the messages being exchanged between agents. Each message is regarded as a Java object containing a tag, information about the sender and the contents of the message, which is in turn a Java object. The use of Java Object Serialization (JOS [88]) allowed for serializing each message at the sender side and deserializing it at the receiver side in a straightforward way.

And finally, external agent interfaces: In order to achieve the most realistic implementation of the auction house activity, we decided to standardize as much as possible all conceivable external agent interactions with the market. We took advantage of the highly structured negotiation convention of auctions, and of the fact that in actual fish markets all bidding round interactions can be mediated through a remote control device. Thus, we built *nomadic agent interfaces* —a sort of mineing devices— that could be used as universal interfaces by buyer and seller agents. This nomadic interface is installed in the external agent's computer and becomes the only channel through which messages can pass between external agents and market (internal) agents. Since the Fishmarket interactions are all linked to illocutions, this interface is all that is needed, in principle, to participate effectively in the electronic auction house. But in fact, these interfaces fulfill other necessary duties as well: they sustain the identity of participants, validate illocution emission and reception, and, generally speaking, enforce the auction-house rules –including the bidding protocol[14]. It should be noted, then, that in FM96.5 there are really no buyer or seller agents, only their nomadic interfaces. But through these nomadic interfaces buyer and seller agents –developed and owned elsewhere or even human buyers or sellers— can participate in electronic auctions.

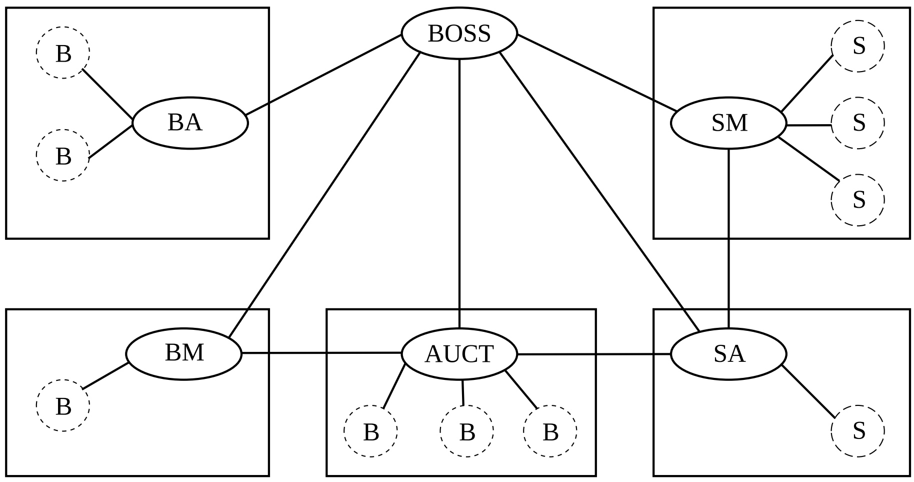

Figure 6.2: A simplified diagram of the communication-flow between agents (balls) and within market scenes (boxes)

In our choice of tools, we profited from our previous experiences too. Having already developed prototypes using PVM and MPI for internetworking and C and EU-Lisp for other features, Java suggested relevant advantages (Cf. Gosling [67]) that were worth testing in the Fishmarket implementation:

- The advantages of object-oriented languages for coding and reusability.
- Its ease of programming and safety features.

[14]Obviously, this interface permits to address the security issues that would arise when arbitrary foreign agents (i.e. whose code we do not know) are admitted into the Fishmarket. In fact the nomadic quality of the interface makes it possible for other external agents —and necessary for the agent who uses it— to prove a *zero-information* property, *i.e.* that through the interface no information of the market, nor any information of the external agent can be transferred outside the interface, except for the one that is explicitly stated by the interface. Note also that our nomadic interfaces are akin to the payment and service cassettes used in the construction of the Java Wallet (cf.JCF [85]), and can in fact be readily connected to them.

- Convenience for distributed network environments.
- Available collection of specialized add–ons for distributed computing (JOS [88], rmi [89], idl [80]), database connectivity (jdbc [84]), security (Sslava [164]), etc.

Additionally, industry commitment and investment, as well as generalized commercial activity around Java, give strong indication that Java may become a *de-facto* standard, therefore having permanence and complementary developments that would facilitate taking FM96.5 to a product-level stage.

6.2.2 Implementation

FM96.5, thus, was developed as an object-oriented client/server distributed application which is actually made up of a collection of Java applications that can run as both applets[15] or standalone applications. There is in fact a Java application for each of the agents depicted in 6.2. In addition, one separate package groups those classes defining data structures while another package contains those classes referring to client and server connections capable of reading and writing whole objects. This last package encapsulates the exception-handling mechanisms that deal with network error conditions. We used JDK 1.0.2, and Java Object Serialization on a LAN composed of a SUN SPARC/20, several SUN SPARC/5 and a few Macintoshes and PCs.

Each market agent works as a multi-threaded process. This multi-threaded architecture allows market agents to service several message-shaped requests concurrently. Nevertheless, not all requests are handled in the same way. There are requests that are regarded as more important than others. Threads servicing different types of requests are initiated with different priorities. Therefore, a market agent would give the highest priority to what it contemplates as the most important tasks, then to requests made by other market agents, requests made by buyers and sellers and, lastly, to the forced closing request issued by the market boss.

Perhaps the major challenge from a technical point of view was the design of the protocols involved in the main activities in the market —activation, bidding round and closing— since they implied the co-ordination of the activities of sets of distributed processes.

Activation and closing follow faithfully the protocols described in Chapter 4. Implementation of the bidding round and the way remote control devices were conceived is discussed in Section 6.3 below.

6.2.3 Extensions

We are currently developing a few extensions of FM 96.5, that I will comment in the next chapter, these should allow us to pursue development in four main directions:

[15]These applets can be activated from browsers such as Netscape and HotJava.

1. Implementation of alternative bidding protocols (English, FCC, MexTR, etc.), in order to have a general electronic auction platform.

2. Development of intelligent buyer and seller agents capable of exhibiting different trading behaviors.

3. Deployment of a "tournament environment" to run simulations and tests of actual auctions on FM.

4. Development of auditing and analysis tools to help code, debug and supervise future releases of FM and audit and study actual auctions.

6.3 Main Contributions

Our main concern when implementing the downward bidding protocol was to ensure fairness while preserving realistic response time[16]. In FM96.5 we achieve it —without supposing common fixed delay intervals as in an ATM network— through a clever alternative to common clocks.

In FM96.5 we regard the termination of a bidding round as the synchronization point of the round participants. All buyers receive syncopated price sequences. If a buyer is going to submit a bid, it will signal this as soon as the price quotation reaches the buyer's target bid. The signal sent back from the remote control device to the auctioneer includes the price at which the buyer signalled its mineing call and the time stamp. As soon as the auctioneer receives a mineing call, it multicasts to all the buyers' remote control devices the information that a bid is in, which these devices must acknowledge. Since we assume a *reliable network*, the order in which messages are transmitted in this network is never altered, thus the auctioneer must receive any delayed bids before it receives the corresponding acknowledgments requested from these bidders. Hence we have two standard (Fishmarket definition) cases:

- *Proper sale.* One bidder

- *Collision.* Multiple bidders at the same price,

(which are dealt with according to the standard Fishmarket conventions), and a new (implementational) case:

- *Multiple bidders at different prices.*

[16] In the fish market this corresponds to time delays between prices that are short enough to be imperceptible to human buyers but long enough to allow for collisions (i.e. one or two seconds between successive prices). In FM96.5 we have milisecond splits.

In this case, the highest price bid wins if there is just one, or we restart as usual.

The task was to guarantee fairness conditions on the bidding process that other implementations are not capable of providing.

A bidding round under the downward bidding protocol may have numerous anomalies. Here are four distinctive ones that are dependent on the synchronization of the waiting period:

1. *Uneven periods.* The duration of the bidding opportunity interval is not the same for every buyer.

2. *Foot–dragging.* A bidder takes more time than allowed in submitting its bid, and imposes this additional time delay on other bidders.

3. *Delayed bid.* A bidder waits until every other bidder has had a chance to submit a bid and then reacts by bidding (within the bidding opportunity).

4. *Premature bid.* A bidder submits a bid before the corresponding bidding opportunity is available to other bidders.

In fact, these anomalies are all intrinsic to the notion of collective speech act in which fair "listening" by buyers *and* by the auctioneer is required. Solutions have to do with the degree of fairness the institution is willing to adopt, and also on the type of communication medium used.

If for instance, an ATM network is assumed, fair multicasting can be implemented as sequential offers, plus a sequential visiting of each buyer (after the waiting period). Every buyer can be given the same time to process the offer and declare its acceptance (or remain silent). But if the network does not have fixed delays, the *uneven periods* anomaly is unavoidable with this round–robin polling scheme. Malicious *foot–dragging* is also possible in this implementation schema if simple token–passing is used as the synchronization mechanism (the slow bidder withholds the token until its deliberation is made).

All these anomalies are properly avoided in FM96.5.

Finally, some comments on buyers' and sellers' nomadic interfaces.

These remote control devices allow the user to determine the scene (or virtual location) where it wants to be active (external agents can only act —or more properly, engage in *dialogue* with market agents— at one place at a time). Depending on the specific location, and the prevalent market conditions, each device displays market information and activates dynamic interface windows —and buttons— through which the external agent receives and transmits the pertinent standardized illocutions.

The devices are market-owned, consequently, some accounting, liveness and security functions can be performed in the background and in fact transmitted to the market agents.

Note that these remote control devices can be coupled with a (higher level) graphic interface when dealing with human agents, while when interacting with external software agents they merely transmit and receive message-shaped illocutions between these external and the internal market agents (See Fig 6.3) .

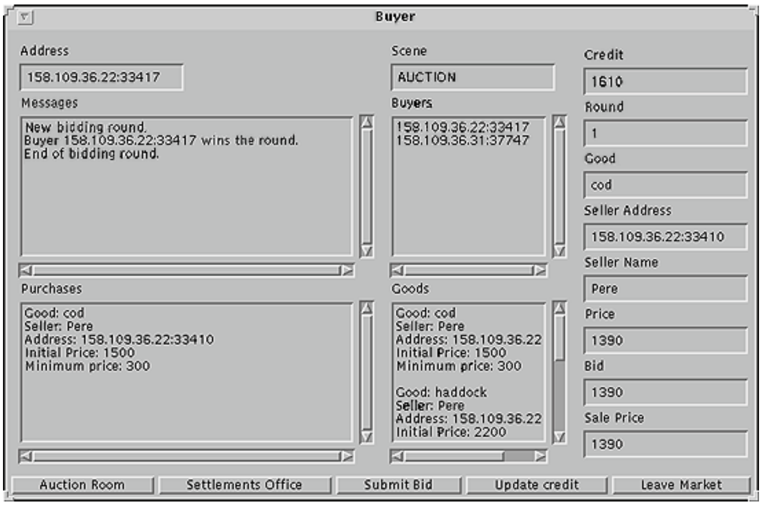

Figure 6.3: A snapshot of a buyer screen in FM96.5

It is important to notice that these FM96.5 nomadic interfaces convey to buyers and sellers information that human buyers and sellers in the fish market would have available *in situ*, and some additional information too. For instance, buyers receive the list of participating buyers (which would be seen by a human buyer taking part in the auction), the list of auctionable goods (which are scattered over the floor in the auction room), details of the next good to be auctioned, and his own current credit and the list of purchases.

Remote control devices *govern* the illocutions of buyers and sellers, and *enforce* the rules and conventions of the Fishmarket institution on these external agents. They shield the institution from unwanted interactions, they protect other buyers and sellers from spoofing and suplantation.

They build trust.

Chapter 7

Fishmarket as an agent testbed

Delimita'm l'espai, però no esperis
que renunciï a res d'allò que estimo.

Miquel Martí i Pol. L'Hoste Insòlit[1]

In this chapter I will explore simple variants of the Fishmarket auctioning conventions. This will allow me to discuss how the Fishmarket environment can be used to design experiments that may be of interest for agent design, mechanism design and electronic commerce practice; and what kind of elements may be pertinent for that purpose.

To illustrate these ideas I will profit from some current developments of the Fishmarket project. I will succinctly describe two software tools: a *tournament description* tool that can be used to specify an experimental trading scenario, and an *auction monitoring* tool that is used to activate, record and analyze auctions. I will also mention briefly a couple of *buyer agents* whose architecture is based in the proposals of Chapter 5[2]. While I will refer to actual developments and comment on what might be the following milestones of the programme, my emphasis here will be not in the specific implementations, but in the underlying motivations, the deeper design concerns and what the expected results ought to be.

[1]Textually, "*... constrain my space, but anything I love, to give up do not expect.*"

[2]The tools and agents I will present in this chapter are in the process of being built by other members of the Fishmarket project at IIIA. Namely, Juan Antonio Rodríguez and Francisco Martín —who have absorbed a significant part of the design effort— and María del Carmen de Toro, Xavier Giménez and David Gutiérrez who have designed and coded the software as part of their research assistantships at IIIA.

7.1 Fiddling with the Fishmarket

In chapter 4 the Fishmarket was characterized as an institution through three constitutive elements: a dialogical framework, a collection of individual rules of behavior and a collection of social conventions. I will now show how, by slightly varying some individual rules of behavior and social rules, variants of the Fishmarket auctioning conventions can be produced. I claim that some variants are easy to describe and implement, and I also claim that some of these produce interesting auctioning alternatives.

A first type of variant is obtained by simply changing the values of some parameters of the downward bidding protocol: the speed of the bidding, the number of successive collisions admitted, etc. These changes are trivial, but may have profound effects on the type of auction that is performable. So, for example, by stepping up, (or down) the bidding clock, certain types of agents (human, deliberative,...) may dramatically decrease or increase their success rate. Consequently, an appropriate tuning of these parameters will be required before any claims on performance of alternative trading agent architectures or strategies can be properly understood.

A second type of variant involves a slight change (usually a filtering condition, or a simplification) of the Fishmarket protocol. For example, *continuous* and *fixed catalogue* auctions are simply a matter of toggling the newlot cycle in the Fishmarket. Making some choices in the variability of good types and how the catalogue is presented to buyers, for example, may produce scenarios that range from a standard "repeated prisoner dilemma" situation, to a fully unpredictable Dutch auction, and therefore the relevance of off–line optimization resources (e.g. game–theoretic modeling, or genetic algorithms) might be more or less evident.

A third type of variant is obtained by a combination of the other two. For example, by simply changing the mineing convention from a nod to a price quotation and using single highest value bid to identify a unique bid, the Fishmarket *Dutch* auction is turned into a *(sealed) higher bid* auction. A *Vickrey* auction is immediately obtained from the sealed bid by fixing the sale price as the one that corresponds to the second highest bid (a simple change in the auctioneer adjudication rule). Thus by just changing two illocutions, and a few individual behavior rules, the Fishmarket auctioning conventions can accommodate two very usual alternative "bidding conventions". A more subtle example is the following: a *(crude) English* auction is obtained by taking the price increment to be negative (a simple "parametric" change of signs), permuting *silence*, *bid* and *bids* reception branches in the Fishmarket bidding protocol, adjusting the tie–breaking criterion, and canceling unnecessary trajectories for reserve pricing (a not too complex protocol adjustment). Once more, the task of producing the change is trivial, while the effects on the auction outcomes are considerable, as economic–theoretic literature attests [188, 104, 176].

In this chapter I will only concern myself with these three types of variants, although it should be obvious that there are auctioning conventions that are not expressible as any of these types of variants. At least not in a natural and simple fashion. These other auctions, however, can be expressed with the same type of formalism advocated for the Fishmarket, but with different contents altogether. In Chapters 8 and 10 I will comment on these other types of auctions[3].

To characterize these variants, informally, I will focus on a few features of the Fishmarket that can be convenient and profitably changed. Formally, all these features (as will be readily seen) can be made to correspond to individual rules of behavior of Fishmarket participants. The default Fishmarket social conventions would have to be made consistent with any of those new rules that change the default ones, but that is easy to accomplish in practice, and its formalization is cumbersome, but obvious.

For descriptive purposes, it is convenient to group variable features in the following five groups:

1. Bidding Parameters
2. Reception of goods
3. Presentation of Goods
4. Catalogueing
5. Revelation of Information
6. Buyer's Credit Update
7. Market Management

I will briefly comment on each in the next few paragraphs, but I should make an experimental bias explicit. The features I will focus on, will not produce all possible variants of the three types mentioned above, although they will be illustrative of the general possibilities of variation, and will capture most of the obviously interesting variants.

Variants may be worth studying for different reasons, two I find fundamental:

1. To explore distinguishing features of an auctioning convention that is to be used in the real world
2. To test agent architectural elements, strategies or decision heuristics, under controlled conditions.

In both cases, variants can be viewed as experimental situations.

This experimental bias is developed further in Section 7.2 where some experimentally relevant features, that are not part of the Fishmarket auctioning conventions proper, are introduced. In Section 7.3 Fishmarket variants and these additional experimental features are combined to produce experimental *competitive scenarios* and *tournaments*.

[3]Full English auction, for instance; or japanese, simultaneous, reactive auction may *artificiously* be expressed as a variant of the Fishmarket, but that is neither natural, nor revealing, thus, they are better defined in their own terms.

7.1.1 Bidding Parameters

These involve those features that affect the dynamics of the bidding rounds proper: waiting periods, collisions, etc. In the Fishmarket Downward bidding protocol I made use of seven that can be modified in obvious ways:

1. Δ_{offers} (waiting period between offers)
2. Δ_{goods} (waiting period between the adjudication or withdrawal of a good and the presentation of a new good)
3. Δ_{lots} (waiting period between the termination of a lot and the presentation of a new lot of goods)
4. Σ_{Col} (maximum number of successive collisions of bids that are recognized by the auctioneer before using a tie–break)
5. Φ_{price} ("price step" function, determines the difference between two successive price quotations)
6. Π_{rebid} (increment factor for an offer after an invalid bid or collision)
7. $\Pi_{sanction}$ (penalty factor, applied to the price quote, that determines the amount to be paid as fine for an unsupported bid).

For the definition of experimental situations, another one, $\Delta_{auctions}$, the waiting period between the end of an auction and the beginning of a new one, should be added to this group.

Note that waiting periods are critical for the type of on–line/off–line deliberation an automated agent may have, thus alternative choices in these will affect relative performance of different types of agents. For instance, reactive agents should perform better under tightly time–bounded rounds. But are highly deliberative BDI agents necessarily slower that human buyers? Would the later be any better whenever they had enough time?

Auction rhythm is fundamental for human based bidding (probably a matter of attention and passion), and therefore the price step function Φ_{price} may need to reflect some proportionallity to pricing, in automated bidding such variability may be irrelevant and be defined as a constant.

Σ_{Col} and Π_{rebid} are needed to set up appropriate price levelling in completely artificial auctions (if credit lines are very large but bounded, Π_{rebid} should scale prices; if Σ_{Col} is too large and bidding heuristics coincide frequently enough, the market may be ineffective[4]).

Sanction factor, $\Pi_{sanction}$, can always be put to nil, but it can be used to prime deliberation and is needed to terminate a vicious repeated collision circle.

Note that these eight parameters (I am including $\Delta_{auctions}$) are characteristic of the Fishmarket downward bidding protocol. It will result convenient to refer

[4]Note that these comments can be expressed precisely and the obvious lemmas should be proved.

to this sequence as the "**DBP parameters**". Other bidding protocols can be parameterized likewise and characterized by their corresponding parametric sequences.

Definition 7.1 (DBP parameters) *The Downward Bidding Protocol parameters is the following ordered sequence:*

$$\langle \Delta_{offers}, \Delta_{goods}, \Delta_{lots}, \Delta_{auctions}, \Sigma_{Col}, \Phi_{price}, \Pi_{rebid}, \Pi_{sanction} \rangle$$

Other bidding round features

Tie-breaking Additionally, one can define alternative *tie breaking criteria*, which may be of interest for real auctions, although the experimental interest is modest. In the Fishmarket we used a *random selection*, but *first registered buyer*, *poorest buyer*, *less successful buyer*, etc. can be also used.

Accounting conventions $\Pi_{spremium}$ and $\Pi_{bpremium}$ may be used to rationalize expenditures (if it is better to save than to buy and pay taxes), but are perhaps better used to have a way of measuring market efficiency.

A "presence" charge to buyers who are present in a bidding round (as a fee for being able to bid) Π_{pres} might also be considered. It could conceivably be interesting to stimulate occupancy changes in the auction hall, thus revealing competitive pressure for specific goods.

7.1.2 Reception of goods

Sellers may be given two mutually exclusive options: to register their goods **continuously** as long as the auction is open (as is defined in the Fishmarket), or to register goods only **once** (as is the case in the Blanes fish market).

Additionally, the *reception period* may be time–bounded. Be it my fixing a **time limit** prior to which all auctionable goods have to be in (previous to the auction, or even while the auction is open), or stating registration conditions of other sorts, such that registration is **continuous** while the registration conditions are satisfied.

This flexibility can have substantial experimental consequences. For sellers, it provides for a more complex decision scenario that may allow for a richer evaluation. For buyers, one shot pre–auction registration allows for a pre–auction catalogue (and off line strategy definition). Continuous open ended registration makes sense to test some sort of seller performance, or to discourage purely analytic and off–line optimization techniques (because of the added complexity of estimating supply).

7.1.3 Presentation of goods

Similar in experimental interest to features related with the reception of goods, because of opacity of supply, in this case the auction house controls the supply flow by choosing different groupings for goods. The natural alternatives are: A **single lot** of individual items offered sequentially. Or **multiple lots** of individual items (also offered one by one). Both are trivially implemented in the Fishmarket by controlling the newlot dialogue (or the corresponding auctioneer rules of behavior).

The real fishmarket, though had yet another convention: **multiple items with quantity option** (choose as many items as wanted from a lot of multiple items of the same good–type in one offer), which is not expressible as a variant of the current protocol[5].

7.1.4 Catalogueing

Yet another way of controlling how much information is made available to buyers, and alternative ways of measuring efficiency of sellers and the market, is in the way default values are put into the auction catalogue. Default setting conventions are also ways of protecting seller interests, or entice buyer propensity to purchase, thus, alternative feature choices may be grounded in pragmatic considerations as well.

The default setting of two variables is of interest. Starting and reserve prices of goods.

Starting price of a good Default setting for $p_0(g)$ can be defined by the seller or by the seller admitter. In the second case (or for simulated supply) various alternatives are at hand, the most obvious are to use the *market history* to set this price, which is the Blanes convention; or use some sort of secondary market or *external* information. In either case, the default value may be set through a convention that gives all goods of the same type the **same starting price**, or one that may give **different starting prices**.

Reserve price In a similar fashion, $p_{rsv}(g)$ can be set either by the seller or by the seller admitter. The natural definition alternatives, again, are to fix it according to an external convention, or one that depends on the market history.

Reserve price setting can be used as a convenient estimator for seller's aptitude and can be used for price levelling as well. If it is randomly fixed within an interval, it makes the generalized prisoner dilemma scenario to have multiple equilibria. But if reserve prices are known to exist and take values with a known

[5]If this convention had been implemented in the Fishmarket, the previous two alternatives would be trivial special cases. Now we would need to change the bidding protocol in a non-trivial manner. Therefore, this is an example of the type of variant I am not going to to discuss in this chapter. Likewise, bidding for as many (different) items *simultaneously* (in one bidding opportunity) per lot as one chooses, is out of the scope of this chapter's variants.

probability distribution, buyer heuristics may be attuned to that fact in clever ways, so it may be a nice experimental feature.

7.1.5 Revelation of Information

Another feature that can be used to alter the opacity of an auction is the moment in which information of a good is revealed to buyers. Three moments are naturally available:

- Before the auction starts
- When a lot is presented
- When a good is offered

Evidently, these options are related to the criteria adopted for reception of goods, and in a way are used in similar fashion, but again pragmatic considerations make it advisable to keep them separate from reception of goods criteria.

Implementation, again is trivial, since it only depends on the contents of illocutions (messages) used in the entrance to the auction room, presentation of lot and presentation of a new good.

7.1.6 Buyer's Credit Update

The Fishmarket allows for *continuous* and *unbounded* updating of credit. It is convenient to filter these features, and consequently twelve variants of credit updating may be worth identifying:

- **any–time** updating, **once per lot**, **once per auction**.
- **Constant** amount deposits vs. **flexible** amount.
- **bounded** total deposits vs. **unbounded** deposits.

All are trivially adopted through credit manager filtering conditions.

7.1.7 Other market management features

Sanctions to buyers In the Fishmarket there were two forms of sanction: *fines* and *expulsion*. Criteria for applicability and conditions may vary easily.

Opening and closing conditions Linked with credit update and registration of goods, the market has to define its conventions for opening and closing, and then for the starting of an auction. The natural variants are:

1. Opening will take place only if a given combination of three types of conditions are satisfied.
   (a) conditions on **time**. A certain date, a waiting period.

   (b) conditions on **number of buyers**. Minimum, minimum with minimum deposits.
   (c) conditions on **offer**. Minimum number of goods, minimum value-quality.

2. Likewise standard and non–standard closing conditions of the Fishmarket can be generalized trivially to include:
   (a) finish all goods or all registered goods
   (b) satisfaction of demand conditions
   (c) satisfaction of timing conditions

7.2 Other experimentally relevant features

An auction is a competitive price–setting mechanism. Some agents may be more apt under certain circumstances than others, and some auctioning conventions may be better suited to certain supply and demand conditions than others. Experimental evaluation of sellers, buyers and auctioning conventions may be a natural aspiration, with a few more features, perhaps it can also be revealing. In this section I will introduce additional concepts (terms) that will permit the definition of alternative *evaluation conventions*.

7.2.1 Buyer performance

If one would like to say which of many buyers has *won* in an auction, the obvious way would be to say that "the one who bought best". But that intuition can be made precise in different ways.

One should take into account the price it paid for all the goods it bought. If this buyer paid more than others for the same type of goods, it should not be considered the best. Unless, of course, because of the time it bought the goods it obtained a better revenue. And how about the resources it had to start with? is a poorer buyer at a disadvantage with respect to a richer buyer and therefore resources ought to be normalized before any comparison is made? Is spending all the money, better than spending it wisely?

There are at least two alternative approaches to buyer evaluation. One is through classical *competitive utility functions*, another is a *satisfaction criterion* (Cf., e.g., Simon [159][Chpt. 2]). They induce different comparative conditions, that are reflected in different information needs and different buyer behavior.

Competitive utility functions

The *best buyer* under classical competitive utility, is the one who makes more *profit*. And profit is measured as the difference between the resources the buyer put into the auction and the value of what it got out (its *bundle*), granting for some possible normalization and discounting to compensate for some advantages or different buying conditions.

In order to reflect this type of considerations, the following features should be available in the definition of an experimental auction:

Resale price This function, $p_{rsl}(g)$, can be **fixed for a good type** for the duration of an auction, or may **fluctuate** in time[6].

It can be **known** before the auction, when the lot is presented, when the good is presented, or only known after the auction.

It can be defined according to the **market history** or the **auction history**, or may be defined on terms of some **external supply** considerations.

Endowment of a buyer That is the amount of resources it can bring to the auction (which may be used to define and update its credit line).

Endowments may be **equal** or **different** among buyers, and if different, defined randomly or according to some Pareto–like distribution, for example. They may be **known** to every other buyer before the auction, or not. Endowment of b at time t will be referred to through $endwt_t(b)$.

Buyer's profit

Definition 7.2 (Simple profit function) *Given a buyer b, with bundle $bundle_t(b)$ at time t, then the **profit** of b at time t is given by:*

$$profit_t(b) = credit_t(g) + \sum_{g \in bundle_t(b)} (p_{rsl}(g) - p_\omega(g))$$

Utility functions With the above features, some alternative utility functions can be defined. A rather general one is:

Definition 7.3 (Utility)

$$Ut(b) = \frac{profit_\omega(b)}{endwt_\omega(b)}$$

Satisfaction utility functions

A different picture emerges when instead of simple profit, some consideration of satisfaction of expectations or needs is made in order to measure a buyer's performance.

Interviewing Blanes buyers, it was clear that they approached the auction with an expected bundle that was to be *satisfied at minimum cost.* Although some leeway for substitutive goods was assumed, thresholds on a few good–types

[6]For some purposes it might result convenient to define the function on good–types, in which case it can always be extended to individual goods.

were set, and a sort of opportunity cost intuitively assigned. The bundle composition, the thresholds and the opportunity costs evolved dynamically, subject to the supply and demand conditions of the market session.

When such a satisfaction–based utility function is taken to evaluate buyer performance, it primes outcomes that are different from the ones competitive utility primes. Satisfaction of goals under minimal cost decision-making would very likely involve modeling and heuristics that are quite different from those of the simpler competitive utility suggested above. It would also need additional experimental features like the following ones.

Opportunity costs If satisfaction, and not simple optimality is used, opportunity cost functions may be conveniently adopted. These can be rather complex. Here is an example of a utility function that assumes fixed proportional bounded opportunity costs for a fixed bundle of good types, no substitutivity value and constant resale price.

Recall from Chapter 4, that $bundle_t(g)$ is the collection of goods purchased by buyer b at time t, and $\widehat{G}$ is the set of good types of the auction. Then, the final bundle of types of b (that is, the number of items of each type that b ends up with) is given by:

Definition 7.4 (good–type bundle) *For a buyer b, with final bundle of goods $bundle_\omega(g)$, and a collection of good types $\widehat{G}$ in the auction, the* ***final good–type bundle*** *of b is given by the mapping:*

$$\widehat{bndl} : B \times \widehat{G} \rightarrow I\!N,$$

such that

$$\widehat{bndl}_\omega(b,h) = |\{g \in bundle(b) : \hat{g} = h\}|$$

If $\widehat{bndl}_0(b,h)$ denotes the (original) expected amount of good–type h of buyer b, then for each good type h, a unitary opportunity cost is defined by $uopco(b,h,r)$ as follows:

Definition 7.5 (Bundle gap for b) *If $\widehat{bndl}_0(b,h)$ denotes the (original) expected good–type bundle of b, and $\widehat{bndl}_\omega(b,h)$ denotes the final good–type bundle of b, then the type–wise difference between expected and final bundles is known as the* ***bundle gap*** *for b. That is,*

$$bundlegap(b,h) = \widehat{bndl}_0(b,h) - \widehat{bndl}_\omega(b,h)$$

and

Definition 7.6 (FPB–uopco) ***Fixed proportional and bounded unitary opportunity costs*** *for a buyer b, a good–type $h \in \widehat{G}$ and h–factor r_h, are given by*

$$uopco(b,h,r_h) = \begin{cases} 0 & \textit{If} \quad bundlegap(b,h) \leq 0 \\ r_h(bundlegap(b,h)) & \textit{otherwise} \end{cases}$$

Where a proportional cost r_h is charged for every missing item of type h up to a threshold value $\widehat{bndl}_0(b,h)$ (and from then on it is 0) [7].

The overall opportunity costs for that auction for that buyer is given by:

Definition 7.7 (FPB–Opportunity costs) *Given a buyer b with expected purchase bundle $\widehat{bndl}_0$ and actual purchased good–type bundle $\widehat{bndl}_\omega(b)$, the **opportunity costs** for b are given by:*

$$oppcost_\omega(b) = \sum_{h \in \widehat{G}} uopco(b, h, r_h)$$

Using then a standard profit function, such as the one defined in Def.7.2 above, we finally have:

Definition 7.8 (Satisfaction utility function) *Given profit, opportunity cost and endowment functions for a buyer b with bundle $bundle(b)$, a satisfaction utility function can be defined as:*

$$Ut_{opp}(b) = \frac{profit_\omega(b) - oppcost_\omega(b)}{end_\omega(b)}$$

7.2.2 Seller performance

Sellers can also be evaluated in competitive terms. For that purpose, the main feature would be the income they make in an auction. Analogously to the considerations made for buyers, however, some normalization to discount market efficiency, or starting conditions may be incorporated into the evaluation function.

Perhaps the most natural performance comparison can be made between the prices that seller gets for its goods, and the market average prices.

7.2.3 Market performance

Market performance can also be evaluated. A trivial measure can be obtained through *ahincome*, the house income derived from seller premiums and sanctions (recall Chapter 4, Definition 4.4). But I believe it is more interesting to analyze how appropriate have market–controlled parameters have been to sell the goods.

Thus, for instance, if most goods are sold quickly (after relatively few offers), with few collisions and with relatively flat price graphs, then it would mean that price ranges are set well for the existing demand. However if prices are erratic, and collisions abundant, that would mean an inadequate price level or an anomaly of demand.

A seller's perspective may also be relevant, and that would mean that increases in historic price tendencies (over auctions), low withdrawal rate, smallish silence intervals, are valued positively.

[7] Evidently, *uopco* is a trivial opportunity cost valuation, other more realistic ones would consider diminishing returns and some convexity properties, and r_h would be time and buyer dependent.

7.2.4 Additional Features

Supply For experimental purposes, it may be advantageous to have a way of simulating supply. A trivial way of doing this in the Fishmarket is to program a few seller agents whose goods and conditions are set in the way the experimental situation requires. However, it may result more convenient to generate directly an auction catalogue, divided into lots, if needed.

The computational task of producing the actual catalogue and its utilization in an experimental auction is trivial, the generation of the catalogue content is straightforward.

In essence, what has to be produced is a list of goods and the default values. Default values can be generated as discussed before for the seller admitter and the list is merely a list of good types, the distribution of which may be set in different ways. However, the task of producing the default catalogue as a unitary object allows for a cleaner description of assumptions. A multivaried time–series approach may profit from actual, previously simulated or otherwise obtained historical data.

Demand Buyers can also be simulated for experimental purposes (by agents or otherwise), and some buyer parameters (endowment, opportunity costs) will almost always require some sort of default setting or artificial definition. Thus appropriate generating functions should be available.

7.3 Competitive Scenarios

Having explored the numerous variants of the Fishmarket that are readily available, and having discussed some additional experimental features that can be added to the Fishmarket institution, we can now proceed to discuss what type of *combinations* of features may result interesting for actual experimentation.

The choice of features is determined by the experimental question, obviously, but some general conventions may be worth typifying. We call these typifications *competitive scenarios*. A competitive scenario will be defined by a combination of features that satisfy the following criteria[8]:

1. **Content**. Explicit choice of features has to be made on
   (a) **Evaluation Conventions**, for
      i. Buyer evaluation
      ii. Seller evaluation
      iii. Market evaluation
   (b) **Supply Conditions**
      i. Type of supply (human, agents, simulated: characteristics)

[8] Note that the formalization in terms of Dialogical Framework, Individual rules of behavior and social conventions are quite straight-forward.

    ii. Revelation of supply convention

(c) **Demand Conditions**

    i. Buyer resources
    ii. Resale price
    iii. Revelation of buyer resources
    iv. Type of demand (agents, human, mixed, simulated: characteristics)
    v. Revelation of type of demand convention

(d) **Auctioning Conventions**, that include

    i. DBP parameters
    ii. Reception of goods
    iii. Presentation of goods
    iv. Catalogueing
    v. Revelation of information
    vi. Buyer's credit update
    vii. Other market management conventions

2. **Feasibility**. Whatever choice of features has been made, the resulting scenario must be feasible, that is, an actual auction can be performed that satisfies all the feature choices.

3. **Recording**. Auctions carried out under these assumptions should be recorded for analysis and validation.

A competitive scenario, therefore, will involve: A clearly defined evaluation convention that is applicable to all participants. A clearly stated and established set of *feasible* supply, demand and market conventions. A set of apt participants (that can participate in the auction and can be active at the appropriate time and during the relevant part of the auction). And appropriate recording conventions and tools.

Three quite different types of scenarios that satisfy these conditions may then be advocated. Extremely simple artificial scenarios in which most information is known by everyone, and are thus susceptible to highly analytical modeling. Very realistic complex scenarios in which features and conditions are faithful to real world models and can therefore be used to explore actual bidding practices. And, finally, intermediate systematically varied scenarios that can be thought of as the intended agent test–beds for the study of agent characteristics, strategies or architectures.

7.3.1 Three Illustrative Scenarios

Here are three examples of competitive scenarios experimental conditions.

Definition 7.9 **(PD_0)** *An extremely simple artificial scenario.*

1. ***Evaluation Conventions***
   (a) *Buyer evaluation. Classical competitive utility*
   (b) *Seller evaluation. None*
   (c) *Market evaluation. None*
2. ***Supply Conditions***
   (a) *Type of supply: artificial, two good types, uniform distribution. Same lot of 50 items. 10 auctions.*
   (b) *Revelation of supply convention: yes.*
3. ***Demand Conditions***
   (a) *Buyer resources: Uniform 100 units endowment.*
   (b) *Resale price: average each auction.*
   (c) *Revelation of buyer resources: yes, all.*
   (d) *Type of demand: arbitrary, 10 buyers.*
   (e) *Revelation of type of demand convention: yes*
4. ***Auctioning Conventions***
   (a) *DBP parameters:* $\langle 1, 1, 1, 60, 3, 10, 20, 5 \rangle$[9].
   (b) *Reception of goods. One shot, prior to auction*
   (c) *Presentation of goods. Complete lot, prior to auction*
   (d) *Catalogueing. Constant fixed 10, 8 resp. No reserve price*
   (e) *Revelation of information. All before auction*
   (f) *Buyer's credit update. Once, full endowment.*
   (g) *Other market management conventions. No commissions.*

Definition 7.10 **(R_0)** *Realistic complex scenario.*

1. ***Evaluation Conventions***
   (a) *Buyer evaluation: Utility (*$Ut_\omega(b)$*)*
   (b) *Seller evaluation: Utility (*$Income_\omega(s)$ *minus average good–type price as opportunity cost for withdrawn goods)*
   (c) *Market evaluation: ahincome*
2. ***Supply Conditions***

[9]Waiting periods in seconds, 3 successive collisions, price step 10 units, rebid and sanction factor: 20 and 5 percent.

(a) *Type of supply: mixed, human/agents. Two types of goods. One auction.*

(b) *Revelation of supply convention: yes*

3. ***Demand Conditions***

   (a) *Buyer resources: Variable endowments, Normal distribution (100,10)*

   (b) *Resale price: Univariate MA time-series. On realistic data shared by players.*

   (c) *Revelation of buyer resources: No*

   (d) *Type of demand: mixed agents/human*

   (e) *Revelation of type of demand convention: yes*

4. ***Auctioning Conventions***

   (a) *DBP parameters:* $\langle 1, 30, 100, 0, 3, 10, 20, 5\rangle$[10].

   (b) *Reception of goods: continuous.*

   (c) *Presentation of goods: by lot of 20 goods (auction house may split or complete).*

   (d) *Catalogueing: defaults by seller. Ordering by arrival time.*

   (e) *Revelation of information:* p_0 *by lot,* p_{rsv}*, no.*

   (f) *Buyer's credit update: open.*

   (g) *Other market management conventions: Announced starting time. 100 auctioned goods determines end, auction house may bring phantom buyers and sellers to keep up auction pace.*

Definition 7.11 (TB_0) *Intermediate artificial scenarios*

1. ***Evaluation Conventions***

   (a) *Buyer evaluation: Competitive utility (*$Ut_\omega(b)$*)*

   (b) *Seller evaluation: None*

   (c) *Market evaluation: Price dispersal.*

2. ***Supply Conditions***

   (a) *Type of supply: simulated, two good types, uniform distribution. Same lot of 50 items. 10 auctions.*

   (b) *Revelation of supply convention: yes*

3. ***Demand Conditions***

[10] Waiting periods in seconds, 3 successive collisions, price step 10 units, rebid and sanction factor: 20 and 5 percent.

(a) *Buyer resources: Uniform 100 units*

(b) *Resale price: average each auction.*

(c) *Revelation of buyer resources: Yes*

(d) *Type of demand: agents*

(e) *Revelation of type of demand convention: yes*

4. ***Auctioning Conventions***

(a) *DBP parameters:* $\langle .1, .1, 0, 60, 3, 10, 20, 5\rangle$[11].

(b) *Reception of goods:one lot per auction*

(c) *Presentation of goods: before auction*

(d) *Catalogueing: starting price constant, 10, 8. Reserve price, 0.*

(e) *Revelation of catalogue information: yes before auction.*

(f) *Buyer's credit update: once, full endowment.*

(g) *Other market management conventions.*

Some comments may be relevant

7.3.2 Choosing Evaluation conventions

This is crucial in the design of experiments and of tournaments. I prefer simple additive utility maximizing functions to be the usual buyer evaluation convention, but for realistic scenarios it may be convenient to have other bundle-satisfaction functions to measure opportunity cost on different grounds.

Choosing Supply conventions If the test is on buyers, make supply easy to repeat, to test statistical variations. Make sure any complexity is truly interesting. What good does it make to have lots of unknown starting prices, for instance? Reveal supply information according to the type of test one wants to perform on agents. If one wants to reward strong on–line reasoning, one should keep supply information opaque, for instance. Reservation price can be puzzling. It is made zero for the very simple scenario, just in order to facilitate a simpler analytical treatment. Probably a nice random setting for buyer and good type would be very realistic and one may conjecture it forces multiple equilibria.

Choosing Demand conventions If one would like to test selling agents, perhaps it would be easy to simulate demand through a time series. But just as fine might be to have a well chosen set of software agents that might more naturally correspond to an intuitive market composition (wholesalers vs retailers).

[11] Waiting periods in seconds, 3 successive collisions, price step 10 units, rebid and sanction factor: 20 and 5 percent.

7.3.3 Buyer resources and resale price

I suspect that money supply may be critical to the overall performance of the market. I would try to set this variable experimentally, but probably Economists may have clever things to say about volatility, income distribution, profitability and other similar concepts, and may suggest some form of parametric setting of this variable. Resale price is basic in the competitive utility function, it would significantly affect buyer strategies, so revelation conventions and default setting may induce high volatility, and would therefore suggest the need for some training of the participants prior to actual competition.

Choosing Market conventions Waiting periods and price step should allow for sensible bidding of the kind of agents that one intends that participate in an auction. Similarly, transaction costs are to be carefully chosen not to bias conducts, and revelation of information conventions ought to be consistent with the type of agent to be tested (or analysis to be made).

7.4 Test–bed and Tournaments

7.4.1 Test–bed functionality

We are now ready to define a test–bed tool on top of the Fishmarket institution. The idea is to have a convenient software environment where:

1. Competitive scenarios can be conveniently specified,
2. Agents and human participants are registered and enabled to participate in an auction or sequences of auctions.
3. An auction or sequences of auctions are activated and every relevant incident or transaction recorded.
4. The results can be thoroughly analyzed.

Ideally, the *content* specification of the competitive scenarios should be as concise and simple as the description of the illustrative scenarios above, but it should result in an executable scenario that could actually be *run* and satisfy the feasibility and recording required of every competitive scenario.

Registration of participants should be made in such a way that full functionality is guaranteed of participants, and proper activation is accomplished on time and under absolutely fair and functionally appropriate conditions. The test–bed environment should guarantee also that no anomalous or malicious behavior be tolerated.

Given that these preliminary conditions are satisfied, then an auction should be performed with the participating agents and properly recorded for analysis. Recording tools should be able to capture all relevant incidents of the auction (bids, price-fluctuation, collisions, fines, expulsions), prevalent context and design conditions at significant moments, and the pertinent local and global changes.

Analysis and visualization tools will also be needed. They should at least allow three types of analysis: Agent–centered, process centered and performance–centered. These tools should also produce a time–graph of incidents, the full catalogue and occupancy information (price evolution, purchasers, competition), flexible cross-correlations (between product types, participants, timing...), and other relevant data-analysis, as well as visualization capabilities.

Now, note that the same type of competitive scenarios may be conducive to test agents as well as auctions. Thus, is what I propose a test–bed for *agents* or a test–bed for *auctions*?

A test–bed for agents should facilitate testing of aspects about agents that are interesting form the point of view of competence, performance, architecture,... of the agent. However, these qualities differ from different perspectives. If BDI architecture is to be tested or stimulated, for example, then utility functions and selected features should reward and be conducive to the exploitation of intentional aspects such as: thinking about goals (e.g., using goal–interesting buyer evaluation functions like "demand bundle satisfaction"), or giving information about rivals' behavior or resources (to reward thinking about rivals' goals and achievements). Thus if one wants to test whether or not it is advantageous to use deliberative agents, one should make sure that, for instance, enough time is given to these agents to deliberate. If given this ideal time, deliberative agents loose against shallow reactive agents, or (on the other extreme) they outperform human buyers, the result would be positive relevant information in favor of deliberative agents. But if, under the same conditions, deliberative agents do not outperform humans or win against shallow reactive agents, the experiment would be inconclusive, and better litmus conditions should be examined and, consequently, other trading conditions should be chosen.

A test–bed for auctions, on the other hand, looks towards identifying which conditions are conducive to successful market practices (and equilibria). For example, one would like to determine under what circumstances more transactions are conducted (more rapidly, more in number, with less interactions), better prices are drawn (by sellers or by buyers) or more benefits are obtained by participants. For that purpose, we may keep a fixed collection of buyers and sellers and vary DBP parameters, or bidding conventions, or transaction costs, or individual utility functions.

7.4.2 FM97.7

David Gutiérrez is implementing FM97.7, a Java–based—test–bed tool on top of FM96.5 (the Fishmarket implementation reported in Chapter 6). The idea is that through this tool one can easily define, activate, register and analyze auctions and perform controlled experiments over FM.

This extension to FM96.5 allows for the specification of two operational modes for FM: an *auction mode*, and a *tournament mode*.

Under both modes, the user is allowed to activate a fishmarket environment, plus (optionally) the auditing tool FM97.6 (that I shall comment on below) and a set of auction displaying and analysis tools. However, under the auction mode, the execution of FM97.7 invokes the regular version of FM96.5, while in tournament mode, simplified admission and settlement scenes from FM96.5 are activated.

In both modes, the user is enabled to define competitive scenarios and activate competing agents or simulate demand and supply conditions. Display and analysis tools will allow the exploitation of user–defined views of the market database.

An example of a specification display can be seen in Figure 7.1.

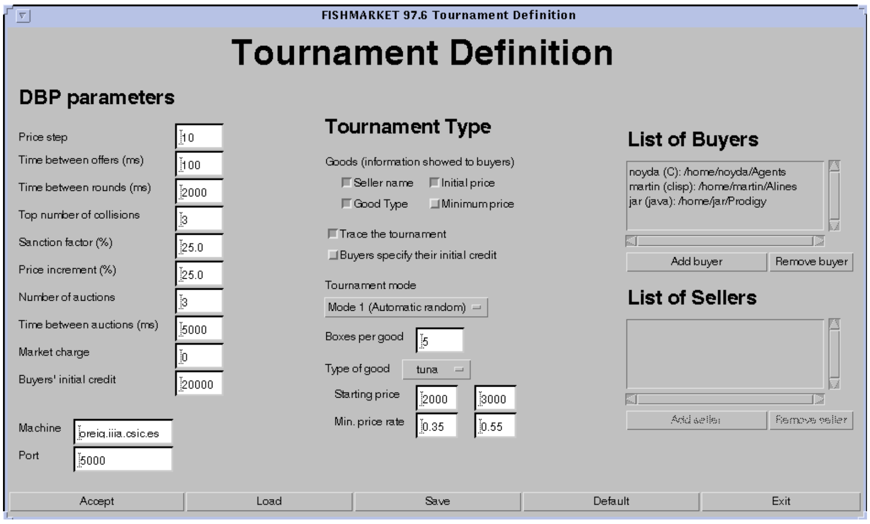

Figure 7.1: Tournament Descriptor snapshot

7.5 Auditing Auctions

A fundamental component of an experimental auction tool is the capability of keeping an appropriate record of an auction. But proper registration of an auction initial conditions and evolution is also essential for building trust in the institution that conducts it.

Are both forms of registration compatible? What are their relevant differences?

7.5.1 Registration for experimental purposes

We need to keep a record of all the market information that is public (because we may want to do data mining or automated learning from these experimental data). We may also want to keep a record of all illocutions uttered, in case the transparency and privacy conditions of the auction are related to them. And, for analysis, we may even want to be able to reconstruct sequential information, to be able to re-enact some decisions, or to validate heuristics or actual behavior.

The same is useful for auditing.

7.5.2 Registration for auditing purposes

A minimal precondition for trustworthy auction house is to be able to thoroughly audit an auction.

Ideally, an auditing data base, should allow to:

- examine every action a staff member takes during an auction
- validate that all illocutions have followed the established protocol
- analyze all sales that take place during an auction, and all the circumstances associated to each sale (ties, occupancy, prices, invalid bids,...)
- reconstruct, step by step what has happened during an auction and identify any anomaly with respect to the accepted conventions.
- re–enact an auction up to a certain point and then proceed under different conditions.
- re–enact an auction (*caeteris paribus*) with additional participants.

Well, all that is accomplished with our auditing tool, (FM97.6), and a bit more. We take the idea of "auditing" literally, we "listen" to each and all illocutions uttered during a market session, and build a data base around them. A redundant, but independent, data base. An auditing data base that complements the market data base in which public commitments are kept. But we keep a dual purpose in mind, being able to verify that conditions are properly upheld —or identify any anomaly— and to document the historical events for analysis and experimental purposes.

FM97.6, was designed and implemented by Juan Antonio Rodríguez and Xavier Giménez. A snapshot of the on–line activity monitorization is presented in Figure 7.2

7.6 Buyer Agents

In a crude and concise way, I would like to comment on a couple of prototype buyer agents for the Fishmarket that were developed by Mari Carmen de Toro and documented in [38]. My intention is to suggest how this trading application may shed light on how to build competent and trustworthy agents.

Designing a buyer agent has to take into account two different types of consideration. On one hand there are *functional* considerations: how to act, and when,

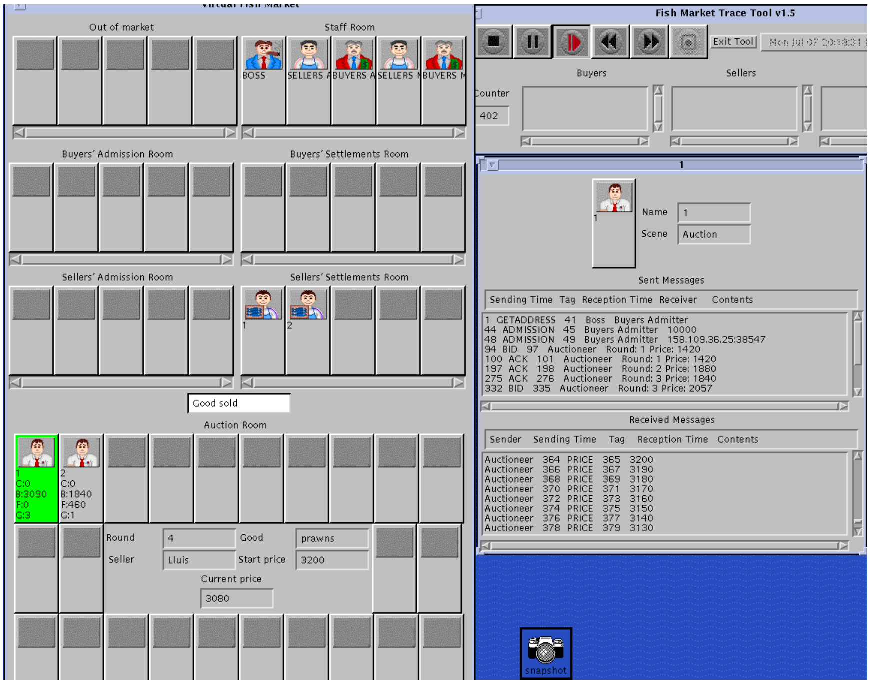

Figure 7.2: Snapshot of the auditing tool

so that the agent is a competent buyer. On the other hand, there are *ergonomic* considerations: how should an agent's behavior be described and specified. How much is left for the user to tune up, or should complex procedural and strategic features should be pre–packaged, and if so, how. What determines the acceptability of a trading agent: performance?, intelligibility?, simplicity, human–like descriptions?

7.6.1 Design considerations

Functional considerations What is involved then in building an FM buyer from a functional point of view?.

In essence a buyer has a trivial dilemma: To bid or not to bid. But *what information* and *what type of deliberation* is relevant in making that decision is not easy to assess in general.

A sound heuristic appears to be to focus on competence, which in a tournament (and evidently in real life) will depend essentially on whatever evaluation function is adopted, a typical additive utility maximizing function or a goal–satisfaction kind of evaluation, or whatever. Each evaluation function implies specific considerations, but in general the information to consider for the actual agent design is present in those features that for each type of evaluation function may constitute an independent variable. Thus, features like the type of good, historical prices, opening price, resale value are usually relevant.

Deliberation depends on other considerations. For example, if any of the above mentioned features is available before the auction starts, it makes sense to take advantage of this fact and process them as much as possible, before the auction starts, to facilitate a quicker and better informed reasoning once the auction starts. Endowments, fines and other transaction costs, as well as competitive pressure, may also be useful objects of deliberation.

Not withstanding what was just said for information and deliberation, a third type of consideration should be given to *operative aspects*. Aspects that have to do not only with the bidding context like time and speed, but also on available knowledge of auctionable goods and whatever resources for their acquisition might be at hand.

Acceptability considerations From the adoption perspective, the importance of features shift. One natural strategy to follow is the *anthropomorphization* of the buyer agent: its tactics, its strategies and its personality

Tactics that, for instance, determine to react to collisions by re–examining a prior decision not to buy, or assuming different price thresholds during different intervals of an auction or while prices are volatile, can be enumerated.

Certain combinations of these tactics, with triggering conditions and sequencing may be organized and then combined into a buyer agent "personality profile", in which a collection of existing and available tactics like the ones mentioned, would produce a "cautious buyer", "an eager buyer", an "imitative buyer" for example.

This "personality" needs to be complemented by procedural knowledge or rules on the application of tactics to define a specific buying strategy that is incorporated into a buyer agent. Strategies and personalities may be labeled in anthropomorphic terms to facilitate their acceptability for certain buyers, while for others such an anthropomorphization would make the heuristics, tactics and strategies wholly suspect and a more analytical description would be preferable. In both cases, objective evidence in favor of given tactics and profiles is probably quite desirable, and it can be presented in terms of statistical performance or some simulation–based training period.

Computational Performance considerations In the Fishmarket context, though, in addition to being apt for trading, buyer agents need to be fast. On–line deliberation *vs.* reactivity is a relevant debate, but perhaps, as in other cases, a hybrid is better than a pure form. In this respect, the crucial features for success are the management of time and information.

Agent templates for FM96.5

One can build this sort of agents, easily, on a multi–context architecture similar to that discussed in Chapter 5. I will briefly comment on two examples discussed by de Toro (in [38]) that were built following that proposal.

The two buyer agents built by de Toro, share the exact same architecture, although the corresponding internal theories are quite different ([38][p. 55]). One of them is a buyer that competes in a tournament with evaluation function similar to $Ut(b)$ above ([38][p. 105]), while the second one emulates a Blanes buyer, and has a satisfaction–like goal–directed behavior ([38][p. 125]).

In both cases, the agents have the same three internal units: a Communication unit, an Off–line reasoning unit, and an On–line reasoning unit. Their heuristics, naturally, are different. In both cases, the on–line reasoning unit incorporates a rude reactive type set of conditions although the on–line and off–line units are deliberative in essence.

The off–line reasoning module takes the auction catalogue and selects a bundle of goods and a price for each item in the bundle that ideally optimizes the evaluation function. This *intended bundle–price* is then updated by the on–line unit which uses the information that is being generated by the auctioning process. Thus, for example, if an item of the original intended bundle is sold to another buyer and the agent is then left with more money than originally planned for that stage of the auction, then the *trigger price* for the next item that is similar to (or of the same type as) the one just sold may be incremented (according to some heuristic) by the on–line unit.

The communication unit is attached to the Fishmarket nomadic interface and consists of a screening module and a decision module. The screening module filters only those pertinent incoming messages to either the on–line or the off–line units, and prepares outgoing messages (received from these units by the decision module) to be deposited on the nomadic interface when appropriate.

The decision module updates the bidding decision for the good in question (modifies the price trigger in fact) by requesting the on–line unit for any updates in the intended bundle for the good being auctioned. The decision module is an any-time automaton, and when the nomadic interface sends the communication unit a quotation that coincides with the price trigger held at that time by the decision module, the communication module produces a mineing call. The on–line unit is constantly reacting and deliberating while the rounds are active. The off–line unit reevaluates its parameters after each auction.

In [38], de Toro implemented a "cautious" agent personality by several specific heuristics (some heuristics were evaluation–function independent, but most were not). For example, the tournament agent would not modify much the intended bundle during the first third of the auction rounds, unless competitive pressure was very light, but would raise the trigger prices aggressively in the last third if it had enough money left and its evaluation function could be improved with respect to its rivals'[12].

What constitutes a template then? Well, I think that is a matter of perspective (or purpose). One can think of the triad (communication, off–line, on–line) architecture *plus* the nomadic interface, as an agent template which the user may then populate with specific heuristics, or theories. Or, one can think of a template to be that *plus* a collection of heuristics (and terms) that can be assembled in different ways to produce the actual agents. Or, one can take the mere nomadic interface as the template.

7.7 FM Developments

Practical Extensions As shown here, FM can rather easily be attuned for different uses by changing many of its inherent variables, even to accommodate different forms of bidding and trading. However, little effort has been put so far in making the other scenes more realistic. If real auctions are to be performed with FM, that would be a necessary improvement. For instance, item presentation is stark (a stark understatement), but it can go far still by just adding standardized information, pictures and relevant documentation and filing features. Evidently, presentation requirements are highly dependent on the type of good being sold and the market itself. A wholesaler's cattle market needs basically a few age–weight–breed categories to trade herds, while local cattlemen need careful physical inspection of each calf before a purchase is remotely feasible. Electronic auctioning is not likely to be different.

Thus even if the Fishmarket model is flexibilized thoroughly in terms of

[12]These two agents were tested in the tournament scenario described in [140] against 8 other agents (mostly reactive) developed by AI students of Barcelona's Politechnical University. As one would expect, the cautious agents lost when little on–line deliberation was given (e.g. Δ_{offers} = .25 sec., Δ_{goods} = 2 sec.), *and* when unlimited resources were available (the winning agent had a trivial heuristic of bidding as soon as possible). However, as expected, these agents won as soon as deliberation time grew and resources were scarce (e.g. $\Delta_{offers} = 2$ sec., Δ_{goods} = 2 sec.). The cautious agent performance improved as auctions were repeated (as expected). Cf. [38, pp.149 ss.].

procedures and rules of behavior, the very ontology of an auction deserves a careful consideration before it is released for actual trading.

Likewise for admission and settlement conventions. In FM we have oversimplified both types of scenes in order to focus on the more proteic components on an auction house —the bidding convention– but for actual trading, these four scenes need to be thoroughly re–engineered. For example: Admission in FM is a one–step deal. In many real world auction houses, admission is better conceived of as a two step process. First an "in principle" admission to the auction house where credit lines are established, identities and competence validated and so on: and second, a market session admission, where actual "logging in" to trade is accomplished. In some cases, both processes can be swiftly performed if needed, and can rely on pre–existing arrangements. Take, for example, a pay–per–view based auction house. It can simply use the regular pay–per–view existing agreements between network and viewers, and register these "on the fly" as willing buyers as soon as they beep their bid. On the other hand in a public procurement setting for, say, long distance telephone carrier rates (Cf, next chapter), competing telecomm companies would need to set up strict identity and bonding qualifications before actually registering for a bid submission. But notice that in general, the four registration and settlement scenes are present, although they need to be adapted to the specific needs and requirements of the market.

Generalized mediators Immediate extensions to FM will most likely take the form of alternative bidding mechanisms that can be readily coded and tailored to the specific needs of the application. These extensions will require a finer adaptation of the grounding procedures of the auction, and a full legal and administrative institutionalization of the auction house. However, the essential functioning can be obtained already from the existing Fishmarket projects developments.

The programs that now perform the roles of staff members in the Fishmarket should evolve into general staffing programs, that can adapt dynamically to the roles, protocols, social and individual rules of behavior that are required of them, and specified to them in a clear and simple fashion.

Thus an auctioneer agent should be able to perform an auction in a variety of auctioning conventions, as instructed by a market boss. And a buyer admitter should be able to filter incoming buyers according to whatever conventions a given auction house imposes, and not only to those already programmed into it as is the case now. I.e., our current mediators should evolve into more general agents who adapt their behavior to the market conventions that are defined when an auction is defined. At the moment, we only feed these staff agents parameters, not rules. But it is conceivable that an auction house represents its rules in a richer declarative formalism, and that these rules are passed to auction house staff, as well as foreign agents, so that they all conform to these rules. This would make it extremely convenient, because one could conceivable have to develop a nice formal system to have a proper specification convention that one could prove consistent and build a (computational) model for it (consisting of an institution and mediators that behave according to the rules and actually enforce them, and furthermore, governors should be automatically synthesized from the specification itself.

Auditable agents Another line of development will be that of generalizing the auditability features already developed for FM. Recall that, now, through the auditing tool we can follow systematically all the activity that happens in an auction through an independent source of information. To achieve that, each staff member has an auditable log–file, and external agent's nomadic interfaces also produce an analogous device for external agents. The auditing tool is already prepared to adapt to changes in the nomadic interface protocols *automatically*, it should evolve in the near future to be able to adapt to new auditing convention specifications automatically as well.

Governors and other forms of shielding foreign agents Finally, the present usage of the remote control devices is merely a nomadic interface device. As is suggested in Chapter 10, that functionality can be substantially increased to enforce protocol compliance in a proactive situated manner.

Part III

Exploring the Metaphor

Content

Now I will take the Fishmarket metaphor developed so far and explore and extend it in three directions.

In Chapter 8, I discuss the *practical aspects* of agent–mediated auctions. Against the background of electronic commerce I make a succinct review of on-line auctions, comment on some plausible applications for the type of agent-mediated auctions that can be built by generalizing the Fishmarket proposal and, finally, discuss some features that may prove useful for the development of real–world agent-mediated auction houses. These remarks are applicable to other forms of agent-mediated trading too.

In Chapter 9, I come back to the ideas introduced in Chapter 4 to examine a different type of dialogue, one that involves persuasion, not merely action coordination, and one that takes place in a far less structured environment: *argumentation-based negotiation.* Once more, my emphasis is in the social aspects that condition the interactions between negotiating agents, and once more I show that the basic methodology, conceptual distinctions and formal tools used for describing the fish market auctions are useful as well in this new context.

In Chapter 10, I bring together many of the contributions made in the previous chapters to characterize the notion of *accountability* of agent interactions, as a way of addressing the practical concern of trust that is needed in electronic commerce. I base that notion on the existence of agent-mediated institutions and governed agents which are the generalizations (from a dialogical point of view) of the agent-mediated auction houses and the nomadic interfaces introduced before.

Chapter 11 includes some closing remarks.

Chapter 8

Agent-Mediated Auctions

An e-mail message to the Fishmarket Project [sic]:

```
From:  "Richard O***" <**fish@***.net>
To:  <fishmarket@iiia.csic.es>
Subject:
Date:  Tue, 17 Sep 1996 21:19:16 -0800
X-Msmail-Priority:  Normal
⋮

I've just tried to read your description of your project and believe
that you cannot be serious.  Who with out a degree in english can
understand what you are trying to accomplish.  If you are trying
to establish an online fish market it will have to be easier to
understand.  you have obviously never sold anything before and
probably need to be tutored.  Now my command of the english language
is not as good as yours but I sell quite a bit of fish and am
interested in people who are trying to promote this type of activity.
Im not just trying to criticize but in hopes of helping you succeed
in putting a tool that I may be able to utilize.
                                        Sincerly
                                        Richard O***
                                        O*** Fish
```

In spite of the probably misleading language I might have used –and perhaps still use— *I am serious* about the real–world applicability of agent–based trading and agent–mediated electronic auction houses. In this chapter I will present some modest ideas to back that claim.

I will start by presenting a broad outlook on Electronic Commerce and then focus on agent–mediated auctions and existing on–line auctions. In section 8.2, I will examine in more detail three examples of agent–mediated auctions that may be realistically implemented. With that background I will then discuss some features that I believe are relevant for the deployment of actual agent–mediated auctions and I will finish this chapter with some remarks on the tools and resources that need to be available for that same purpose.

8.1 Electronic Market Places

Electronic Commerce is a polysemic term, but it is also an emerging reality. A reality in which concerns and interests of very different types confluence. There are technological, scientific, economic, political interests, and from each of these a different picture of what is and what ought to be electronic commerce results. In this chapter I want to start with such a wide–ranging perspective to be able to sketch a richer picture on agent mediated auctions than the austere one that could perhaps be grasped from the specifics I have been concerned with before in this dissertation.

The picture that could be painted is in no ways simple, and I don't intend to do more than suggest the main strokes. The background is painted with money, the horizon with concrete applications, the details with issues of trust, adoptability and innovation.

Economic interests may be very large, mainly because Internet enables forms of globalization and proximity, of market differentiation and innovation that were simply not existent a few months ago. Estimates of the potential value of this emerging economic reality are available, although their accuracy is questionable. Mostly, I believe, because the degree to which available and emerging technology may generate new business opportunities is difficult to assess. Some of these estimates are based on analysis that ignore fundamental distinctions between radically different market sectors: e.g., retailing *vs.* wholesale procurement, or presume simple multiplicative scaling effects in the use of different technologies, (e.g., on–line retailing *vs.* agent–mediated retailing). But a few figures are beginning to trickle from the market that indicate that the order of magnitude of electronic commerce business is on the higher end of the optimistic forecasts[1].

How much of the potential is developed, how and by whom, will very likely depend on the significant innovations that are brought to the market in the coming years, and the manner in which these innovations are absorbed by that market. I am convinced that agent–based technologies will play a preeminent role in those innovations, and I am also convinced that in the commercial practices that will emerge, agent–mediate market places will be one of these radical innovations. Nevertheless, I am also convinced that if that potential is to be realized, it will need a careful assessment of the specific elements that may favor or deter that absorption.

There are at least four lines of activity that are bringing innovation to electronic commerce, and to which considerable attention have been given. First, most policy documents, and much of concerted efforts seem to address immediate operative concerns. That is the case of the European Commission policy document [29], or Commercenet basic guidelines and pilots and the background policy for the first phase of the US strategy [172]. The likely explanation for this priorization lies in the need to solve the grounding issues of money and property transference. Thus, security of internet based transactions, e-cash, cryptography are obvious targets for policy makers and ready adaptations. They are funda-

[1] A good compilation of many different sources is available in [106], see also [172].

mental for serious electronic commerce, I will not address them here and I will assume they are being properly dealt with elsewhere. Another line of activity is based on the existing efforts on EDI (Electronic Data Interchange), in which catalogueing of goods and services, standardization of identities, codes, units are fundamental tasks. Again this is also a fundamental task that I *assume* will produce adequate standardization of some sort (communication, interaction, entities, identities,...) that may be available for actual trading. A third, and far more significant, line of developments come from the appearance in the internet of *mobile* agents who pull information or purchases, or push options or information. Once again. I will assume these developments are happening and will make available new important tools and resources that may very well be essential for the type of developments I will focus on, but I will not discuss them. Finally there exists another line to which the preceding three contribute, but which I will distinguish from them: virtual marketplaces. That is the only one I will address here, and that only in part.

In very general terms, a *virtual market place* is an electronic location where agents or people may perform economic transactions by exchanging computer–based messages. It may be independent of buyers or sellers, and should probably be better understood as a third party that facilitates trading. It imposes certain conventions on participants that have to do with the *grounding* of transactions (namely, payment and delivery of goods, identities of participants), and somehow imposes a convention for performing the actual transactions (how to offer a good or service, how to purchase a good or service). It should sustain some sort of permanence over time, and should permit transactions under some explicit time periods. I will say it is an *online* market place if it is accessible via a network (public or private), and I will say it is *agent–mediated* if it is on–line and participants *may* be software agents. A virtual market place can become an *actual* electronic market place institution if it adopts a legally acceptable personality, and actual transactions take place through its intervention.

Examples of various types of virtual and actual market places are available on–line. These may range from specialized shops to department stores and malls, and the trading conventions may range from open bargaining to auctions. For example, Kasbah and FM are virtual market places. Amazon Books, AUCTIONLINE are actual market institutions. Kasbah models an open bargaining market place, Amazon is a fixed–price book–store (for the moment), AUCTIONLINE is an auction house. Kasbah and FM are agent–mediated. AUCTIONLINE is, for the moment, purely human–enabled.

In these examples many innovations are present. Although these market places mimic traditional markets in many ways, in many ways these on–line markets deal with a substantially different reality, and new concerns need to be addressed to make them operational, and successful. Coverage, speed and permanence, are three obvious aspects of commercial reality that differ in essential ways between traditional and on–line market places but there are more, and many are subtle. An on–line institution may take advantage of these differences to provide better service, or to differentiate its market share. Likewise, an on–line market place may suffer because of these differences, by drawing an unwanted clientele, facing unexpected competition or failing to uphold assumed or expected trading conventions to mention obvious threats. Innovations, in the above examples, are sometimes direct adaptations of existing technology and practices to the new conditions, but occasionally radical innovations can be observed or devised. Perhaps some of these innovations will prove irrelevant or costly, but ideally, some will prove critical in providing a competitive advantage or survival skills to the on–line institutions. I would like to speculate on both, but I will have to confine my analysis to on–line auctions. Careful analysis of the new conditions, of the enabling innovations and the venues for other innovations is, I believe, not only an interesting endeavor, but one that may prove valuable in practice.

8.1.1 On–line auctions

I will examine on–line auctions and, in particular, agent–mediated auctions. I will start by taking the dialogical intuitions I developed in Chapter 4 and some of the distinctions I established in Chapter 7 to characterize auction houses as a special type of institution, and then examine existing on–line auctions. The first part will be more technical, the second is casuistic.

Institutions and auction houses

An auction house (as discussed in Section 4.2, above) can be thought of as a certain type of institution that establishes explicit conditions on the way participating agents negotiate the price (through bidding) of certain goods that are inscribed in a catalogue. I will try to make the underlying notions more precise in the following paragraphs (I make these notions formal in Chapter 10).

Notion 8.1 (Institution) *An Institution will be an entity that coordinates agent*[2] *interactions by establishing and enforcing three types of conventions:*

1. ***Ontological and communicational conventions****: in the form of a* dialogical framework *which states the objects, actions and commitments that are subject to interaction, coordination, negotiation,... within the institution.*

2. ***social conventions****: in the form of a* performative structure *that regulates the way agents (and participants) may interact among each other and the institution while performing the actions that the institution is intended to articulate.*

3. ***individual rules of behavior****: that regulate the behavior of different types of participants while they act within the institutional domain.*

[2]In this subsection I will use *agent* to mean a software agent or a person who acts in an institution according to a role

Notion 8.2 (Market place) *A market place is an institution where* ***buyers*** *and* ***sellers*** *exchange* goods*, according to shared* ***trading conventions****, possibly with the mediation of house* ***staff****. Buyers and sellers are subject to* ***eligibility conventions*** *that determine their admission and permanence in the market place, as well as those guarantees and resources (legal, financial or otherwise) required for the proper accomplishment of the trading that happens in that market place. The institution* ***enforces*** *these trading and eligibility conventions.*

A market is an ***on–line*** *market, if it is located in a stable electronic address an trading can be accomplished through network–based message exchanges.*

An on–line market is ***agent–mediated*** *if software agents can participate as buyers, sellers or staff agents.*

Notion 8.3 (Auction House) *An auction house is a market place that involves* ***buyers****,* ***sellers*** *and* ***staff*** *agents. These participants exchange* ***goods*** *through* bidding rounds *which are subject to* auctioning conventions. *Auctioning conventions make explicit the following features:*

1. *Bidding convention (bidding protocol and its parameters)*
2. *Reception of goods*
3. *Presentation of goods*
4. *Catalogueing*
5. *Revelation of information*
6. *Buyer credit updates*
7. *Other market management conventions (opening and closing times,*

The institution enforces the conventions on buyers and sellers and must guarantee that its staff upholds its corresponding rules of behavior.

An auction house is an ***F–Auction House*** *if it upholds a variant of the Fishmarket conventions like the ones discussed in Chapter 7 (Sec. 7.1).*

Existing on–line auction houses exhibit only partly these proposed components. In most cases, the institutional aspects are only reifiable from common business practice, and even auctioning conventions are only partially made explicit. However, the picture is changing rapidly as will be illustrated in the following paragraphs.

Examples of existing on–line auction houses

The growth of on–line auctions is spectacular. While in May 1996, there were less than 20 hits through an Altavista search (internet and auction), the same search produces in October 1997 over a quarter of a million hits !!!, and in an October 1997 listing by Auction Line there were more than 15,000 auctions registered through them alone. The picture, thus, is moving, and difficult to get at this stage. Well established auction houses like Sotheby's and Christie's, or the chartered American Auctioneers Association, are actively participating in this new medium alongside with what by all evidence seem to be grass–roots family business and ad-hoc one–shot events.

By far the most frequent institution is based on a premise that combines traditional auction conventions with web-based technology, leading to a number of on–line auctions of a **naive** type. These are being used to trade a wide variety of goods: For example, vintage records (Nauck [113]), computers and electronics (Onsale Auctions [122]), art (SevenSeas auctions [153]) objects in general (Auctionline [10],Interauction [81], Phoebus [128].

Buyers and sellers interactions are in most of these cases quite natural and simple:

- Goods –which may be inscribed directly by external sellers Auctionline, Interauction, Phoebus, or otherwise obtained by the auction house– are catalogued and even sometimes displayed –electronically and/or physically– before and during an auction.

- After registering in a given auction –usually a simple e-mail inscription– a buyer can submit his bids either by e-mail (Nauck, Phoebus), by fax (Nauck), by submitting a web-form (Auctionline, Interauction, SevenSeas) or even by post (Nauck).

- Payments are usually through credit cards, and sales are definite up to actual payment, but most of the time the physical transactions (actual payments) are explicitly relinquished by the auction houses. Some sales are defeasible if protested –and properly supported– within a period of time Phoebus, SevenSeas.

- Most service providers adopt a rather primitive sealed-bid *English* auction protocol, Auctionline which has an on-line simplified English auction or similar, (like SSeas, whose only auction format is *Buy or Bid*).

- The evolution of each bidding round is displayed on a browser (Auctionline, Interauction, Phoebus) or sent by e-mail (Auctionline, Interauction, Nauck, Phoebus, SevenSeas to participating buyers.

- In most cases, single bidding rounds are open for an extended period of time –up to a couple of months; the exception is Auctionline that allows for more lively bidding rounds– and terminate on a previously announced closing date, though sometimes the auctioneer determines when a bidding round closes.

- Security is an important concern in some of these applications (Auctionline in particular, handles security by utilizing the Netscape Commercial Server which uses the HTTPS protocol to encrypt bids; whereas Interauction uses a validation code for bidder identification in each auction.

Special attention deserves ONSALE auctions, because it is similar to these naive auction houses in a way, but its success makes it also completely different. ONSALE [122] auctions specializes in computers and electronics, and advertises profusely through net–search services. In contrast with the above mentioned examples, it offers several auction formats (*Yankee auction, Dutch auction, Straight sale, Buy or Bid* and *English Auction*). And while the rest of the auctioning conventions are simple, and similar to those mentioned above (bidding round evolution is displayed in the browser or e–mailed; buyer registration through e–mail and Fax; security, through the commercial server's encryption mechanisms) this auction house is notable for its amazing economic success, due to the sheer volume of transactions it handles.

Another group of on–line auctions takes an existing traditional auction house, and **extends** its services by allowing internet bidding of some sort, or under special conditions. That is the case, for example, of Australia's Woolnet [191], which takes its automated in–house auction (which started in the early sixties [22]) and is now available through an Intranet, and partially available also via Internet. Legacy technological conventions and practices are being rapidly upgraded (as can be gathered through the evolution of the webpage in the past months) to extend the market coverage and specialize further the existing standard auctions. *Sotheby's*, on the other extreme, is an illustrative example of a far more restrained extension strategy. Its rich webpage, [163], provides information on all its current activities. It also details information on procedures and house auctioning conventions, in far greater detail than any of its traditional competitors (e.g. *Christie's*, *Phillips*). But it does not, yet, allow for internet based bidding. Not even absentee bids, which are still only possible through mailed request and validated telephone calls (as has been the practice for many years). Such positioning is perhaps indicative of a cautious strategy in which the diffusion and communication advantages of Internet are immediately profited, but the risks and opportunities of an extended transaction volume are avoided. One can argue that this caution is excessive, but I prefer to think that Sotheby's understanding of the finer aspects of auction house institutional commitments are overriding any windfall profiting schemas.

A different group is formed by what may be called **complementary auctioneering**. These are auctions sponsored by companies who find auctioning to be a convenient price–setting mechanism that complements their conventional trading practices. An interesting example of this type is *American Airlines' Internet Silent Auction* [4]. In it, a *real time* upward, price–quoting, electronic closed bid, with multiple chance, fixed bidding opportunity periods, is available for on–line purchase of round-trip airline tickets. Payment is through credit cards, and delivery is made through the standard airline company channels. A simpler technological infrastructure, but in a sense more innovative, is the way *Lego*, (the toy factory) sponsors auctions for used lego sets and parts among clients (presumably parents) and distributors [96]. While AA's auctions are intended for human participants (at least for the moment), Lego's are clearly geared towards automated or semi–automated bidding for seller activated auctions which have to submit to "popular" auctioning conventions. Institutional aspects, however, in this case are difficult to assess.

Finally, *Agorics* deserves also a specific comment. This company, which appears to be an auction enabler draws from its own experience in classical e–commerce grounding projects and its apparent closeness to Wellman's *Auction Bot* project to propose full–fledged auction conventions for the construction of on–line market places of different sorts. Its webpage is not too revealing of what the business project is, but it indicates marketing, technological and business skills that appear to be superior to other on–line auction companies.

Other forms of on–line auctions have been developed recently. On one hand, there are actual auction simulation environments like FCC (Cf. [13, 98]), whose purpose is to train bidders, or to test innovative bidding protocols and trading mechanisms. Additionally, on–line auctions have been used as coordination mechanisms in market-oriented programming (*cf. e.g.* [146, 170, 182]). Although these developments have many points of contact with the Fishmarket project, a full comparison, as indicated in Chapter 2, is beyond the scope of this dissertation.

8.2 Feasible Applications

Could fish be sold through Internet? Yes. But many changes should be made to the Fishmarket institution as it stands or to the Blanes current practice to make either of them operational on line. Moreover, I think it unlikely to be as successful or as immediate as other applications of agent mediated auctions. Nevertheless I will venture a few comments:

There are indications that some people think it is worthwhile exploring the possibility of having on-line fish auctions. Two on–line fish market offers have recently appeared: The Seafood Exchange and FISHROUTE. And –in addition to the discouraging interaction started with this chapter's epigraph message– we have been getting sporadic requests for information and at least two *bona–fide* collaboration proposals for automating fish market practices.

The Seafood Exchange [148] is an electronic exchange board where offers and requests are manually matched. Infrastructure appears to be in place to have an interactive trading floor and even auctions. Suppliers from around the world may participate, and the current page shows a wide–spread constituency, although still modest in size.

FISHROUTE, [51] on its part, seems to be more of a personalized advisory service for local fish markets. It nevertheless offers the possibility of a simulated fish auction and promises the actual development of one.

Albeit these two examples to the contrary, in my opinion, the more reasonable way to address an on–line version of the fishmarket would be by an Intranet evolution of existing auction houses, which may extend geographically the access to the auction hall only to well accredited buyers. A second step may involve Internet based bidding from remote locations, once the practice is assimilated by the naturally skeptic community, and then only for non-first markets.

A primary first market (like the one in Blanes) where a local fleet sells to local merchants at top price is very unlikely going to benefit from a globalized auction (although a carefully devised extension may be feasible and probably advisable). However, massive generic markets for whole fleets or regional secondary markets may be real candidates for a global automation keeping in mind that the distinctive features of an auctioning convention may be conducive to vivacious bidding only if high speed delivery is also guaranteed or, more interesting, if on the ship selling is achieved. Evidently, the problems of catalogueing, quality control, logistics and enforcement of grounding conventions are tremendous. In light of a more vertically integrated intermediation —something that is suggested by the *Seafood Exchange* model, and is also an expressed possibility in Catalunya— auctioning may very well prove to be a convenient and effective price–setting mechanism in a chain with intense bursatility and volatile supply.

Thus, I would be cautious in forecasting any quick developments here, but one should keep the options open.

I am much more confident in terms of the immediate applicability of global auctioning in other markets though. Mainly because agent–mediated trading would make these markets far more effective. Three I will comment here: Long Distance telephone contracting by government, public procurement and financial liquidation of collateral. The last two are actual projects in course in Mexico, with which I have had some acquaintance. The first one was at some time considered in Mexico, and has now been postponed there, but as I will show is amenable for any derregulated national–wide market.

Public Procurement Last year, the Mexican Federal Government started a carefully designed plan for public *on–line* tendering (and, eventually, procurement) of all its contracts for acquisition of goods, services and construction. Project *Compranet* [32] was designed as part of the Information Technologies Strategic Plan to incorporate IT into small and medium companies [107]. The Mexican Federal Government constitutes a large demand base for goods and services, and it is regulated in such a way that all acquisitions are made through a form of sealed bid auction. Through *Compranet* it is now possible, and will eventually be mandatory, to announce all call for tenders via Internet. It is now also possible to submit tenders by Internet. Existing legislation was adapted to contend with the some technological issues (bonding and signatures, mainly) and the Federal Comptroller Office supervises and manages the on–line tendering. In fact, *Compranet* started as a Federal Government procurement system that has now been adopted by some State Governments, *and* is available for any other purchasing organization. Local and national Chambers of Commerce and Better Business Bureaux, as well as Notary Publics and Banks are an integral part of the project and act as institutional mediators to guarantee identities and facilitate access when needed. Independent third parties, software developers and system integrators have been developing value–added tools and contents to the nuclear system, and a network of service organizations has spawned.

The impact is enormous, and can be applied in other places as well. A similar conception has been advocated as part of the Bangemann challenge in the European Union, although no such on-line procurement mechanisms are (to my knowledge) available yet. The *Compranet* project has been in operation since August of 1996 and is systematically incorporating more and more functionality. It is now feasible to introduce different purchasing conventions –not only closed sealed bid— through the same uniform, universally accessible, nation–wide Federal Procurement system. Agent–based tools for data–mining, supervision and auditing are part of the original design. Agent–mediated procurement, and negotiation are likely developments.

Telephone bids Another particularly attractive example of a rather natural agent–mediated auction market is the public auctioning of long distance telephone carriers. An agent–mediated on–line auctioning convention was seriously considered by the Mexican Government at the beginning of this year, although for the moment a standard sealed–bid tendering has been adopted.

The situation is as follows. Now that nine long-distance telephone carriers offer their services (and infrastructure) in Mexico, national and international long distance calls can be contracted with any or all of these. The Mexican Government devised a contracting schema by which every semester the long distance service of the Federal Government offices in 70 cities is adjudicated to the best offer. The Federal Government can split its demand in different ways (so that a single city or a region may be served by more than one carrier), and suppliers should offer flat rates for national, North–American and world–wide calls, under identical conditions of quality and service.

The composition of the auction lots, the frequency of the auction dates and the possibility of changing market conditions make this problem specially amenable for an internet based deployment, and attractive as well for the appearance of tools and resources for bidding and for lotification. The problem will very likely be present in other countries in the near future.

Collateral liquidation A third mexican example is also at hand. It is the liquidation of collateral of defaulted loans which the Mexican Government took over from commercial banks as a healing measure after the financial crisis of 1994. The large volume and the diversity of the collaterals, and the need for transparency and efficiency, make it highly advisable to conduct a world–wide auctioning which unless it is Internet based it would hardly be feasible in speed and security. The first auction took place in early July. Liquidation of the collaterals is expected to take over three years under standard auctioning conventions.

8.3 Remarks on Applicability

Relevant Features The illustrative examples and the characteristics of existing on–line auctions provide some indication of features one should consider before constructing a commercial agent–mediated auction house, or on deciding the type of auction or the the type of goods that are conducive to a successful endeavor. In this section I will list the ones I find more relevant.

1. **Ontology** One has to decide what *type of goods* or services are going to be auctioned. The choice will depend on the clientele as much as the degree of differentiation that is needed or feasible, as in regular auctions. But for agent–mediated auctions the referential grounding of the incumbent goods and services becomes more relevant. Thus unless appropriate means for identification, delivery and property transferral are available, some familiar auctionable goods may be unadvisable for agent–mediated auctions.

2. **Social Issues** Aspects such as *presence* of buyers and sellers (length, feasibility, willingness, competitive pressure); *diffusion and coverage* of the auction call and participation (recall Sotheby's reticence).

3. **Performance** Type of protocol and the quality of the implementation. Speed of rounds. Robustness of the process. Fault–tolerance. Advantages and disadvantages of dedicated links and Intranets.

4. **Fairness** Conditions like unwanted or unavoidable time–delays, uneven opportunities, discretionality on auction house staff. Aspects that should not or may not be regulated.

5. **Exploitation** Supplantation of participants by malicious participants, misrepresentation, posturing as market. Predictivity of agent heuristics or strategies.

6. **Trust** What features increase it, what features affect it. Privacy as a way of accruing trust, and how to guarantee and protect privacy. Deception, falsehood, unkept promises, unkeepable promises. Features that increment confidence, and accidents that may break it.

Remarks on Tools In a similar fashion I will enumerate some issues that appear to be relevant with respect to the tools needed for an agent–mediated auction house.

1. **Auctioning Environments**

   (a) **Admission**. Functionality of admission is complex. Depending on the type of auction, two-phase, or screening mechanisms might become valuable.

   (b) **Practice**. To inspire confidence, in some auction houses having simulated auctions or non–committing auctions for practicing might be advisable, specially for vivacious or high-value auction. For training agents it will be absolutely necessary.

(c) **Explicit Conditions**. As part of the contract or the admission requirements.

(d) **Auditability**. Of the auction house, of every auction, of every staff decision, and of client interactions as well.

(e) **Third party management**. It is conceivable that some basic auction-house–building tools become available and that professional auctioneers or already institutionalized auctions use such software to expand their current business in the net. Just as likely new auction markets will start demanding such enabling resources.

(f) **Certifiability**. Of sites, of governors and nomadic interfaces. On specific and generic characteristics (fairness, responsiveness, tightness).

(g) **Public Code of Conduct**. Agent–mediated auction houses might eventually need to become part of supranational organizations and submit to a public code of conduct and charter of service. Both to inspire confidence, but also to be protected.

2. **Software agents**

   (a) **Ergonomic Features**. Trading agents have to be intelligible to users, reliable, and trustworthy.

   (b) **Safety**. In addition, they have to be able to guarantee that information transference to and from the market is as tight as should be. Thus if privacy, income or property are at hand, leakages, contamination, corruption of messages (or their loss) are hardly acceptable. It may need to be encryptable, should preserve identities well and these properties may eventually ought to become legally binding.

   (c) **Unpredictability**. Unless there is a high turn-over of participants, trading agents are at risk of becoming predictable to rivals, who may then exploit or outperform them systematically.

   (d) **Agent developers**: To produce templates, heuristics, data–mining tools, packaged traders, analytic strategies, add–ons.

3. **Needed Developments**

   (a) **Flexible Environments**. To define new auction houses, and new auctioning conventions, based in the type of features economists claim to be adequate for specific purposes. With the corresponding tools and practices.

   (b) **Standards**. Of performance, security, identity, good description, delivery, payment.

   (c) **Markets**. Actual goods, sellers and buyers. Creation of new markets, invention of new applications.

8.4 A Closing Remark

Technology is at hand to produce new innovations. What form these innovation will finally take is difficult to assess. However, it is not unlikely that the mimetic quality of these agent mediated markets will inspire confidence in users, and developers, to consolidate the speculative projects that are beginning to appear.

If prototypes and experiments are to survive, though, the delicate issue of trust will need to be properly dealt with. For that purpose, classical tools such as contracting and bonding are available, but will need to adapt —cleverly and rapidly— to the new realities of presence, individuality, representativity, agency,... that software agents bring. New forms of deceit an fraud will inevitably appear if incentives to cheat exist. Fraud and deceit can be dealt technologically but only to a point, it it is important to make clear just how far one can trust the new institutions and the new intermediaries that are emerging. Unless clear and reliable forms of validation of behavior, of confinement of interaction, of regulation enforcement are developed, tested and certified, the immense promise of the markets that are to be invented may fizzle. The scientific and technological challenge is big, the opportunity is even greater.

Chapter 9

Argumentation-based negotiation

Nasr Eddin, sur la question du douaire de sa deuxième femme, s'oppose à son beau–père, qui estime de son côté trop petit le mahr légal et menace son gendre de faire frapper de nullité le mariage, comme l'y autorise la jurisprudence.
Aucun compromis amiable n'intervenant, on finit par aller devant la justice.
Le juge entend les deux partis puis, les jeux mi–clos, se met à méditer sa sentence.
En fait, il observe le comportement de Nasr Eddin et de son beau–père. Le Hodja s'en aperçoit et s'empresse alors de montrer discrètement du doigt son caftan, sous lequel est caché on ne sait quoi, mais sans nul doute y a–t–il là quelque pot–de–vin. Manifestement la partie adverse ne s'est pas entouré de la même garantie...
Après mûre réflexion, le magistrat rend son arrêt: non seulement le mariage est valable, mais encore une partie du mahr doit être remboursée à Nasr Eddin.
Le beau–père quitte alors le tribunal, furieux et amer. Quand le gendre et le juge restent en tête à tête, le second demande au premier:
— N'ai–je pas rendu un jugement impartial, Nasr Eddin? Allons, fais moi voir ce que tu m'as apporté.
Nasr Eddin entrouvre son caftan et lui montre qu'il y a placé deux grosses pierres.
— Par Allah ! s'étonne le cadi, ce ne sont quand même pas des pierres que tu comptais m'offrir?
— Certainement non, cadi, je les remporte chez moi. Simplement, je te les aurais jetées a la tête si ton jugement m'avait donné tort![1]

It is now time to turn away from auctions and look into other forms of agent interaction. Keeping up with the dialogical stance I assumed since Chapter 4, I will now take a look at another form of *coordination dialogue*, that of negotiation. Again, as was the case in auctions, the point of the dialogical interaction is for intervening agents to agree on a certain *course of action.* If forced co–operation is designed into a multi agent system, and that co–operation could only proceed through standardized sequences of action, negotiation would not be required, but because the co–operation of other agents cannot be guaranteed in many

[1]Sublimes paroles et idioties de Nasr Eddin Hodja. Recueillies et presèntées par Jean–Louis Maunoury. Phébus, Paris, 1990. P. 79

systems, or because co–operation requires certain conditions to be agreed upon before it can take place, negotiation (of different types) happens to be a common need in multi agent systems.

In this chapter I will present a dialogical model for *argumentation–based negotiation*, a form of negotiation in which participating agents have to *persuade* their counterparts of a specific course of action, and they do so by advancing "arguments" in favor or against that course, or proposing alternatives and arguing for them.

The model has many features in common with the Fishmarket institution: a dialogical framework that captures contextual elements that are shared by participants, a set of social conventions that take the form of a protocol and individual rules of behavior that govern the basic interpretation and utterance of illocutions. But differences are worth pointing out too. First, notice that the dialogical framework here involves different elements than the ones needed for auctions. Second, notice that there is a single scene. And notice also that this being a less structured form of interaction, negotiating agents have to choose illocutions and react to their opponent's utterances always on deliberative terms, while in the Fishmarket that had to be the case only for bidding. Thus, in this case more attention needs to be given to the individual aspects of the agent architecture to enable it to engage in this form of negotiation.

The exercise is interesting because these similarities and differences facilitate a generalization of the underlying concepts to more general agent–mediated institutions. But it is also interesting because it shows that the dialogical stance is applicable to a superficially different type of interaction. It is a nice example of a complex dialogical process in which some illocutions deal with action coordination, and others with modification of beliefs, and both can be made to fit neatly into the same basic framework we needed for the Fishmarket.

This chapter is a superficial revision of [157], of which Carles Sierra, Nick Jennings and Simon Parson were coauthors. Some additional ideas that were intended for a longer version of the article —and so noted in the original version– have been slightly elaborated for this revision and I have also modified the introductory and closing remarks to show the relevance of this negotiation framework to the rest of the dissertation, but the overall content of this chapter is essentially the one originally developed with Sierra, Jennings and Parsons, I would like to gratefully acknowledge their permission to use it here.

9.1 Introduction

Negotiation is a key form of interaction in systems composed of multiple autonomous agents. In such environments, agents often have no inherent control over one another and so the only way they can influence one another's behavior is by persuasion. In some cases, the persuadee may require little or no convincing to act in the way desired by the persuader, for example because the proposed course of action is consistent with their plans. However, in other cases, the persuadee may be unwilling to accept the proposal initially and must be persuaded to change its beliefs, goals or preferences so that the proposal, or some variant thereof, is accepted. In either case, the minimum requirement for negotiation is for the agents to be able to make proposals to one another. These proposals can then either be accepted or rejected as is the case in the contract net protocol [161], for instance. Another level of sophistication occurs when recipients do not just have the choice of accepting or rejecting proposals, but have the option of making counter offers to alter aspects of the proposal which are unsatisfactory (e.g. [155]). An even more elaborate form of negotiation—argumentation-based—is that in which parties are able to send justifications or arguments along with (counter) proposals indicating why they should be accepted (Cf. e.g. [95, 125, 166]). Arguments such as: "this is my final offer, take it or leave it", "last time this job cost £5, I'm not going to pay £10 now", and "the job will take longer than usual because one of the workers is sick" may be necessary to change the persuadee's goals or preferences.

This model deals with argumentation-based negotiation. Because it is a large research topic (Cf.[90, 181]) the scope is limited to argumentation between computational agents where a persuader tries to convince a persuadee to undertake a particular course of action on its behalf. The components of a formal model for the process of argumentation-based negotiation which can ultimately be used to build negotiating agents for real world applications are here outlined. The emphasis of this model is on the social aspects of the negotiation. Moreover, it takes advantage of the work on Dialogical Frameworks introduced in [120] and elaborated in Chapter 4 to define the static aspects of the negotiation process: shared ontology, social relations, communication language and protocol. The model defines a minimal notion of the *state* of an agent which captures the evolutionary character of negotiation—enabling the resulting model to recognize different types of arguments that agents can make in support of their proposals. Finally, it is indicated how these arguments can be generated and interpreted by agents.

The model involves three types of illocutions: (i) *threats*—failure to accept this proposal means something negative will happen to the agent; (ii) *rewards*—acceptance of this proposal means something positive will happen to the agent; and (iii) *appeals*—the agent should prefer this option over that alternative for this reason. Evidently, these are a subset of the illocutions that are involved in persuasive negotiation (see [90] for a list based on psychological research), but the emphasis, again, is in providing an ample framework in which the key components of argumentation can be described, rather than providing an exhaustive formalization of all the argument types which can be found in the literature. These constructs are illustrated through a running example introduced in the following section. The main contribution of this work is, therefore, to provide a formal framework in which agents can undertake persuasive negotiation to change each other's beliefs and preferences using an expressive communication language. Moreover, the framework is neutral with respect to the agent's internal architecture and imposes few constraints on its formal resources.

9.2 Argumentation in Practice

This section describes the scenario which will be used to illustrate the principles and concepts of the dialogical model of argumentation. The scenario is motivated by work in the ADEPT project [86] which has developed negotiating agents for business process management applications. In particular, it considers a multi-agent system for managing a British Telecom (BT) business process—namely, providing a quotation for designing a network which offers particular services to a customer (Figure 9.1). The overall process receives a customer service request as its input and generates as its output a quote specifying how much it would cost to build a network to realize that service. Here only a subset of the agents involved in this activity is considered: the customer service division (CSD) agent, the design division (DD) agent, the surveyor department (SD) agent, and the various agents who provide the out-sourced service of vetting customers (VC agents). A full account of all the agents and their negotiations is given in [155].

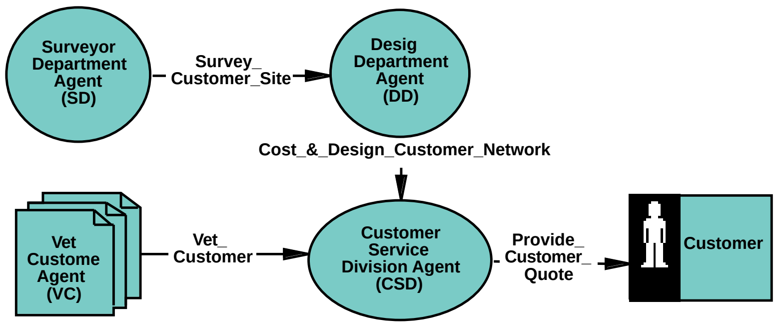

Figure 9.1: Agent system for BT's "*Provide_Customer_Quote*" business process. The direction of the arrow indicates who provides the service labeling the arrow to whom.

The first stages of the Provide_Customer_Quote service involve the CSD agent capturing basic information about the customer and vetting the customer in terms of their credit worthiness. The latter service is performed by one of the VC agents and negotiation is used to determine which one is selected. If the customer fails the vetting procedure, then the quote process terminates. Assuming the customer is satisfactory, the CSD agent maps their requirements against a service portfolio. If the requirements can be met by a standard off-the-shelf portfolio item then an immediate quote can be offered based on previous examples. In the case of bespoke services the process is more complex. The CSD agent negotiates with the DD agent for the service of costing and designing the desired network service. To prepare a network design it is usually necessary to have a detailed plan of the existing equipment at the customer's premises. Sometimes such plans might not exist and sometimes they may be out of date. In either case, the DD agent determines whether the customer site(s) should be surveyed. If such a survey is warranted, the DD agent negotiates with the SD agent for the

Survey_Customer_Site service. This negotiation differs from the others present in this scenario in that the two agents are part of the same department. Moreover, the DD agent has a degree of authority over SD. Agent negotiation is still required to set the timings of the service, but the SD agent cannot simply refuse to perform the service. On completion of the network design and costing, the DD agent informs the CSD agent which informs the customer of the service quote. The business process then terminates.

The precise nature of the argumentation which can occur in the aforementioned negotiations is determined by three main factors: (i) the negotiation arity—pairwise (1 to 1) negotiations (e.g. the CSD and DD agents for the design network service) differ from 1 to many negotiations (e.g. the CSD and VC agents for the Vet_Customer service); (ii) the power relations (Castellfranchi [23]) between the negotiators—most negotiations are peer-to-peer, but the DD and SD negotiation over the Survey_Customer_Site service is an example of boss-to-subordinate negotiation; and (iii) the organizational relationship of the negotiators—some negotiations are between agents of the same organization (e.g. the CSD, DD and SD agents), while others are between agents of different organizations (e.g. the CSD and VC agents). Experience in the domain shows that the argumentation between agents can be captured by the three types of argument mentioned in the Introduction—threats, rewards and appeals. Some examples of such arguments are given in Table 9.1.

9.3 Negotiation model

This model describes the process of a single encounter negotiation between multiple agents over a deal. Deals are always between two agents, though an agent may be engaged simultaneously in negotiation with many agents for a given deal. Negotiation is achieved through the exchange of illocutions in a shared communication language CL. The actual exchange of illocutions is driven by the participating agents' *individual* needs and goals—something that will not be part of this negotiation model. Nevertheless, this exchange is subject to some *minimal shared conventions* on the intended usage of the illocutions in CL, and a simple negotiation protocol. These conventions relate to:

1. The elements that are relevant for the negotiation of a deal—in the form of *issues* and *values* that may evolve as negotiation proceeds.

2. The rationality of the participating agents—in terms of some form of preference relationships or utility functions which enable the agents to evaluate and compare different proposals.

3. The deliberation capability of the participating agents—in the form of an internal *state* in which the agent may register the history of the negotiation as well as the evolution of its own theoretical elements on which its decisions are founded.

Type	Id	Parties	Content	Comments
Threaten	1	CSD-VCs	Match the offer I have from another VC, otherwise I'll break off this negotiation.	Threaten to terminate current negotiation thread.
	2	CSD-VCs	Make sure you get back to me in the specified time period or I won't involve you in future rounds of bidding.	Threaten to terminate all future negotiation threads.
	3	DD-SD	If you cannot complete the service sooner, I'll inform your boss that we missed the deadline because of you.	Threaten to inform outside party of (perceived) poor performance.
Reward	4	CSD-DD	If you produce this design by this time we'll be able to get the quote to our major customer ahead of time.	Indicate positive effect of performing action by specified time.
	5	CSD-VCs	If you vet this customer by this time, I'll make sure you're involved in subsequent rounds of bidding.	Promise future involvement for accepting current proposal.
Appeal	6	CSD-VCs	Last time you vetted this customer, it took this length of time and cost this much.	Appeal to precedent.
	7	CSD-DD	You must complete this design within 48 hours because company policy says customers must be responded to within this time frame.	Appeal to (company's) prevailing practice.
	8	VC-CSD	This customer may be in financial trouble, therefore more time is needed to carry out a higher quality vetting.	Appeal to (CSD's) self interest.
	9	DD-CSD	The design will take longer than normal because one of our surveyors is on holiday this week.	Revealing new information.
	10	SD-DD	Customer has many premises and they all need to be surveyed, thus this service will take longer than normal.	Revealing new information.

Table 9.1: Sample arguments in the BT application.

4. The minimal shared meaning of the acceptable illocutions—this is captured in the way that a *received* illocution should be interpreted when heard by an agent, and by making explicit the conditions that enable an agent to use (or 'generate') a given illocution at a given time.

A minimal set of concepts which are necessary to represent the static components in automated negotiation are presented in Section 9.3.1, and the dynamic components—the concepts of a negotiation thread and a negotiation state—are introduced in Section 9.3.2. Social aspects that are relevant for persuasive arguments are dealt with in Section 9.3.3, and the process of interpreting and generating illocutions is illustrated in Section 9.3.4.

9.3.1 A Basic Negotiation Ontology

Negotiation requires communication between the agents and, for it to be unambiguous, each agent must have a unique identifier. We denote the set of identifiers of the agents involved in a negotiation as $Agents$[2]. The agents involved in a negotiation will have a variety of social relationships with one another. These relationships have an important impact upon the persuasion and argumentation process. For instance, prestigious speakers have a large persuasive impact and peers can be persuaded more easily than non-peers [90]. To model this characteristic, we assume that a general and shared social relation is defined between the agents. This relation can be modeled as a binary function over a set of social roles, denoted as $Roles$. In the BT scenario, for example, $Roles$ would be: $\{Customer, Contractor, Boss, Peer\}$. Finally, we assume that agents, when negotiating, interchange illocutions in a common communication language CL defined over a set of illocutionary particles whose propositional content is expressed in a shared logical language L[3]. The precise nature of L is unimportant in our model (e.g. it could be a propositional language or a modal language), however it must contain at least the following:

1. *Variables.* To represent the issues under negotiation. They have to be variables because issues need to be bound to different values during negotiation.

2. *Constants.* To represent values for the issues under negotiation. A special constant '?' is needed to represent the absence of value, and allow for underdefined proposals between agents. (Note this constant does not mean "don't care".)

3. *Equality.* To specify the value of an issue under negotiation.

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[2]In practice, this set may change dynamically (e.g. new vetting companies may be created and old ones may disappear). However, since this process can be seen as independent from the negotiation process, our model is presented with respect to a fixed set.

[3]In practice, agents often have heterogeneous information models and so need to use one of the variety of techniques for allowing them to interoperate (see for example, [60, 69]). However, in this work we adopt the simplest solution and assume a common language.

4. *Conjunction.* To define complex sentences.

All of these features are necessary to express the kinds of sentences involved in the negotiation proposals discussed in this paper. An example of such a sentence is:

$$(Price = £10) \wedge (Quality = High) \wedge (Penalty = ?)$$

where '*Price*', '*Quality*', and '*Penalty*' are the issues under negotiation and so are represented as variables; '£10', '*High*', and '?' are values for those issues and so are constants; '=' denotes equality; and '∧' denotes conjunction. However, the language defined so far is not expressive enough to describe everything that is involved in a negotiation. In particular, to 'reason' and 'argue' about offers it is necessary at the very least to have some way of expressing preferences between offers. Offers are formulae in L, hence the most obvious way of representing preferences between formulae would be as a second-order relation in L. However, this would mean that L would be a higher-order logic, with the associated computational problems of such logics (Cf. Goldfarb [64]). As a result we prefer to express preferences as a meta-language ML with the following minimum requirements:

1. *Quoting functions.* To represent formulae in L as terms in ML.
2. *A preference meta-predicate.* To express preferences between formulae in L.

For example, given the sentences $Price = £10$, and $Price = £20$ in L, we can express a preference for the first over the second as:

$$Pref(equal(\lceil Price \rceil, \lceil £10 \rceil), equal(\lceil Price \rceil, \lceil £20 \rceil))$$

where '*equal*' is the quoting in ML of the predicate '=' in L, and '*Pref*' represents the preference meta-predicate. In the remainder of the paper, instead of writing $equal(\lceil Price \rceil, \lceil £10 \rceil)$ the more compact representation $\lceil Price = £10 \rceil$ is used.

The common communication language, CL, accounts for the set of illocutionary particles necessary to model the set of illocutionary acts we study in this paper. The acts can be divided into two sets, I_{nego} corresponding to negotiation particles (those used to make offers and counter offers) and I_{pers} corresponding to persuasive particles (those used in argumentation). $I_{nego} = \{\texttt{offer}, \texttt{request}, \texttt{accept}, \texttt{reject}, \texttt{withdraw}\}$, $I_{pers} = \{\texttt{appeal}, \texttt{threaten}, \texttt{reward}\}$. Other illocutions could conceivably be brought into CL but the present set is sufficient for our purposes.

The negotiation dialogue between two agents consists of a sequence of offers and counter offers containing values for the issues. These offers and counteroffers can be just conjunctions of '*issue* = *value*' pairs (`offer`) or can be accompanied by persuasive arguments (`threaten`, `reward`, `appeal`). 'Persuasion' is a general term covering the different illocutionary acts by which agents try to change other agent's beliefs and goals. The selection of three persuasive particles in the set I_{pers} is the result of an analysis of the domain, as explained in Section

9.2, as well as of the persuasion literature (for example, [90, 166]). `appeal` is a particle with a broad meaning, since there are many different types of appeal. For example, an agent can appeal to authority, to prevailing practice or to self-interest [166]. The structure of the illocutionary act is $\texttt{appeal}(a, b, \xi, [not]\varphi, t)$, where φ is the argument—a formula in L or in ML, or an illocution in CL—that agent a communicates to b in support of a formula ξ (which may be a formula either in L or ML). All types of appeal adhere to this structure. The differing nature of the appeal is achieved by varying the φ in L or ML or by varying $[not]\varphi$ in CL—*not* φ is understood as the fact that action φ does not take place. `threaten` and `reward` are simpler because they have a narrower range of interpretations. Their structure, $\texttt{threaten}(a, b, [not]\psi_1, [not]\psi_2, t)$ and $\texttt{reward}(a, b, [not]\psi_1, [not]\psi_2, t)$ is recursive since formulae ψ_1 and ψ_2 again may be illocutions in CL. This recursive definition allows for a rich set of possible (illocutionary) actions supporting the persuasion. For instance, agent DD can threaten agent SD that it will inform SD's boss about SD's incompetence if SD does not accept a particular deal:

$$\texttt{threaten}(DD, SD, not\ \texttt{accept}(SD, DD, time = 24h, t_2),$$
$$\texttt{appeal}(DD, Boss\_of\_SD, SD = incompetent,$$
$$not\ \texttt{accept}(SD, DD, time = 24h, t_2), t_3), t_1)$$

Having introduced all the components, we can now describe our dialogical framework for persuasive negotiation.

Definition 9.1 *A* Dialogical Framework *is a tuple* $DF = \langle Agents, Roles, R, L, ML, CL, Time\rangle$*, where*

1. *Agents is a set of agent identifiers.*
2. *Roles is a set of role identifiers.*
3. $R : Agents \times Agents \rightarrow Roles$*, assigns a social role to each pair of agents. Social relations can therefore be viewed as a labeled graph.*
4. *L is a logical language*[4] *satisfying the requirements mentioned above.* $Deals(L)$ *denotes the set of all possible conjunctive formulae in L over equalities between issues and values, i.e.* $x_1 = v_1 \wedge ... \wedge x_n = v_n$*.* $Deals_{?-free}(L) \subset Deals(L)$ *excludes '?' as an acceptable value in a deal.*
5. *ML is a metalanguage over L satisfying the requirements mentioned above.*
6. *CL is the language for communication between agents. Given* $a, b \in Agents$ *and* $t \in Time$ *it is defined as:*
   (a) *if* $\delta \in Deals(L)$ *then* $\texttt{request}(a, b, \delta, t) \in CL$*.*
   (b) *if* $\delta \in Deals_{?-free}(L)$ *then* $\texttt{offer}(a, b, \delta, t)\texttt{accept}(a, b, \delta, t)$*,* $\texttt{reject}(a, b, \delta, t) \in CL$*.*

[4]In keeping with the spirit of specifying a framework which is neutral with respect to the agent architecture, no commitment to any specific formal language is made but note that L could be as simple as a propositional language or as elaborate as a multi-modal BDI logic [94, 136].

(c) withdraw$(a,b,t) \in CL$.

(d) *if* $\psi_1, \psi_2 \in CL$, $\xi \in L \cup ML$, *and* $\varphi \in L \cup ML \cup CL$ *then* threaten $(a,b,[not]\psi_1,[not]\psi_2,t)$, reward$(a,b,[not]\psi_1,\ [not]\psi_2,t)$, appeal$(a,b,\ \xi,\ [not]\varphi,t) \in CL$.

7. *Time is a discrete totally ordered set of instants.*

Note that the time stamp, which appears as the last argument in all illocutions, will be omitted when there is no ambiguity.

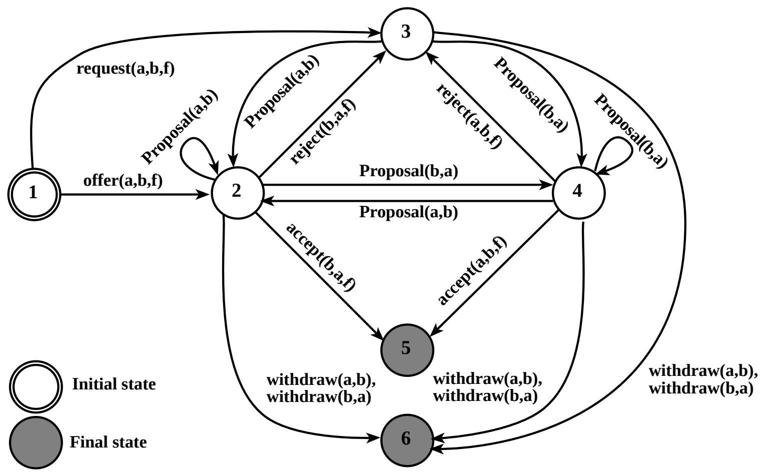

Figure 9.2: Negotiation protocol. In accept(x,y,φ) and reject(x,y,φ) illocutions φ always refers to the last proposal. $Proposal(x,y)$ stands for any illocution constructed with any of the following particles: offer, threaten, reward, appeal, and between agents x and y. Time stamp in the illocutions is omitted.

Agents can use the illocutions in CL according to the following negotiation protocol (see Figure 9.2):

1. A negotiation always starts with a *deal proposal*, i.e. an offer or request. In request illocutions the special constant '?' may appear. This is thought of as a petition to an agent to make a detailed proposal by filling the '?'s with defined values.

2. This is followed by an exchange of possibly many counter proposals (that agents may reject) and many persuasive illocutions.

3. Finally, a *closing* illocution is uttered, i.e. an accept or withdraw.

9.3.2 Negotiating agents

The Dialogical Framework and the interaction protocol described in the previous section represent the shared contextual components of the negotiation model—those that are fixed for all negotiations. This section presents the individual dynamic elements—those that change as a particular negotiation proceeds—that are needed for a minimally shared interpretation of illocutions.

Although this model aims to be as neutral as possible about the agent architecture, in order to capture essential aspects of persuasion it is necessary to assume that the agents have memory and are deliberative. Memory is expressed by means of an evolving *negotiation state* which, in turn, requires the notion of a *negotiation thread* (see [111]) to capture the history of the negotiation dialogue between a pair of agents.

Definition 9.2 *A* **Negotiation Thread** *between agents* $a, b \in Agents$*, at time* $t \in Time$*, noted* $\vartheta^t_{a \leftrightarrow b}$*, is a finite sequence (ordered on* $Time$*) of the form* $\langle x^{t_j}_{d_i \rightarrow e_i} : t_j \leq t \rangle$ *where:*

1. $x^{t_j}_{d_i \rightarrow e_i} \in CL$,
2. $d_i, e_i \in \{a, b\}$*, the thread contains only illocutions between agents* a *and* b*,*
3. $d_i \neq e_i$*, the illocutions are* between *agents, and*
4. *if* $t_k < t_l$ *then* $issues(x^{t_k}_{d_i \rightarrow e_i}) \subseteq issues(x^{t_l}_{d_j \rightarrow e_j})$*, where* $issues(x)$ *represents the set of issues mentioned in illocution* x*. That is, we assume monotonicity over the set of issues under negotiation, so that once an issue has been brought into the negotiation, it is never suppressed. We will use ellipsis whenever useful to make more compact expressions.*

We denote the last illocution in a thread as $\check{\vartheta}$*. We say a negotiation thread* ϑ *is* **active** *if* $\check{\vartheta}$ *is not an* `accept` *or* `withdraw` *illocution.*

Extending some ideas from [155], in this model it is intended to capture the idea that new issues may arise during the negotiation process. This is necessary because one of the usual ways in which an agent may persuade another about the desirability of a particular proposal is to introduce new issues that have hitherto not featured in the thread. This means that an explicit representation of the set Ω of issues an agent is aware of will be needed. Preferences also evolve. This may be because Ω evolves or because the agent is persuaded to change its preferences. Thus the agent's internal theory T, which includes its preferences in ML and a set of other formulae in L modeling the domain, must be explicitly represented in the agent's state. The model does not impose any specific requirements on T. Hence the following definition:

Definition 9.3 *A* **Negotiation State** *for an agent* a *at time* t *is any 3-tuple* $s = \langle \Omega, T, H \rangle$*, where*

- Ω *is a finite collection of negotiable issues.*
- $T \subseteq L \cup ML$*, is a theory in the common languages.*
- H*, the negotiation history, is the set of all negotiation threads involving agent* a*. That is,* $H = \{\vartheta_{i \leftrightarrow a} | i \in Agents\}$*.*

All possible negotiation states for agent a will be denoted by S_a. As an illustration of how these notions are used, consider the following example:

Example 1 *The CSD agent is negotiating for the Vet_Customer service, for company A with a VC_i agent. The CSD agent proposes that the service be completed for £10 and should take 24 hours. VC_i responds that company A is known to be in financial difficulty and therefore a more time consuming and expensive vetting should be undertaken (Table 9.1, id 8). Moreover, in order to meet the deadline, VC_i will need to delay the vetting of another BT customer (company B) for which an agreement has already been reached. This dialogue may be represented in CL as the sequence:*

1. $\texttt{offer}(CSD, VC_i, Company = A \wedge price = £10 \wedge time = 24h, t_1)$
2. $\texttt{appeal}(VC_i, CSD, Company = A \wedge price = £20 \wedge time = 48h,$
   $Financial\_Status = bad \wedge Quality\_vetting = high, t_2)$
3. $\texttt{appeal}(VC_i, CSD, Company = B \wedge delay = 24h,$
   $\texttt{accept}(VC_i, CSD, Company = A \wedge price = £20 \wedge time = 48h, t_2), t_3)$

This example shows how the range of issues Ω involved in the negotiation is extended (the delaying of the vet customer service for company B) and how new information (the fact that company A is known to be in financial difficulty) can be brought to bear. This revelation of information means that the CSD agent extends its domain theory T (to include the fact that A may not be creditworthy).
■

9.3.3 Persuasive agents

As the previous example showed, the illocutionary acts in CL built from I_{pers} allow arguments to be made in support of a deal. The basic building block for argumentation is $\texttt{appeal}(a, b, \xi, [not]\varphi, t)$ where $a, b \in Agents$, $\xi \in L \cup ML$, and $\varphi \in L \cup ML \cup CL$. This is read as "agent a wants agent b to add ξ to its current theory with argument $[not]\varphi$ supporting it". The other persuasive illocutionary acts, $\texttt{threaten}(a, b, [not]\psi_1, [not]\psi_2, t)$ and $\texttt{reward}(a, b, [not]\psi_1, [not]\psi_2, t)$ with $\psi_1, \psi_2 \in CL$, can contain arguments as long as ψ_1 and/or ψ_2 are appeals, or, recursively, contain appeals.

The interpretation of a persuasive argument for a formula determines whether the hearing agent changes its theory. To make a choice the agent considers the (possibly conflicting) arguments coming from other agents, and from itself, as proofs generated by its own theory. In our domain, and in other work on MAS (for example, Castelfranchi's [23]), the social role between the agents is a determining factor in deciding which argument should be preferred. Hence, an authority relation is derived from the social roles and this is then used as the mechanism for comparing arguments. Precisely which social roles correspond to a power relation between the agents depends on the particular domain. In this scenario, for example, the role 'contractor' determines a power relation between the CSD agent and the vetting companies. To build a directed graph representing the authority that one agent has over another, we take the labeled graph associated with the social relation R, remove the links labeled with non-power roles, and add the necessary links to make the relation transitive. Hence the following definition:

Definition 9.4 *Given a Dialogical Framework $DF = \langle Agents, Roles, R, L, ML, CL, Time\rangle$ and a set of authority roles $Power \subseteq Roles$, we define the* authority graph*, $AG \subseteq Agents \times Agents$, for DF as:*

1. *If $R(a,b) \in Power$ then $(a,b) \in AG$*
2. *If $(a,b),(b,c) \in AG$ then $(a,c) \in AG$*

We say an authority graph is well defined if it is acyclic.

The authority graph encodes the authority relation—or lack of it, since in general AG is not totally connected—between any two agents. It can be argued that in this domain the 'power' of an argument is determined solely by the authority of the agents which contribute formulae to its construction. Hence, it is necessary to extend the notion of authority from a relation between agents, as captured in the authority graph, to a relation over sets of agents which will be used to establish which arguments to prefer. There are two obvious ways of defining such a relation. We say that a set of agents A has *lower minimum authority* than B, $A \sqsubset_{\min} B$, if and only if for all $b \in B$ there exists $a \in A$ such that $(b,a) \in AG$. And that A has *lower maximum authority* than B, $A \sqsubset_{\max} B$, if and only if for all $a \in A$ there exists $b \in B$ such that $(b,a) \in AG$. Thus, intuitively, the order $\sqsubset_{\min}$ assumes that if any formula used in the argument was proposed by somebody low in the authority graph the argument is weak, while $\sqsubset_{\max}$ assumes that as soon as any formula in the argument is proposed by somebody high in the authority graph the argument is strong. Obviously other authority relations might also be proposed. From now on we refer to any authority relation by the symbol $\sqsubset$.

An argument can be understood as a **proof** for a formula [131, 180, 18], and one can assume that all agents share the same deductive systems for L ($\vdash_L$) and ML ($\vdash_{ML}$)[5]. Hence, in this restricted context, a proof can be represented as the conjunction of all the formulas used in it because it can be reconstructed by the agent receiving it. An argument is then a formula $\varphi \in L \cup ML \cup CL$ that might be constructed from atomic formulae present initially in the theory of the agent or obtained in previous negotiation encounters from different agents. Assuming the existence of a function $Support : L \cup ML \cup CL \to 2^{Agents}$ that gives the agents whose formulae are used in the construction of an argument, or the agent that uttered the illocution when $\varphi \in CL$. We can use the social role of those agents to decide how forceful an argument is.

[5] This is a convenient assumption from a proof–theoretic perspective, and is adopted for the moment because the focus is in the social interaction, not the actual individual reasoning schemas. However, from a dialogical perspective it is questionable and should give way to a more general one.

Fundamental to this view of decision making is the idea that one argument may attack another (see Praaken [131], for example). We represent the fact that an argument Arg supports a formula φ as a pair (Arg, φ) and the fact that the argument pair (Arg_1, φ_1) attacks (Arg_2, φ_2) by:

$$Attacks((Arg_1, \varphi_1), (Arg_2, \varphi_2)).$$

The precise meaning of *Attacks* depends strongly on the concrete languages L and ML being used.

Definition 9.5 *Given the two argument pairs* (Arg_1, φ_1) *and* (Arg_2, φ_2) *such that* $Attacks((Arg_1, \varphi_1), (Arg_2, \varphi_2))$ *then* (Arg_1, φ_1) ***will be preferred to*** (Arg_2, φ_2), *which we write as* $(Arg_2, \varphi_2) \prec (Arg_1, \varphi_1)$, *iff* $Support(Arg_2) \sqsubset Support(Arg_1)$.

When $(Arg_2, \varphi_2) \not\prec (Arg_1, \varphi_1)$ *and* $(Arg_1, \varphi_1) \not\prec (Arg_2, \varphi_2)$ *we say that an agent is indifferent with respect to the arguments—and denote this by* $(Arg_1, \varphi_1) \sim (Arg_2, \varphi_2)$.

The agents use argumentation as the means to decide how to interpret incoming and generate outgoing illocutions. On receiving an argument pair (Arg_1, φ_1) that is not attacked by any argument pair (Arg_2, φ_2) built from its current theory, an open-minded agent may simply add the argument Arg_1 and the formula φ_1 to its theory. In contrast, a more conservative agent may not accept a proposition unless it comes from a higher authority. When $Attacks((Arg_1, \varphi_1), (Arg_2, \varphi_2))$ the most preferred (in the sense defined above) argument pair is kept. If $(Arg_1, \varphi_1) \sim (Arg_2, \varphi_2)$ some additional criteria must be applied to decide which to keep, for instance epistemic entrenchment (Gardenfors [57]).

Example 2 *The DD and SD agents negotiate over the Survey_Customer_Site service. DD proposes that the service should be completed within 24 hours. SD indicates that one of its surveyors was planning to go on holiday and so the survey will take 48 hours (Table 9.1, id 9). DD indicates that it must have the service completed within 24 hours. In CL this is expressed as:*

1. $\texttt{offer}(DD, SD, time = 24h \wedge service = Survey\_Customer\_Site, t_1)$
2. $\texttt{appeal}(SD, DD, time = 48h, surveyor(Smith) \wedge holiday(Smith), t_2)$
3. $\texttt{appeal}(DD, SD, time = 24h, time = 24h, t_3)$

In this example, SD issues an appeal to DD for more time to complete the survey service. DD rejects this argument saying the service must be completed within 24 hours. SD now has two arguments that attack one another: $Attacks((surveyor(Smith) \wedge holiday(Smith), time = 48h), (time = 24h, time = 24h))$. *It resolves them by referring to its authority graph which indicates that the authority of DD's argument is more powerful than its own (since DD is its boss, that is,* $(DD, SD) \in AG$ *) and therefore it must do whatever is necessary to ensure the service is completed within 24 hours. That is,* $Support(surveyor(Smith) \wedge holiday(Smith)) = \{SD\}$, $Support(time = 24h) = \{DD\}$ *and given that* $(DD, SD) \in AG$ *we have that* $(surveyor(Smith) \wedge holiday(Smith), time = 48h) \prec (time = 24h, time = 24h)$ *because in our example* $\{SD\} \sqsubset \{DD\}$ *(using either of the measures mentioned above).* ■

9.3.4 Interpretation and Generation of Illocutions

For pragmatic reasons, we separate the definition of the semantics of illocutions into two different operations, I and G (see examples 3 and 4). The former implements the negotiation-state transition associated with hearing a given illocution, while the latter determines the illocutionary action to be taken in a particular state.

The underlying idea is that any illocution may introduce new issues into a negotiation, while appeals may, in addition, modify the preference relationships and the agent's theory. However, the actual effect of an illocution depends on the agent's interpretation of the utterances it receives. This interpretation process is highly domain-specific and is also dependent upon the internal structures present in the agent architecture. For this reason, we illustrate how our framework can be used to define a comparatively simple open-minded agent. Naturally this does not prescribe how all agents should behave, but rather exemplifies the concepts of our model which can be used to define many other types of agent.

The illocution interpretation function I for an open-minded agent is based on the following intuitions:

- Every illocution extends the corresponding thread in the negotiation history[6]. In this way, for example, complete illocutionary histories allow agents with total recall to be modeled. Forgetful agents can then be modeled by discarding part of the negotiation thread.
- All illocutions may introduce new issues into the negotiation.
- Appeals may change an agent's preference relationship. They may change the theory as well by extending it with the formulae of the argument in the appeal, provided that the current theory cannot build attacking arguments for the appeal.

Example 3 Open-minded Interpretation. *Given a communication language CL, a dialogical framework DF, and the set of all possible negotiation states S_b for an agent b, the interpretation function for an* open-minded agent *is defined by $I : CL \times S_b \times DF \to S_b$ such that—having $s = (\Omega, T, H)$, $H = \{\vartheta_{i \leftrightarrow b} | i \in Agents\}$, and '$\oplus$' representing concatenation— we have*[7]*:*

1. $I(\iota(a, b, \delta, t), s, df) = (\Omega \cup issues(\delta), T, H - \vartheta_{b\leftrightarrow a} + \vartheta'_{b\leftrightarrow a})$
   with $\iota \in I_{nego}$; $\vartheta'_{b\leftrightarrow a} = \vartheta_{b\leftrightarrow a} \oplus \iota(a, b, \delta, t)$
2. $I(\texttt{threaten}(a, b, [not]\psi_1, [not]\psi_2, t), s, df) =$
   $(\Omega \cup issues(\psi_1) \cup issues(\psi_2), T, H - \vartheta_{b\leftrightarrow a} + \vartheta'_{b\leftrightarrow a})$
   with $\vartheta'_{b\leftrightarrow a} = \vartheta_{b\leftrightarrow a} \oplus \texttt{threaten}(a, b, [not]\psi_1, [not]\psi_2, t)$

[6]However, we do not update agents' theories in this minimal semantics because we wish to keep the interpretation of illocutions reasonably neutral with respect to the agents' internal architectures.

[7]An alternative way of looking at the interpretation of illocutions is as programs that transform one state into another. A natural formalism for that interpretation is Dynamic Logic, as suggested in Chapter 5.

3. $I(\texttt{reward}(a, b, [not]\psi_1, [not]\psi_2, t), s, df) =$
$(\Omega \cup issues(\psi_1) \cup issues(\psi_2), T, H - \vartheta_{b\leftrightarrow a} + \vartheta'_{b\leftrightarrow a})$
with $\vartheta'_{b\leftrightarrow a} = \vartheta_{b\leftrightarrow a} \oplus \texttt{reward}(a, b, [not]\psi_1, [not]\psi_2, t)$

4. $I(\texttt{appeal}(a, b, \xi, [not]\varphi, t), s, df) = (\Omega', T', H - \vartheta_{b\leftrightarrow a} + \vartheta'_{b\leftrightarrow a})$
with $\vartheta'_{b\leftrightarrow a} = \vartheta_{b\leftrightarrow a} \oplus \texttt{appeal}(a, b, \xi, [not]\varphi, t)$;
if *no* (Arg, ψ) *built from* T *such that* $Attacks(([not]\varphi, \xi), (Arg, \psi))$
then $\Omega' = \Omega \cup issues(\xi) \cup issues(\varphi)$;
if $\varphi \in L \cup ML$ **then** $T' = T + \xi + \varphi$ **else** $T' = T + \xi$
else $\Omega' = \Omega$; $T' = T$

■

Finally, an agent a's specification must include a way of computing the next illocution to be uttered in the negotiation thread. That is a function $G : S_a \times DF \to CL$ needs to be defined. This function must conform with the protocol depicted in Figure 9.2 and can conveniently be represented as a collection of condition-action rules, where the action is an illocutionary action. How an agent chooses which illocution to utter depends on many factors: the history of the negotiation, the active goals of the agent, or its theory, and it also depends on the way that particular agent interprets those illocutions. The following example illustrates a simple negotiation dialogue between two agents and contains a fragment of a G function.

Example 4 *An expanded version of the argument presented in Example 2 is used to illustrate specific instances of illocution generation and interpretation functions. Given the two initial illocution interchanges:*

1. $\texttt{offer}(DD, SD, time = 24h \wedge service = Survey\_Customer\_Site, t_1)$
2. $\texttt{appeal}(SD, DD, time = 48h, surveyor(Smith) \wedge holiday(Smith), t_2)$

Two decisions are shown, taken by two different types of agent; an 'authoritarian' DD agent which exploits its social power (and threatens to inform the company chairman that SD did not agree to complete the task within 24h), and a 'conciliatory' DD agent which resorts to an explanatory appeal (that it is company policy that quotes must be handled within 24h):

3.1 **Authoritarian***:* $\texttt{threaten}(DD, SD,\ not\ \texttt{accept}(SD, DD,$
$time = 24h, t_3), \texttt{appeal}(DD, Chairman,\ not\ \texttt{accept}(SD, DD, time = 24h, t_3), t_4))$

3.2 **Conciliatory***:* $\texttt{appeal}(DD, SD, time = 24h,$
$BT\_Policy\_Time = 24h, t_3)$

The G function of an 'obedient' SD agent that, whenever possible, does what it is told could include the following decision rules where 'self' represents the agent interpreting the illocution:

if $\check{\vartheta}_{x\leftrightarrow self} = \texttt{threaten}(x, self, not\ \texttt{accept}(self, x, \delta), \psi_2)$ **and** $(x, self) \in AG$
and $can\_do(\delta)$ **then** $\texttt{accept}(self, x, \delta)$
if $\check{\vartheta}_{x\leftrightarrow self} = \texttt{threaten}(x, self, not\ \texttt{accept}(self, x, \delta), \psi_2)$ **and** $(x, self) \in AG$
and not $can\_do(\delta)$ **then** $\delta' = compute\_counter\_offer(s, DF)$;$\texttt{offer}(self, x, \delta')$
if $\check{\vartheta}_{x\leftrightarrow self} = \texttt{appeal}(x, self, \xi, \varphi)$ **and** $\psi \to \neg\varphi \in T$ **then** $\texttt{appeal}(self, x, \neg\varphi, \psi)$

Id	Dialogue
1	$\texttt{appeal}(CSD, VC_i, \texttt{offer}(VC_j, CSD, \delta), true), \texttt{threaten}(CSD, VC_i,$ $not\ \texttt{offer}(VC_i, CSD, \delta), \texttt{withdraw}(CSD, VC_i))$
2	$\texttt{threaten}(CSD, VC_i, not\ \texttt{offer}(VC_i, CSD, \ldots \wedge time < limit),$ $not\ \texttt{request}(CSD, VC_i, Future^a))$ [a] *Future* is an universally quantified variable over the future instants in *Time*.
3	$\texttt{threaten}(DD, SD, not\ \texttt{acccept}(SD, DD, \ldots \wedge time < limit),$ $\texttt{appeal}(DD, Boss_{SD}, \psi^a,$ $not\ \texttt{acccept}(SD, DD, \ldots \wedge time < limit)))$ [a] ψ expressing the fact that the deadline has been missed.
4	$\texttt{reward}(CSD, DD, \texttt{accept}(DD, CSD, \delta),$ $\texttt{appeal}(CSD, OurBoss, \psi, \texttt{accept}(DD, CSD, \delta)))^a$ [a] $\delta = \ldots Vet = Customer_i \wedge time < limit$. The reward consists of passing the information to our boss. ψ represents the satisfaction of $Customer_i$.
5	$\texttt{reward}(CSD, VC_i, \texttt{accept}(VC_i, CSD, \ldots \wedge time = k \wedge \ldots),$ $\texttt{request}(CSD, VC_i, \Delta, Future))^a$ [a] Δ stands for a deal, and *Future* stands for an instant in the future.
6	$\texttt{appeal}(CSD, VC_i, time = t \wedge cost = c,$ $\texttt{accept}(VC_i, CSD, \ldots \wedge time = t \wedge cost = c, Before^a))$ [a] *Before* represents a previous instant in *Time*.
7	$\texttt{appeal}(CSD, DD, time = 48h, BT\_policy\_time = 48h)$
8	$\texttt{appeal}(VC_i, CSD, time = high, Financial\_status = trouble,$ $\wedge\ Quality\_vetting = high)$
9	$\texttt{appeal}(DD, CSD, time > t_{normal}, surveyor(Smith) \wedge holiday(Smith))$
10	$\texttt{appeal}(SD, DD, time > t_{normal}, Number\_premises = High)$

Table 9.2: Formalization of the arguments presented in Table 1.

Assuming that $can\_do(time = 24h \wedge service = Survey\_Customer\_Site)$ *is true, by subcontracting the task say, the dialogue with the authoritarian DD ends with:*

4.1 $\texttt{accept}(SD, DD, time = 24h \wedge service = Survey\_Customer\_Site, t_4)$

On the other hand, if we assume that the rule $BT\_Policy\_Time = 24h \leftrightarrow Fully\_staffed$ *is true and DD utters 3.2, the agent could reply with:*

4.2 $\texttt{appeal}(SD, DD, not\ (BT\_Policy\_Time = 24h), not\ Fully\_staffed)$ ■

To further illustrate the power of our framework, Table 9.2 shows the representation in CL of the arguments presented in Table 9.1.

9.4 Remarks

This exercise illustrates how by focusing in illocutory exchanges, a novel framework for describing persuasive negotiations can be introduced. Only the contextual and social aspects have been addressed so far, thus the intended effects of illocutions, as well as their triggering conditions have merely been suggested. This framework, however, should provide a foundation for building specific artificial agents by instantiating the generic components such as L, ML and T.

There are a number of issues which require further investigation.

First there is the matter of how expressive CL is required to be. For instance, here an agent can only make threats and promises about illocutionary actions (e.g. to tell somebody about something). It is also desirable for non-illocutionary actions to be the consequence of a threat or promise. Similarly, while appeals could be used to model a wide range of illocutions, it may be useful to characterize subtly different types of illocution through more refined interpretation and generation functions.

Secondly, an agent's preferences, and the changes in those preferences, have been reflected simply as sentences and updates in the agent's theory T. Further work is required to tie these preferences to notions of rationality and in particular to standard ideas of expected utility.

Finally, the simplifying assumption that negotiating agents have a common notion of deduction needs elaboration. Uniform rationality may be inadequate for some domains, in which case it will be necessary for agents to be able to *argue* about what rules of inference are appropriate.

Chapter 10

Dialogical Institutions

O homo, qualis futurus es in factis, si disolutus inveniaris in verbis?

Alan de Lille. [1]

Although the potential for electronic commerce is readily acknowledged, some assessments (like Hoffman's [78]) have clearly identified the significance of "consumer trust" in its actual development. In fact, both EC policy guidelines for electronic commerce in the Information Society [29] and US "Framework for Global Electronic Commerce" [172] address specifically this concern and state the need of technological developments and new legal and market practices to contend with this problematic issue. Agent based technologies may constitute a crucial technology for electronic commerce but much of their success will depend on the degree of confidence they may inspire to their potential users.

I propose to contribute in this direction by developing a notion of "accountability" of agent interactions, which I base on two constitutive elements: dialogical institutions, and "governed" agents. These two notions are essential in such notion of accountability for electronic commerce, but are general notions that may be applicable in other quite different domains.

10.1 Guiding Intuitions

Intuitively —as was discussed originally in Chapter 4, and developed in the following chapters— an agent–mediated institution is the computational realization of a set of explicit enforceable restrictions imposed on a collection of dialogical

[1] "Oh man. What will lie ahead of you in deeds, if you are found ungoverned in speech?" [37](ChXXVI, col.163)

agent types that concur in space and time to perform a finite repertoire of satisfiable actions.

For that characterization, I have assumed that agents are “dialogical entities” that interact with other agents within a multi agent context which is relatively static in ontological terms. Intuitively, I assume that agents exhibit rational behavior by engaging in dialogical exchanges, i.e., that agent interactions are systematically linked to illocutions that are comprehensible to participants and refer to a basic shared ontology and that the exchanges can be (externally) construed as rational. I consider, moreover, that it is indeed the Institution the real depositary of the ontology and interaction conventions used by the participating dialogical agents.

For my present purposes, then, I assume a dialogical stance by which agents are entities that are capable of expressing illocutions and react to illocutions addressed to them and, furthermore, only illocutions (and the contextual effects of their associated actions, e.g. commitments to sell a box of fish) constitute observable agent behavior. Individual agents may have other capabilities —perception, intentions, beliefs,...— but I will assume that as long as those agents interact in an agent-mediated institution, only illocutions are perceptible by other agents, and each illocution has a set of associated actions whose meaning and conditions of satisfaction are objectively established (and accounted for) within the shared context. Recall also that individual agents, within an institution, can only utter illocutions that are consistent with the “role” they are playing, thus a characterization of “agent types” that play a given role —in addition to individual agents who instantiate that type— is needed.

But how can one “enforce” restrictions on these illocutions? How can one guarantee that agents utter only acceptable illocutions and these only and always according to the intended protocol? Well, I propose a way of “governing” individual agents through a formal and computational device that (generalizing further the functionality of the original Blanes mineing devices) will supervise all of the individual agent interactions and act as a dynamic two-way illocutory filter that is consistent with the role that agent is playing. Intuitively, a governor is a sort of “costume” that invests the agent with all the accoutrements needed to perform a role flawlessly, but it also shields it from getting any information that is not part of the market–place protocol, and shields the market place from any unwanted illocution or action that a malicious or inept external agent might introduce[2].

From a functional point of view, these governors not only passively incarnate the rules of behavior the agent is supposed to follow, but may also react to any attempted misbehaviour by inhibiting, clarifying, negotiating, sanctioning

[2]A terminological remark: the term *governor* was proposed by Carles Sierra, evoking the meaning of the word as (active) tutors responsible for the correct behavior of children, in Spanish, the word is *institutriz* a (feminine) “institutor”. At some–time we considered “shield”, which was too static, and the theatrical “persona” was considered and discarded on similar grounds (we later on realized that Wahlster and others use it to denote a type of avatar. The historic (pedagogue) and textual (strict adherence to rules) meaning of “pedant” is perhaps closer to our intuitions, but its unpleasant connotations did not please us.

or otherwise adapting to the prevalent situation of the agent and the institution[3]. However, from a formal point of view a governor can be construed quite simply as dynamic agent-type constraints on utterances and protocols that can be implemented as another agent. Hence, such governors are a type of simplified agent that *tutors* the behavior of agents in an institution.

Governors have an evident pragmatic interest: *Governors make agent–mediated institutions agent–architecture neutral*, something that is good for market institutions and for market participants. Electronic markets would rather not risk any interference in their computing machinery by externally-defined agents, hence, from a security point of view, electronic markets will probably prefer to "send" their own governors to the agent's site, than "receive" mobile agents. While external participants in an electronic market would very likely prefer not to relinquish to the market–place any independence they may have in terms of tools, resources or knowledge, but may accept a "governed interface" as an admission requirement[4].

By thinking of roles and agents in this way, the verification of properties becomes a much simpler task. Partly because the sources of failure are reduced –the failure of an agent is always constrained by the failures identifiable through the governor, and governors are monitorizable by and from the institution itself– and mainly because one only needs to verify the behavior allowed by the governors, thus involving uniform agent-types and not distinguishable individual agents. This is neatly illustrated in the case of the Fishmarket bidding protocol, which in FM96.5 can be proved "fair" by showing how footdragging, premature bidding, suplantation, are all impossible for governed agents irrespective of their individual architecture or capabilities. Finally, obvious as it is, it is in no way irrelevant that governors are *owned and developed by the very market institution*, thus the institution can test at will their behavior, and may certify their performance as part of its institutional role.

In the next sections I will lay the formal grounds for these two notions. In order to formalize institutions I will draw upon the devices I introduced in previous chapters: A shared ontology and communication language will be defined into a "dialogical framework" and the notion of "context" localized, so that terms adopt meaning according to the time and place of utterance. Illocutory exchanges will be subject to "protocols" which I will express through explicit sequencing conditions of both illocutions and associated actions for pairs of agents. I will amalgamate protocols into scenes, and scenes into a "performative structure". The agent-mediated institution will then be the result of an implementation of a coherent description of the Performative Structure. A governor will be formalized as a dialogical agent that satisfies all the individual rules of behavior of an agent–mediated institution and co-laborates with another agent within that institution.

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[3] An example of dynamic behavior of the governor, for example, would be reacting when a deadline is reached, if the agent does not react on time, the governor takes a default action.

[4] Note that trading agents are not likely to be developed by the same developers of an agent-mediated market-place, because of the conflict of interests and the unnecessary (and unlikely) confinement of external agents' internal architecture.

The intended interpretation of these constructs will be computational, thus the use of CDDL as in Chapter 5.

10.2 An Illustrative example, F–auctions

In Chapter 4 I discussed one example of an auctioning convention, that of the fish market. Recall that its dialogical description involved: a dialogical framework, a performative structure and rules of individual behavior all of which ought to satisfy certain requirements. I will now venture a very unambitious generalization of those concepts to illustrate the above intuitions on institutions. I will define *F–auctioning convention*, *F–auction* and *F–auction house* as well as some other "Fishmarket–like" new components. For that purpose, I will build on the concepts and notation introduced in Chapter 4, and once more I will remain in an ambivalent *formalizable* level in which notation is introduced only to facilitate descriptions, and not in a rigorous formal fashion.

The generalizations are straightforward. The idea is that an *F-institution* will be similar to the Fishmarket in general, but will differ in specific individual rules and protocols in order to capture any of the F–variants introduced in Chapter 7. I start with a quasi–definition of F-auction house, the following definitions make that notion, hopefully, more precise.

Notion 10.1 *An **F–auction house** $\mathcal{H}$ is a three-tuple $\langle \mathcal{DF}_F, \mathcal{PS}_F, \mathcal{RB}_F \rangle$, where $\mathcal{DF}$ is a dialogical framework that defines an* F–market environment*, $\mathcal{PS}$ is a performative structure that defines the* F–auctioning conventions *and $\mathcal{BR}$ is a set of individual* F–rules of behavior *for participating agents.*

Where:

1. *An **F–market environment** is a dialogical framework that has the same elements of the Fishmarket's dialogical framework, i.e.,*

$$\mathcal{DF}_F = \mathcal{DF}_{FM}$$

2. *An **F–auctioning convention** is a modification of the Fishmarket performative structure that involves the same scenes as those of the Fishmarket, but their atomic protocols (i.e., agent-type–pairwise protocols) and market commitments have to be:*
   - (a) ***consistent** with the corresponding F–rules of individual behavior and*
   - (b) *the resulting combined protocols are **performable**, in the sense that given any auction A (goods, buyers and sellers with an initial property and endowment situation), there exists a sequence of dialogues that follow the F–auctioning conventions and terminates on a final situation of property and endowment of the original goods and participants.*

3. ***F–rules of behavior*** *to be consistent with the protocols, must include at least the following sets of individual rules (for each role that intervenes in a corresponding scene of the performative structure)*
   (a) *A set of rules that determine* ***market opening and closing*** *conventions.*
   (b) *A set of rules that define* ***admission requirements for buyers and sellers***
   (c) *A set of rules that determine how the* ***bidding round*** *proceeds:*
      i. *parameters (Protocol dynamics)*
      ii. *opening conditions*
      iii. *termination conditions*
      iv. *tie-breaking criteria*
   (d) *A set of rules that define conditions on the* ***reception of goods*** *(that may be either one newlot or multiple newlots; bounded or continuous,...).*
   (e) *A set of rules that determine the* ***catalogueing of goods*** *(i.e., that determine who sets the default values of the catalogue and what those values are).*
   (f) *A set of rules that determine the* ***revelation of information*** *(when certain values of the catalogue are made public, or known to what participants).*
   (g) *A set of rules that determine the* ***presentation of goods*** *(one lot or multiple lots).*
   (h) *A set of rules that determine the* ***credit update*** *conditions for buyers (fixed, extendible, bounded or not).*
   (i) *A set of rules that define how* ***seller income*** *is computed.*
   (j) *A set of rules that determine how* ***buyer transactions*** *are charged.*

I will elaborate on the contents of that quasi–definition in the rest of this section.

F-market environment Recall that the Fishmarket dialogical framework captured all ontological and communicational *static* conventions needed to accomplish an auction in the Fishmarket. Hence it involved a model of time, an object language L_F, a communication language $\mathcal{CL}_F$ and a metalanguage $\mathcal{ML}_F$ whose signatures included symbols for illocutory particles ($\mathcal{I}_F$), locations, roles, actions,..., These languages were expressive enough to include all illocutions, market commitments and rules of behavior described in Chapter 4. An F-market environment will have a dialogical framework that is *identical* to the Fishmarket's[5]. I will eventually generalize this notion to encompass auction houses in general and other agent–mediated market places.

[5]Thus, the dialogical framework for an F–institution has to be, *ontologically*, as rich as that of the Fishmarket. Note, nevertheless, that this does not mean that an F–institution has

Definition 10.1 *Let $\mathcal{DF}_{FM}$ be the Fishmarket dialogical framework. Then, an **F–Market Environment** is a dialogical framework*
$\mathcal{DF}_{\mathcal{F}} = \langle \mathbf{Agents}_F, \mathbf{Roles}_F, \mathcal{SR}_F, \mathbf{Loc}_F, \mathcal{L}_F, \mathcal{CL}_F, \mathcal{ML}_F, T \rangle$*, such that:*

- $\mathbf{Agents}_F$ *is a set of agent identifiers,*
- $\mathbf{Roles}_F = Roles_{FM} = \{\mathbf{boss}, \mathbf{auct}, \mathbf{sa}, \mathbf{sm}, \mathbf{ba}, \mathbf{bm}\} \cup \{s_j\}_{j \in J} \cup \{b_i\}_{i \in I}$ *(The set of agent types is the same as that of the Fishmarket)*
- $\mathcal{SR}_F = \{\langle \mathbf{boss}, x \rangle : x \in \mathbf{staff}\}$ *(Boss has authority over staff)*
- $\boldsymbol{Loc}_F = \{AH, RR, AR, DR, BO, M\}$ *(market locations)*
- $\mathcal{L}_F = \mathcal{L}_{FM} = \{\mathbf{staff}, \ldots \Delta_{bid}, \Pi_{spremium}, \ldots, tosell, moveout, \ldots\}$
- $\mathcal{CL}_F = \mathcal{CL}_{FM}$ *(is a communication language built on $\mathcal{L}_F$ with the illocutory particles $\mathcal{I}_{FM} = \{assert, request, deny, accept,$ $declare, command, \ldots\}$),*
- $\mathcal{ML}_F = \mathcal{ML}_{FM}$ *the F–metalanguage (includes all other F–languages).*
- T *a model of time (e.g. discrete–acyclic–forward-branching time).*

F-auctioning conventions I now need to make some semantic and pragmatic features of the Fishmarket part of all F–institutions as well. I will fix the essential meaning of some symbols and the basic roles and scenes of the Fishmarket, however I will leave open most of the specifics so that F-variants can be easily expressed. So for instance, in the following quasi-definition I am demanding that every auction house contains the five rooms the Fishmarket institution had, with the corresponding scenes, plus the market place as a buffer location to handle activation and closing scenes, as well as entrance and exit of external agents. I include all these locations and scenes, because variations in auctioning conditions (as shown in Chapter 7) may involve any of the scenes or roles of the Fishmarket institution.

Notion 10.2 *A Performative Structure that defines **F–auctioning conventions** is a 6-tuple $\mathcal{PS}_F = \langle P_\lambda : \lambda \in \mathbf{Loc}_F \rangle$ such that for each market location λ, and each pair of roles ρ_1, ρ_2 that interact in that location, $P_\lambda(\rho_1, \rho_2)$ is a function that states the interaction protocol between ρ_1 and ρ_2 and the corresponding market commitments of that interaction that are* consistent *with the individual rules of behavior for the participants roles in $\mathcal{BR}_F$.*

In particular, $P_{AH}(auct, b)$ defines the bidding round conventions *to which every buyer b is subject within the auction hall, and (among other commitments, how the catalogue evolves during bidding rounds). $P_{RR}(sa, a)$ defines the seller admission protocol and the social conventions for reception of goods. $P_{AR}(bm, b)$ defines the buyer credit management and buyer account (update, charging,...) conventions, etc.*

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to use all of this richness, because it may be a simpler F-variant and some symbols may be vacuous.

Notice now that I have required atomic protocols between two agent roles in one location. This is again a trick to facilitate the description of variants, but I also make that requirement now to permit eventually the amalgamation of these atomic protocols into a complex performative structure like the one described in Chapter 4[6]. Atomic protocols and market commitments are required to be consistent with the individual rules of behavior. A convenient formalization is possible by establishing a link among illocutions and market commitments in those individual rules of behavior.

F-rules of behavior The restrictions that will characterize an *F–institution* (as indicated in Notion 10.1) will be expressed in terms of the individual rules of behavior of participants.

The individual **Rules of Behavior** map each role ρ to a set of behavior rules that should be consistent with the auctioning conventions of the institution for that role $BR(\rho)$. A subset of these role–specific rules correspond to each location ($BR_\lambda(\rho)$), and these will have to be consistent with the corresponding atomic–scene-protocol. I can express it by saying that illocutionary preconditions are consistent with individual rule premises, and that illocutory effects are consistent with the consequents of individual rules of behavior[7]. The second condition is made precise by the following definition:

Definition 10.2 *Let $\rho, \sigma \in \mathbf{Roles}_F$, and location $\lambda \in \mathbf{Loc}_F$, and let $\varphi \in \mathcal{ML}_F$ be a new market commitment in state S_m of the atomic protocol $P_\lambda(\rho, \sigma)$. Then for another state S_n in $P_\lambda(\rho, \sigma)$, there are an illocution $\iota \in P_\lambda(\rho, \sigma)$, and an individual rule of behavior $\psi \in BR_\lambda(\rho) \cup BR_\lambda(\sigma)$ such that*

- *ι links S_n to S_m,*
- *ι is a premise in ψ and φ is a consequent in ψ*

Performance of an auction Finally, I want to require that the F–conventions do constitute feasible auctioning conventions, in the sense that an actual auction can take place subject to those auctioning conventions. For that purpose, I will introduce the notions of *auction*, *state* and *performance*

[6]I still refrain from committing to a formalism for protocol specification. Atomic protocols are adequately specified as finite–state machines with illocution-labeled transitions and state memories that hold market commitments, but as was evident in Chapter 4, amalgamated scenes became rather obscure in those diagrams, and market commitment specification was cumbersome. I would like to have an "algebraic" form of amalgamation, and for that purpose, it seems that Colored Petri Nets may be a better convention that should be explored in the future.

[7]Recall from the examples in Chapter 4 that an individual rule of behavior is a conditional expression in $\mathcal{ML}_F$ of the form: $IF\ p_1\ AND\ p_2\ AND\ \ldots\ AND\ p_k, THEN\ c_1\ AND\ c_2\ AND\ \ldots\ AND\ c_l$, where the p_i's and the c_j's are expressions in $\mathcal{ML}_F$. A more thorough formalization might profit from a speech–acts formalism (e.g., Singh [160], Dignum and VanLinder [43], Vandervecken [175]) and re-express consistency by qualifying pre-conditions and effects with respect to the illocutory particle present in the illocution.

Notion 10.3 *An* ***F–Auction*** *is a triple* $\langle \mathcal{A}, \mathcal{G}, \mathcal{E} \rangle$ *where,*

1. $\mathcal{A}$ *is a set of agents,*
2. $\mathcal{G}$ *is a set of goods,*
3. $\mathcal{E} = \{\mathcal{E}_t\}_{0 \leq t \leq \omega}$ *is a finite set of* market states*, such that* $\mathcal{E}_0$ *is the initial market state and* $\mathcal{E}_\omega$ *is the final market state.*

And market state at time t*,* $\mathcal{E}_t$*, correspond to the value of market commitment sets at time* t

Notion 10.4 *An auction* $A = \langle \mathcal{A}, \mathcal{G}, \langle \mathcal{E}_0 \ldots \mathcal{E}_\omega \rangle \rangle$ *is* ***performed*** *in an auction house* $\mathcal{H}$*,*

$$\mathcal{H} \models A,$$

if $\mathcal{E}_0$ *is transformed into* $\mathcal{E}_\omega$ *through a dialogical process involving* $\mathcal{A}$ *and* $\mathcal{G}$ *that satisfies the explicit auctioning conventions upheld by the auction house* $\mathcal{H}$*.*

Now we can generalize these concepts, in an almost immediate way to define a notion of agent–mediated auction house as any extension of an F–auction house, and slightly more generally to agent–mediated market places and agent–mediated institutions.

10.3 Agent–Mediated Institutions

We can think of agent-based institutions as the computational realization of a traditional institution, which intuitively amounts to a set of clearly established conventions that somehow restrict participating agents' interactions. An institution, therefore, defines a shared reality. It says what types of agents may participate, doing what and how.

Certain aspects of an institution are stable, and constitute a context or frame of reference that grounds its symbolic characterization. In a dialogical institution, agents interact through illocutions. Acceptable illocutions are defined by the institution who therefore defines a shared ontology —involving roles, locations and time— a shared common language to refer to the "world", L; a shared common language to communicate, CL; and a common metalanguage, ML. In many cases (as was the case in auction house with staff, and in the argumentation based negotiation example of Chapter 9), an institution may recognize relevant social relations among participating agents —in terms of authority, for instance— or some kind of "personality" traits or recognizable individual behaviors that may affect social interactions (as in Chapter 9). These *contextual aspects* of an institution I shall call the *Dialogical Framework.*

An institution also determines how illocutions may be exchanged, among whom, with what effect or under what circumstances. I make these conventions explicit through what I have called a *protocol.* Protocols will be defined for pairs of agent roles, and localized. They are combined into a *Performative Structure.*

However, an institution also imposes restrictions on individual agents' behavior, not only state transition graphs, but also some conditions on those transitions. I will also include a collection of *rules of behavior* for each type of agent that participates in a given location. These rules restrict all possible actions of that agent type at a given moment of a scene, to only those that are consistent with its role.

More precisely:

Definition 10.3 *An **Institution**, I, is a 3-tuple $I = \langle \mathcal{DF}, \mathcal{PS}, \mathcal{BR} \rangle$, where,*

1. *$\mathcal{DF}$ is a* dialogical framework
2. *$\mathcal{PS}$ is a* performative structure*,*
3. *$\mathcal{BR}$ are the* rules of behavior *to which participating agents are subject to.*

10.3.1 Dialogical Frameworks

The *Dialogical Framework*, $\mathcal{DF} = \langle \mathbf{Agents}, \mathbf{Roles}, \mathbf{SocialStructure}, \mathcal{CL}, \mathcal{L}, \mathbf{Time} \rangle$ captures the intuition of *context.* It makes explicit, on one hand, the participants and their basic roles, as well as their relevant social interrelationships. On the other, it also makes explicit the communication and object languages, $\mathcal{CL}$, $\mathcal{L}$ that will be needed for illocutions to be shared between participating agents, as well as a common notion of time to which sequencing of interactions may need to refer. Note, however, that nothing is said about the internal components of participating agents in this framework, only general rules of behavior are later on prescribed (in Section 10.3.2).

Definition 10.4 *A **Dialogical Framework**, DF, is a tuple*

$$DF = \langle Agents, Roles, \mathcal{SR}, Loc, L, ML, CL, T \rangle,$$

where,

1. *$Agents$ is a set of agent identifiers.*
2. *$Roles$ is a set of agent types,*
3. *$\mathcal{SR}$ is a set of relevant social relations and individual distinctive characteristics that may be relevant for the description of an institution,*
4. *Loc is a set of locations,*
5. *L is an object language,*
6. *ML is a metalanguage,*
7. *CL is a communication language, and*
8. *T is a model of time.*

Different institutions will have different Dialogical Frameworks. Compare for instance, the above $\mathcal{DF}_{FM}$ with the dialogical frameworks for agent mediated auction houses, agent mediated markets and open ended argumentation–based negotiation of the following examples.

Example 1 *In an **Agent Mediated Auction Market-environment,***

$$DF_{\mathrm{A}} = \langle Agents_{\mathrm{A}}, Roles_{\mathrm{A}}, \mathcal{SR}_{\mathrm{A}}, Loc_{\mathrm{A}}, L_{\mathrm{A}}, ML_{\mathrm{A}}, CL_{\mathrm{A}}, T\rangle,$$

where

1. $Agents_{\mathrm{A}}$ *is a set of agent identifiers.*
2. $Roles_{\mathrm{A}}$=*{Boss, Auctioneer, Buyer Admitter, Buyer Manager, Buyer, Seller Admitter, Seller Manager, Seller},*
3. $\mathcal{SR}_{\mathrm{A}} = \{\mathbf{authority}_{\mathrm{A}} = \{(Boss, x) \mid x \in Roles_{\mathrm{A}} - \{Seller, Buyer\}\}$, *denotes that the Boss has authority over all of the institutional agents in* A
4. $Loc_{\mathrm{A}} = \{AH, RR, AR, BO, DR, M\}$
5. $L_{\mathrm{A}} = \mathcal{L}_{\omega,\omega} \cup \{\{goodtype_1, goodtype_2, \ldots, price, \ldots\},$
   $\{Admittance, Tosell, \ldots\}, \ldots\},$
6. $CL_{\mathrm{A}} = \{\mathtt{request}, \mathtt{offer}, \mathtt{accept}, \mathtt{declare}, \ldots\}$, *and*
7. $ML_{\mathrm{A}} = ML_{FM}$,
8. T *is a discrete, acyclic, forward-branching order*

Analogously, to describe a framework for agent mediated markets, the basic Dialogical Framework could be given by :

Example 2 *In an **Agent Mediated Market-environment,***

$$DF_{\mathrm{M}} = \langle Agents_{\mathrm{M}}, Roles_{\mathrm{M}}, \mathcal{SR}_{\mathrm{M}}, Loc_{\mathrm{M}}, L_{\mathrm{M}}, ML_{\mathrm{M}}, CL_{\mathrm{M}}, T\rangle,$$

where

1. $Agents_{\mathrm{M}}$ *is a set of agent identifiers.*
2. $Roles_{\mathrm{M}} = \{buyer, seller\} \cup staff$, *($staff$ denotes a possibly empty set of market mediators.)*
3. $\mathcal{SR}_{\mathrm{M}}$ *will depend on the type of market institution.*
4. $Loc_{\mathrm{M}} \supseteq \{M\}$ *(at least one location)*
5. L_{M} *should be able to refer to goods, prices, participants, accounts,...*
6. $CL_{\mathrm{M}} = \{\mathtt{request}, \mathtt{offer}, \mathtt{accept}, \mathtt{declare}, \ldots\}$, *to express all needed illocutions to trade in that market.*

7. *ML_{M} to express rules of behavior and performative structure conditions.*

8. *T an appropriate model of time.*

And following the ideas of Chapter 9:

Example 3 *In* ***negotiation****, the* Dialogical Framework *is a tuple* $DF = \langle Agents, Roles, SR, Loc, L, CL, ML, Time\rangle$*, where*

1. *Agents is a set of agent identifiers.*

2. *Roles is a set of role identifiers.*

3. *$R : Agents \times Agents \rightarrow Roles$, assigns a social role to each pair of agents. Social relations can therefore be viewed as a labeled graph.*

4. *Loc a single scene–location.*

5. *L is a logical language satisfying the previously expressed requirements (Chapter 9). $Deals(L)$ denotes the set of all possible conjunctive formulae in L over equalities between issues and values, i.e. $x_1 = v_1 \wedge ... \wedge x_n = v_n$. $Deals_{?-free}(L) \subset Deals(L)$ excludes '?' as an acceptable value in a deal.*

6. *CL is the communication language among agents. Given $a, b \in Agents$ and $t \in Time$ it is defined as:*

   (a) if $\delta \in Deals(L)$ then $\texttt{request}(a, b, \delta, t) \in CL$.

   (b) if $\delta \in Deals_{?-free}(L)$ then $\texttt{offer}(a, b, \delta, t)$, $\texttt{accept}(a, b, \delta, t), \texttt{reject}(a, b, \delta, t) \in CL$.

   (c) $\texttt{withdraw}(a, b, t) \in CL$.

   (d) if $\psi_1, \psi_2 \in CL$, $\xi \in L \cup ML$, and $\varphi \in L \cup ML \cup CL$ then $\texttt{threaten}(a, b, [not]\psi_1, [not]\psi_2, t)$, $\texttt{reward}(a, b, [not]\psi_1, [not]\psi_2, t)$, $\texttt{appeal}(a, b, \xi, [not]\varphi, t) \in CL$.

7. *ML is a metalanguage over L satisfying the previously (Chapter 9) expressed requirements.*

8. *$Time$ is a discrete totally ordered set of instants.*

10.3.2 Performative Structure

A *performative structure*, $\mathcal{PS} = \langle \mathbf{S}, \mathbf{SDG}\rangle$, is a set of interdependent located scenes. Each scene is defined as a set of agents who are each to assume a given *role*, each pair of agents who ever exchange an illocution are subject to a common *atomic interaction protocol*. Protocols are finite state machines where state transitions are labeled by illocutions and states have associated memory stacks (of "commitments"). I use a *Scene Dependence Graph* to establish causal and temporal co-dependencies among initial and terminal state commitments of different scenes.

In some cases, the whole institution is representable in a single scene. That is the case, for example, of the negotiation model presented in Chapter 9:

Example 4 *In **negotiation**, agents can use the illocutions in CL according to the following negotiation protocol (see Figure 10.1):*

1. *A negotiation always starts with a* deal proposal, *i.e. an* `offer` *or* `request`. *In* `request` *illocutions the special constant '?' may appear. This is thought of as a petition to an agent to make a detailed proposal by filling the '?'s with defined values.*

2. *This is followed by an exchange of possibly many counter proposals (that agents may* `reject`*) and many persuasive illocutions.*

3. *Finally, a* closing *illocution is uttered, i.e. an* `accept` *or* `withdraw`.

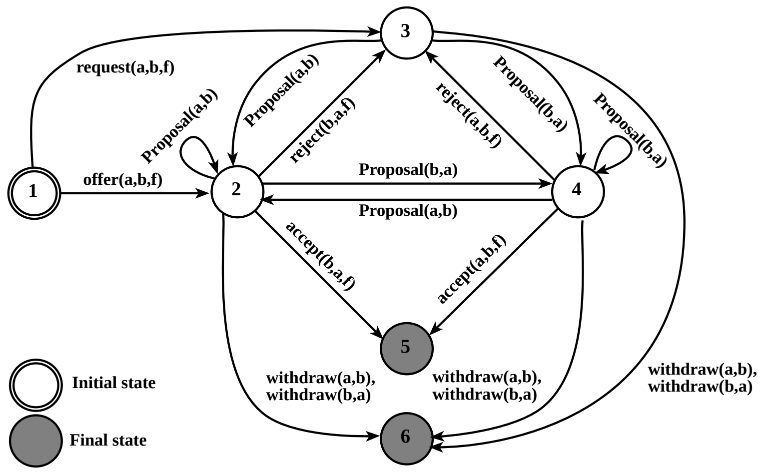

Figure 10.1: Argumentation Protocol.

In other cases, the institution may involve different scenes, whose interrelationship needs to be made explicit. The bidding round scene of the Fishmarket is given by the following transition graph (Fig 10.2)[8].

10.3.3 Rules of Behavior

Even though scene protocols are necessary to describe agent interactions, they may not be sufficient to make fully explicit the "rules of the game" which all participating agents are supposed to follow in a given institution. These rules will be defined as the *individual rules of behavior* of each agent role ρ, $B_{rules}(\rho)$. Such rules are, ideally, part of the internal model of each participating agent, thus they are essential for the governor definition.

[8]It should be noted that in the Fishmarket graph (Fig. 10.2), different terminating states may carry different commitments to different scenes.

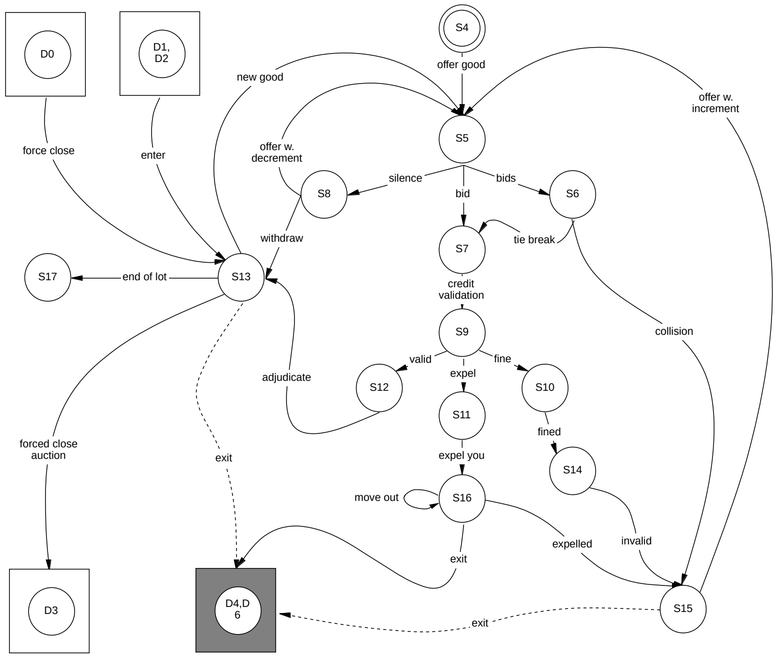

Figure 10.2: Bidding Round Protocol of the Fishmarket.

I introduce the notion of *governor* —or *co-agent*— to denote an agent-like entity c_a that enforces the rules of behavior for an agent-type role onto a specific agent a.

10.4 Governors

As I mentioned before, in most institutions one can distinguish between *internal* or *institutional* agents —for which the institution is fully responsible— and *external agents* who participate in whatever interactions the institution allows them to, and then *ideally* only as long as they submit to the institution's rules. In many agent-mediated institutions it is necessary to guarantee that external agents behave exactly as supposed, in that case they are to guarantee —and the institution ought to be able to make sure they do— that they comply with the aforementioned protocol.

Notion 10.5 *Given an agent a of role $Role(a)$, whose rules of behavior are $\mathcal{BR}(Role(a))$, c_a actual behavior should be consistent with those rules in the sense that for whatever illocution $\iota(a,b,\phi,t)$, if it is* required *by the behavior rules, it will be uttered by the agent–co-agent pair, and if $\iota(a,b,\phi,t)$ is uttered by the agent–co-agent pair, it is not forbidden by the rules of behavior.*

Operationally, these ideas would be as follows: I will have a pair of agents —an agent a and its co-agent c_a— acting as one. The co-agent c_a filters all incoming and outgoing illocutions, and in general guarantees that all rules of behavior associated with the agent's type are actually met. Thus c_a receives all incoming illocutions and re-sends them to a who may deliberate on them. In the meanwhile, the co-agent deliberates and prepares whatever illocutory actions may be required by the rules of behavior, and also identifies those that may be consistent with it. When, after its deliberation, a utters an illocution, it is filtered by the c_a –if the illocution is appropriate it is re-uttered by the co-agent, and if the illocution is inappropriate the co-agent does not make it, and gives the agent an indication of failure– and the pair c_a–a proceeds to a new state. Note, however, that if a triggering condition is met —*e.g.*if there is a time constraint for a response to be made— and a has not been able to produce a *required answer*, then c_a should provide a default answer to guarantee compliance with the existing protocol and rules of behavior, and informs the agent of its execution.

10.5 A CDDL–Interpretation of Institutions

Assuming a reasonable extension of Peleg's Dynamic Logic, such as the one outlined in Chapter 5, one can express the execution control conventions for agents and for institutions.

The underlying intuitions are the following:

1. All illocutionary actions are understood as *bridge rules* (Giunchiglia et al. [60]) of the form:

$$\frac{a : \iota(a, b, \phi, t)}{b : \iota(a, b, \phi, t)}\texttt{IOTA}$$

   Where the numerator indicates the meaning of $\iota(a, b, \phi, t)$ for the uttering agent a, and the denominator its meaning for the listening agent b.

2. Individual agents are always listening and deliberating and in the possibility of uttering illocutions as well.

3. An institution is the simultaneous execution of all its participating agents.

4. When agents are governed by a co-agent, each co-agent controls the illocutory conduct of its agent.

Consequently, each agent's atomic programs must include the canonical interpretation of the illocutions in CL, plus the regular interpretation of its internal deductive cycle. Ideally, as I suggested, an agent is always "listening" to the environment, thus a concurrent execution should be assumed. That is expressed as follows.

Definition 10.5 *An* agent a execution cycle *is:*

$$\pi_a = \{\mathtt{I}OTA_\iota \mid \iota \in CL\} \cap \{T_a \vdash \phi\}.$$

Where, $\{\mathtt{IOTA}_\iota \mid \iota \in CL\}$ *denotes the canonical interpretation of all illocutions* IOTA *in* CL.

The same definition holds when a is an agent–co-agent pair $\langle a, c_a\rangle$, except that the pair's execution program gives priority to the co-agent's deliberations, and all illocutions —to and from the agent— are filtered by the co-agent. *I.e.,* the execution of a governed agent implies that the co-agent filters incoming illocutions, and then enables a to deliberate. Concurrently c_a deliberates and waits until a default value needs to be uttered or an appropriate illocution is generated by a's own theory (T_a) and filtered out by the co-agent:

Definition 10.6 *For a governed agent a, with co-agent* c_a*, the* execution cycle for the pair *is given by:*

$$\pi_{\langle a,c_a\rangle} = \{\mathtt{IOTA}_\iota \mid \iota \in CL\} \cap (\{T_{c_a} \vdash \phi\} \cup (\{T_a \vdash \phi\} \cap \{T_{c_a} \vdash \phi\}))$$

An institution's execution control is just the concurrent execution of all participating agents. When the institution involves governors, then agent–co-agent pairs —and not only agent programs— are executed. Thus

Definition 10.7 *The* institution's execution control *is given by:*

$$\bigcap_{a \in Agents} \pi_{\langle a,c_a\rangle}$$

Or, when the institution involves no governors, by

$$\bigcap_{a \in Agents} \pi_a$$

Now absolute compliance can be achieved, in principle, through these governors. But in practice, it may be enough, for many applications to have a simpler passive *shielding*. This is possible through, for example, the simple governor–like devices that we used in FM96.5. With these, one can prove that shielded foreign agents are "tight" (they receive all and only those market illocutions that they are supposed to listen to) and "secure" (they can only utter acceptable illocutions at the time and place these are acceptable. The implemented bidding protocol is "fair", "synchronic", and "vivacious" because in addition to the above properties, the "premature bid" and the "delayed bid" conditions are avoided. With full governors, the type of dialogue that can be performed between the agent and the governor can be varied. In some cases, the governor might simply inhibit or react with a default action, but in some cases, the co–agent might have to negotiate for a response or explain its actions to the agent, or learn to adequate its behavior. At any rate, this is a rich research topic.

10.6 Institutions and Trust

Auction houses –as other standard commodities-trading institutions– serve an important social purpose by establishing an effective way of articulating buyer's and seller's interactions. A particular auction house serves this purpose well when it becomes a trusted mediator between a particular community of buyers and sellers. Several factors are involved in building this trust, some, perhaps, have to do with peculiar sociological aspects but many too have to do with the way participant's actions are *accounted* for.

This accountability is achieved by the auction house striving to uphold acceptable stable auctioning conditions.

In a traditional auction house, for instance, these conditions are established as "restrictions" on the participants' interactions. These "rules of the game" (some times implicit or tacit rules, though, as we saw in the case of Blanes) are to be observed –"obeyed" as well as "supervised"– by buyers and sellers, and enforced by the auction house employees. Thus if a buyer or a seller does not comply with a rule, he or she should be dealt with appropriately (corrected, admonished, shut down, fined, expelled,...) by an auction house employee. And if the institution fails to observe or enforce a rule –or its employees fail in doing so– buyers or sellers need to be able to demand its observance, because otherwise trust would be at loss.

Accountability then, requires some statement of the (immutable) rules of the game and making sure these rules are properly enforced. This is not trivial. Transgressions need to identified –always and fairly– and then corrective actions ought to be executed, and for these, some means, force or authority need to be available.

When building an electronic institution where software agents may participate (as sellers, buyers or employees), the issue of accountability and the underlying problem of accruing trust involve additional considerations. The most relevant one is that those conditions that articulate participant's interactions can be expressed as constraints on participant's illocutions. In order to identify these constraints I proposed to focus on the dialogical exchanges between participating agents and defining a way to actually restricting agent illocutions according to the conventions stated by the institution.

In fact, restrictions in a market place, and in an auction house in particular, are behavioral and ontological, certainly, but they are almost always reflected through illocutory expressions [9].

In an auction house, the most notable restriction imposed is the one that establishes a bidding protocol for the negotiation of prices, but there are others. The bidding protocol restricts explicitly the illocutions that participants need –and may– utter during the auction, and under what circumstances. Implicitly, this protocol imposes obligations to the participants, namely to pay when a given price is accepted, and to deliver the purchased produce. And implicitly,

[9] Note that in order to "institute a restriction" one is usually forced to use new resources: a standardized language, an intermediary, or an explicit rule.

too, other subsidiary processes are induced by the bidding protocol: some form of "admission" or eligibility processes –both for buyers and for goods– and some form of "exit" processes through which goods are delivered and payments are made. All these subsidiary processes can be viewed as restrictions –or protocols– where illocutions among participants have to follow an orderly sequence and certain actions (and their intended effects) ought to follow or precede those illocutions for the process to be successful. These restrictions, thus, can all be termed "dialogical", since they are inherent to the dialogical exchanges between participants in the auction house.

Other restrictions can be called "para-dialogical". These, for example, involve the type of goods that may be traded, the way these goods are presented to the buyers, the way payment is given to the sellers, and the kinds and forms of guarantees that are required from buyers. These other restrictions can be said to be"para–dialogical", in the sense that they are reflected in the dialogical exchanges –usually as "terms"– but constitute not illocutorial restrictions, but actual behavioral or ontological restrictions –and commitments.

Dialogical restrictions can be formalized, as I suggested in the previous sections, and their implementation tested to determine whether or not certain accountability conditions hold. These conditions have to do (in general) with three main features: the capability of participants to "utter" or "listen to" illocutions, the actual content of illocutions, and the sequencing or structuring of illocutions (into protocols).

So, for example, a bidding protocol should be "fair" in the sense that all participants may bid under identical "listening" and "uttering" conditions, but it may also be required to be "synchronic" in the sense of guaranteeing equal timing for each price call for all bidders, or "vivacious" (fast price changes) or "private" (not revealing bidder identities). I believe that as these conditions are adequately characterized, implemented, verified and upheld, electronic transactions become trustworthy.

To make these restrictions (and commitments) operational and computationally modellable, the formal framework was developed. It can now be applied to a agent–mediated institutions.

Chapter 11

Concluding Remarks

Los casos dificultosos,
tan justamente alabados,
empréndenlos los honrados
y acábanlos los dichosos.

Quevedo

Y luego se soltó cantando una canción que decía:
"Lo bonito es el camino,
llegar es como morir."

Juan Rulfo[1]

In retrospect, writing this dissertation has been like a trip into an unknown land. I did have an idea of how far I wanted to go, now I *know* all the things I would like to do in a second trip.

The guiding theme of this exploration has been the notion of dialogue, and finding out how a highly structured multi agent interaction, that of the fish market auction, lent itself to be analyzed dialogically.

But the exploration had a pragmatic motivation as well, which was to identify ways in which multi agent systems could be put to work. From the beginning we thought Electronic Commerce would constitute an adequate domain to investigate, and the idea of taking auctions as a starting simple example appeared sound. The experience of this work shows that the example was appropriate

[1]Los Cuadernos de Juan Rulfo. Transcripción y nota de Yvette Jiménez de Báez. Ediciones Era, 1994, p.71

indeed, and that plenty of work still lies ahead for agents to participate aptly in real auctions.

In the process of exploration I came upon unexpected finds and difficulties. One aspect I was not prepared for, and has become central in this dissertation, is the notion of trust in agent mediated institutions. It also proved elusive.

Let me use these three themes: dialogues, auctions and trust as the scaffolding from which I will hang, so to speak, the final remarks of this experience —and my best intentions for the future.

11.1 Dialogues

In this dissertation I decided to focus only on the context where the dialogue takes place, and in the conventions that govern the dialogue itself; rather than focus in how the participants of the dialogue decide on what to say and do. And in Chapter 4 I introduced three theoretical constructs that I believe deserve further development: the *dialogical stance* the notion of a *dialogical institution* and the idea of an agent *governor*.

Dialogical Stance I am convinced that thinking of multi agent systems in terms of dialogues is not just a conventional choice. I believe that dialogical notions are pertinent, relevant and unavoidable to deal with the type of complex interaction that multi agent systems involve. Classical dialogical distinctions and tools, as well as recent computational dialectics proposals will probably find in multi agent systems a fertile field for application, and stimuli for further development. And I am also convinced that much of the fundamental debates inherent in the agent metaphor —autonomy, representativity, situatedness, cooperation, deceit, liberty, teleology— can profit considerably from an articulation in dialogical terms.

Three examples were presented in this dissertation that lend support to these claims:

1. The description of the fish market auctioning conventions (Chapter 4), and its generalization to agent–mediated auctions (Chapters 7 and 8) and agent mediated trading (Chapters 8, 9 and 10).
2. The dialogical model of agents (presented in Chapter 5 and whose implementation is reported in Chapter 7).
3. And the model for argumentation based negotiation (Chapter 9).

In all these cases, however, my contribution has been limited to a descriptive perspective in which I have attempted to point out the relevance of the dialogical stance and explore the *material* aspects of dialogue. Now it would be time to start looking into the *dynamic* aspects of dialogue, and develop some predictive elements as well.

Dialogical Institutions The characterization of a dialogical institution as a triad (Dialogical Framework, Individual Rules of Behavior and Social Conventions) was fortunate. The details deserve careful reassessment.

As shown in Chapters 4, 7, 8, 9 and 10, that schema is simple and flexible, and lends itself for a thorough formalization. That should be an immediate task, and one for which tools seem to be quite at hand. Notions of internal consistency between social conventions and individual rules of behavior, as those suggested in Chapters 7 and 10, appear to lend themselves to a rich pragmatic treatment, and one that can profit from semantic approaches. Constitutive elements such as the idea of scene or an atomic protocol, and how two–party protocols can be combined into more complex dialogical processes, for example, are merely sketched. And specific properties, such as the ones mentioned in regard to fairness, bidding reductibility and livelihood deserve also a formal treatment that no doubt will produce interesting and useful results.

In this dissertation I have been referring to institutions as if they were static objects, I dont think that is a necessary assumption. In fact, there is no reason (neither in principle, nor in practice) why the sets of social conventions and rules have to be fixed, not even the dialogical framework for that matter. I consider the possibility of having evolving institutions to be a limit case for dialogical stance, in the sense that if these are not expressible naturally in a formalism, then the formalism should be suspect.

The way the Fishmarket institution, in particular, was treated in Chapters 4,5, 6 and 7, served to show that highly structured multi agent interactions can in fact be minutiously described and formalized, implemented and utilized. But by the same token, it showed that any generalization of this tasks to equally or more structured new types of institutions will require description, specification, deployment and validation tools of better performance than the ones used here. Colored Petri Nets, π–calculus, etc. may perhaps prove adequate for some of these tasks, but at any rate new developments will be needed to be able to pass from description to certification (which is the likely destiny of agent mediated commercial institutions) and consequently a fertile area of work is there open. Chapter 9 on its part, though, shows how the dialogical stance can still be useful for non–structured interactions, but it indicates also how some additional distinctions are very evidently going to be needed to assess the contents and individual behavior of agents. If these different concerns will require tools that are to be similar or even the same as those needed in highly structured multi agent systems remains to be seen.

Agent Governors In Chapter 6 I reported how the simple mineing devices used by buyers in the Blanes fish market were generalized into the *nomadic devices* that acted as two–way interfaces for FM96.5 external participants, be they human or software agents. In Chapter 7 I mentioned how tournaments and auditing profited from the fact that external agent interactions were all mediated through these *remote control devices*, but it was not until Chapter 10 that I gave a definition and the real intention behind these modest examples. Although they serve, evidently, quite practical purposes: to facilitate communication, facilitate the propagation of a standardized convention, facilitate the compliance with a protocol, agent governors are in fact more significant, because they can enforce the rules of an institution and therefore establish some guarantees.

From a practical perspective this idea has at least three important consequences:

1. It can establish product differentiation.
2. It can certify acceptable behavior for the governed agent and for all others that interact with it.
3. It lends itself for independent auditing.

From a formal point of view, the definition is still close to the originating example and should perhaps be revised to make it more elegant and —more important— more convenient for actual formal testing of properties and reliable certification procedures.

Agent governors are a nitid example of the fertility of the dialogical stance, it was because the focus of attention of this research has been in the illocutory exchanges, that the notion of having a pro–active filtering of illocutions was conceived.

11.2 Agent Mediated Auctions

When we first thought of using an auction as a multi agent problem domain we were barely aware of its intrinsic richness. From my naive point of view, auctions were fine *to start with*, and that because of two rather evident reasons: Auctions seemed a convenient way of circumventing the push–pull dilemma of commercial applications of agents. And auctions seemed simpler to study than other market places. Those two appreciations I still hold, but now with strong qualifications. Although a virtual market place may circumvent the push–pull problem, it only does so partially, and it creates new, different problems that in some fortunate cases may be dealt with conveniently. Auction houses are not really that simple as market institutions, and especially not for participating agents. However, I can now claim, because of that mixture of structural simplicity and non–apparent real complexity and richness, that auctions constitute an attractive research topic and an important application domain. I will elaborate an argument for this claim in the three paragraphs that follow.

The Auction Testbed Because of the real simplicity of the auctioning interaction protocol, and the development of our nomadic interfaces, the Fishmarket has spawned a flexible test bed that is agent–architecture neutral and accessible to any agent developer to test her or his proposal competitively. As described in Chapter 7, the variety of experimental conditions that can be devised is considerable, and many aspects of agent architecture, trading strategies and auctioning or bidding heuristics can be tested in standardized, repeatable, controlled and recordable conditions. It is now time to define some convenient reference criteria. For instance, the amount of money that is available in the market and its allocation, the variability of items, the evaluation criteria. Some of these criteria can and should be set on technical grounds, like the ones economists may advance. Others will probably benefit from some experimentation, while others will emerge from the actual usage of the tool. And now it is time, also, to start developing, and examining under systematic experimental conditions, agent shells, specific heuristics, learning strategies .

Such ground setting effort and the ensuing experimental work should not be confined to the Fishmarket project participants, but opened to other researchers from complementary disciplines and from complementary interests. But it should be well documented and at least in some future work–enabling aspects, carefully planned. Planning, in particular, will be advisable for future developments of the basic FM platform. On one hand more analysis and visualization tools should be incorporated. And better data handling and documentation of historical data should be incorporated. Additionally, but perhaps as important, the basic bidding convention has to evolve to incorporate other protocols and other forms of competitive and negotiation–based price setting.

Taxonomy So far, I have given two characterizations of auctions, one that is very general (Chapter 10), and another one influenced by the Fishmarket specific features (Chapters 4 and 7). In between, I have advanced multiple examples of auctions, and some comments that indicate how close the above mentioned characterizations are to some of those examples. However I did not produce a detailed characterization for auctions that are not what I called F–variants, nor a true taxonomy of auctions and agent mediated market institutions. Both are tasks that can now be attempted with confidence, since crucial distinctions are (at least to me) now at hand. I realize that economists, lawyers or historians might have had their own distinctions available but, from an agent perspective, their taxonomies and characterization of auctions were not adequate, in my opinion.

A finer characterization, and an associated taxonomy, should have useful consequences. On one hand it should allow for a more rigorous way of stating interdefinability and reductibility of bidding conventions. But, more importantly, it should serve to express and test (objectively) the existence or absence of specific characteristics, features and properties that may have theoretical, operational or commercial interest. And if the characterization and taxonomies are good, they should guide the development of new trading institutions whose features, characteristics and properties can be assessed and tested (objectively) by any potential user or owner.

Applications FM is a naive auction house, but it should not be difficult to turn it into a real agent mediated auction house. How and when depends on the availability of a project.

Commercial Internet based auctions are now appearing, as was discussed in Chapter 8. Agent–mediated auctions are still not existent, but it is likely that they will also appear in the near future. As shown by the Fishmarket exercise, though, many aspects have to be properly taken care of to have safe agent mediated trading. Some aspects, cryptography, cash transference are being developed already by software and hardware vendors and should be incorporated to FM if and when it turns to commercial applications, but in this research effort we realized that other issues beyond those should be well taken care of, as well.

11.3 Trust

The central concern, I now think, that should guide innovation and commercial development will be trust. What features build trust, what features deteriorate it, how far one can go in guaranteeing certain things, how much structuring we put in a convention, how much we leave to individual regulation, are but the obvious concerns.

Properties To start addressing the issue of trust, we needed some words to talk about, some properties of processes to validate, some features to characterize. In this dissertation some of that was accomplished. In Chapter 6 some properties of the bidding implementation were characterized and in chapter 10 others were defined. Formal proofs should be devised to test whether a property (positive or negative) holds or not.

But trust is not a matter of a procedural feature only. As the discussion of Blanes unenforceable rules (in Chapter 3) showed, Institutional trust may depend on structurally enforced procedures and rules, but always with a carefully balanced discretionality. If agent mediated institutions are going to be trustworthy, it will depend largely on how effective they are in enforcing the structural rules, and therefore in the type of rules they decide to make structural. And also on what behavior is left unregulated and uncontrolled by the auction house.

From a multi agent perspective, the balance between fully agent–based mediation (house staff) and some human intervention will, in practice, be of fundamental importance. And because of that, powerful conceptual and technical resources will be needed which I am afraid are not yet at hand. In the absence of a fully developed theory of trust and availability of ready to use trust–building components, some caution is advisable in any claims made on safety and reliability of agent–mediated markets. It would seem preferable to depend on a clear and objective distinction between what is enforced and what is not. And in this direction, the notion of an explicit protocol, and explicit rules of behavior incarnate in testable agents and remote control devices is, in my opinion, a step in the right direction.

The next step is to certify agents and interfaces behavior, and attempt to achieve guarantees. On the other hand, I believe that a clear characterization of unwanted features, mischievous and malicious behavior, deceit and fraud is urgently needed as well. And, perhaps, new forms of contracting agents will be needed.

11.4 A final remark

I believe that a sound theory is good in practice. The Fishmarket project is another exercise in approaching reality analytically and attempting to obtain an abstract counterpart of it. Much is lost in the abstraction process, but much is learned as well. By re–expressing a fragment of reality in a new language, new reality is produced.

Sometimes this poetic effort results in beauty. Sometimes in something useful as well.

And, then, the trip is worthwhile.

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