

Web-i(2): Electronic Institutions: Extending the Core Notion TIC2003-08763-C02

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Abstract

Electronic Institutions are means to implement interaction conventions for agents — human or software— who can establish commitments in a virtual environment.

The *Web-i(2)* project explores different ways of using and extending the primitive notion of electronic institution. It is organized around three themes: the study of the ideas underlying electronic institutions (EIs), the development of tools and methodologies for the construction of EIs, and the actual construction of examples of EIs. The project draws inspiration from two main sources: the work on coordination in agent societies developed by the URJC team and the work on electronic institutions of the IIIA team.

This document reports the results of the first twenty months of the project life.

Keywords: Multi-agent systems, electronic institutions.

1 Background

Agent-based technologies were originally focused on the features that enabled individual agents to interact, namely agent rationality and communication. The appearance of multi-agent systems (MAS) brought forward the social component of the interactions of groups or populations of agents. Although emphasis in MAS research has largely been put in the internal architecture of those agents and the communication capabilities, issues like task allocation, cooperative and competitive behavior, coordination mechanisms and their constitutive elements have gradually become part of the mainstream.

The notion of *electronic institution* (EI) focuses on the *environment* where agent interactions take place and structures them mirroring the way traditional institutions have articulated interactions among human agents. EIs have been conceived as coordination artifacts where the social elements of the coordination are made explicit and the subjective elements are left to the individual agents that join the electronic institution. The term *electronic institution* was coined at the IIIA to refer to the computational analogue of traditional institutions. Those concerns

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and ideas behind that proposal have motivated alternative and complementary developments. Nowadays, the notion of virtual organizations, and electronic institutions in particular, has become one of the standard topics of interest in MAS. In the meanwhile the original IIIA proposal has evolved over seven years and is stable enough to deserve revisiting its foundations and goals.

In this context, the *Web-i(2)* project aims at studying the intuitions behind EIs in order to have a sounder theory and better tools to construct open multiagent systems building on the previous work of the two participating groups of researchers. The URJC team has centered their previous research around the use of agent technologies for decision support systems and in particular in communication and coordination among agents for that purpose. In this project they contribute along two lines: (i) the coordination of agent societies through normative structures and (ii) objective and subjective elements in coordination mechanisms in agent societies. The IIIA team has been interested in organizing agent interactions through electronic institutions (EIs) and developing tools and examples around that concept.

The EI proposal is based on the following assumptions:

1. *Agent-architecture neutrality*: Nothing is assumed about the rationality, capabilities or intentions of participating agents.
2. *Dialogical stance*: All agent interactions are construable as speech acts.
3. *Repetitive interactions*: Agent interactions may be organized into some hierarchical system composed by sets of speech acts and relations among these sets.
4. *Institutional commitments*: The institution is the warrant of the intended conditions for illocution utterance and their effects.

These assumptions allow us to think of institutions as a set of conventions that constrain the class of possible dialogues to a set of admissible ones and their intended effects. Likewise, an EI can be seen as a set of norms that regulate agent interactions. We operationalize these assumptions through three simple concepts: the language for illocutions (*dialogical framework*); the structuring of interactions (*performative structure*); and *rules of behavior*, the conventions that regulate commitments (cf. <http://e-institutions.iiia.csic.es/>).

What we call the *core notion*, EI_0 , is one way of defining those three concepts. Roughly speaking, in EI_0 , the dialogical framework establishes a simple illocutory language that involves roles and a rather simple social structure among roles. The performative structure is composed of scenes and transitions between scenes. Scenes are finite-state graphs whose arcs are admissible illocutions and nodes reflect the state of social commitments as they change through the admissible utterances; transitions are a set of standard scenes that are used to control conversation flow. Finally, rules of behavior are bundled up as *obligations* that establish the conditions and social effects of illocutions uttered at some point in the enactment of an institution.

EI_0 produces institutions with explicit, fixed *a priori* conventions whose compliance is obligatory and strictly enforced for participating agents. Although that is a large and quite interesting set of institutions, in the present project we intend to go beyond this state of the art and investigate essentially along three major lines: (i) to develop a better understanding of the core notions of EIs, (ii) to develop adequate tools for building EI_0 -based institutions, and (iii) to be able to define and implement other types of institutions.

2 Project objectives

The *Web-i(2)* project aims at making explicit and precise the intuitions of the EI proposal by looking carefully into EI_0 and exploring some extensions that are formally or empirically interesting, in order to have better tools for modeling institutional environments that are more complex and require more flexibility than those EI_0 may give us. We translated these intentions into five tasks that organize the analysis of EI_0 and its potential extensions, the construction of tools that enable the design, construction and refinement of actual EIs and the exploration of application domains that may serve to elicit and test the extensions of EI_0 . The tasks, subtasks and deliverables that correspond to these objectives of project *Web-i(2)* are summarized in Table 1.

Coord	Task	Subtask	Resp.	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	q11	q12	
PN	T1: Core Notion Extensions	a) Core Notion	PN	X	X	X	R	X	X	X	R	X	g	g	R	
		b) Alternative Normative Notions	PN	X	X	X	R		X	X	R	X	X	X	R	
		c) Dynamic. Institutions	CS	X	g	g	R	X	X	X	R	X	X	X	R	
		d) Negotiation	FE	X	X	X	R	X	X	X	R	X	X	X	R	
		e) Formal treatment	LV	X	X	X	R	X	X	X	R	X	X	X	R	
		f) Institutions ABSM	SO	g	g	X	R	X	X	X	R	X	X	X	R	
JR	T2: Tools for an Institutional Layer	a) ISLANDER extensions	CS	X	X	X	RP	X	X	X	RP	X	g	X	RP	
		b) Governors	JR	g	g	g	RP	g	g	g	RP	g	g	g	RP	
		c) Governor validation	LV	g	g	g	RP	g	g	g	RP	g	g	g	RP	
		d) Activation	JR	g	g	g	RP	g	g	g	RP	g	g	g	RP	
		e) Executability tests	JR	g	g	g	RP	g	g	g	RP	g	g	g	RP	
		f) Visualization	JR	g	X	X	RP	X	X	X	RP	X	g	X	RP	
SO	T3: Visualization and Modelling Tools	b) Simulation	AF	g	X	X	RP	X	X	X	RP	X	X	X	RP	
		d) ABSM	JMS	g	X	X	RP	X	X	X	RP	X	X	X	RP	
		a) Mechanism Design	JR	g	g	X	RP	X	g	X	RP	X	X	X	RP	
		b) DSS-ABSM	SO	g	g	X	RP	X	g	X	RP	X	X	X	RP	
JR	T4: Application Domains	c) Multifunctional EIs	PN	g	g	X	RP	X	g	X	RP	X	X	X	RP	
		a) Coordination	PN	C	C	C	C	C	C	C	C	C	C	C	C	
		b) Prototype evaluation	JR	g	X	X	R	X	X	X	R	X	X	X	R	
PN	T5: Dissemination and Technology Transference	c) TT entities	PN	M	g	C	C	C	g	C	C	C	C	C	C	
		d) European Space	SO	X	X	X	X	X	X	X	X	X	X	X	X	W
		e) Dissemination of results	PN	R	R	R	R	R	R	R	R	R	R	R	R	

Keys:

Researchers:

IIIa: a) J. Agustí, Francesc Esteva (FE), Pablo Noriega (PN), Juan Antonio Rodríguez (JR), Carles Sierra (CS), Lluís Vila (LV)

URJC: a) Sascha Ossowski (SO), A. Pradera, Juan Manuel Serrano (JMS)

q1, ..., q12: quarters

X = Coordinated activity for both groups in this task
P = Prototype

g = Independent activity of one group at least
C = Coordination meeting

R = Report
W = Workshop

Table 1: *Web-i(2)* Workplan

3 Accomplishments

The project has proceeded along the expected path. The two groups have interacted fruitfully, holding regular coordination meetings, plus exchanging visits, co-organizing events and producing complementary and joint developments as the following paragraphs show. Most of the original project objectives have either been accomplished already or are well on the way of being accomplished. The overall balance is very positive and, since the project is about halfway through, we anticipate a successful conclusion.

Current achievements suggest productive and challenging collaborative work beyond the *Web-i(2)* project time-frame.

Theoretical extensions of the core notion of electronic institution (Task T1). In the last twenty months the groups have been involved in a careful discussion of the intuitions behind each of the components of EI_0 following three complementary lines of work. First, there has been a characterization of different structural operations on *performative structures*, second, a first attempt on defining standard —reusable— scenes and, finally, on expressing conventions as rules (or norms).

- The idea behind *structural extensions* of EI_0 is to be able to splice new scenes into existing structures, or even whole performative substructures assembled from other substructures. The purpose is twofold, on one hand to facilitate a modular construction and testing of EIs and, on the other, enabling a straightforward mechanism for EI updating or modification. In particular, we have characterized hierarchic *performative structures* so that one institution may be embedded into another provided some consistency constraints hold. This feature is being incorporated into the forthcoming release of the EIDE platform mentioned below.
- We have attempted an alignment of the RICA conceptual framework developed by the URJC team with EI_0 . In that process we looked into generic extensions of the RICA communication frameworks and their meta-model. That effort has led us to explore *standard scenes* that may be instantiated or refined to fit particular requirements while being readily spliced into a *performative structure*. This line of research is based on the social communication contexts proposed by J. M. Serrano in his dissertation and the splicing techniques just mentioned. We expect to move in the direction of some sort of compositional language to specify and modify performative structures. We are now using these ideas plus the structural extensions mentioned above in the problem domains mentioned in Task 4.
- The idea of expressing *conventions as norms* is really a generalization of the behavior rules that underlie the notion of commitment in EI_0 . The purpose is to formalize EIs as theories in a formal language (with some type of deduction). We have, so far, proposed a very conservative extension to the current notion of obligation and with that we have defined and implemented an interpretable language that is expressive enough to capture many types of normative expressions. This topic is theoretically very fertile and has attracted the attention of many researchers in MAS. It has also been the motivation for us to organize three different meetings that we mention below.

A somewhat complementary line of research was spawned during the visit of Michael Luck and Mark D’Inverno to the IIIA this winter: a *Z-specification* of EI_0 for which a tentative first version has already been produced.

Tools for an institutional layer in MAS (Task T2). Our aim is to produce a toolbox for building EIs in a principled and practical way. We started from *ISLANDER* and produced an extension of it plus a complete suit of tools for specification and deployment of EIs. The tools have been organized into an electronic institutions development environment, EIDE, whose third release is now underway. The following are the tools in EIDE:

- *Tools for specification and validation of EIs.* *ISLANDER* has become a graphic specification language that includes some automated verification functionalities of syntactic

features (completion, consistency and coherence). Extensions to RICA-J for AUML-based organizational models, and further extensions to incorporate normative elements in the specification are underway.

- *Tools for deployment.* *AMELI* is a middleware layer that enables the enactment of *ISLANDER* specified EIs on top of a FIPA-compatible agent communication infrastructure like JADE. *AMELI* generates all staff agents for an EI, including the *governor* agent wrappers for external agents. Additionally, we are working on extensions to RICA-J to deal with scalability in EIs.
- *Tools for the generation of agents.* Although *AMELI*-generated *governors* handle all the communication constraints and flow control conventions that the EI imposes on external agents —without assuming any particular external agent architecture— users still need to have their agents decide what to communicate and when. *AGENTBUILDER* is a tool that may be used to construct agents that comply with *ISLANDER* spawned governors, hence liberating the external designer from any interfacing concerns and allowing her to focus only in the decisional aspects of her agents.

Visualization and modeling tools (Task T3). Following the original workplan we are working along two other lines of tool building activities that complement those in Task T2.

- *Visualization tools.* In order to observe the activities of agents in an institutional-based MAS, we are building a visualization tool —based on the RICA organization and communication concepts— to show in an intuitive way the organizational activity, the roles agents are playing and their interactions. For the same purposes, we have developed (In collaboration with the University of Technology of Sydney) a tool that produces a 3-D animation of any *ISLANDER*-specified EI.
- *Tools for simulation and monitoring.* Given an *ISLANDER* specification of an EI, the *SIMDEI* tool produces a lightweight (object-based) version of it —including simple agent skeletons for all agents involved— that the designer may use to realistically explore the functionalities of the EI and go back to the drawing board if needed. *SIMDEI* is built around a REPAST simulator. In addition to *SIMDEI* and the visualization tools mentioned above, we have also built, *EIMONITOR*, a tool that keeps track of all the interactions that take place in an EI during a run-time enactment of it. *EIMONITOR* works on top of the *AMELI* middleware.

Application domains (Task T4). We are working in the following directions:

- *Mechanism design.* Analysis and implementation of a new type of negotiation mechanism: generalized combinatorial auctions. Conceived as non-trivial EI_0 -definable EIs are now undergoing the typical analytical testing for mechanism design, plus the empirical testing through its EIDE implementation. We have also implemented several examples of other EIs.
- *Negotiation.* Work has proceeded in two lines. First the design and testing of decisional models for fish-buying agents that participate in the federated auctions of the MASFIT

market institution. Second, the development of a theory and experimental methodology of Information-based negotiation, in collaboration with J. Debenham (U. Technology Sydney).

- *Modeling agent-based social systems.* We were involved with the World Tourism Organization and a tourism consultant firm in the development of an agent-based DSS for the management of tourism destinations, TMS. A prototype, based on the SADDE methodology, was released in August 2004. For the time being, we do not foresee further work in this direction.
- *Complex-flexible institutional environments.* This line is where we are putting most of our effort. We are exploring three problem domains that have many significant features in common: Conference workflow management; Help desk services and local government actions; corporate hotel management. The three domains are amenable to EI treatment and require the type of structural and normative flexibility we have mentioned above.

Dissemination and technology transfer (Task T5).

- *Coordination tasks.* Both groups have been in touch regularly. There have been three scheduled group meetings (two in Barcelona, one in Madrid) and short reciprocal visits from the PhD students. In addition, the many international events organized by the teams have provided extra opportunity to collaborate. A project webpage is up (<http://webi2.urjc.es/englishIndex.html>).
- *Prototype evaluation.* The EIDE open-source platform has had two different releases. Furthermore, a *beta* version of a new EIDE upgrade and five implemented EI_0 examples are now publicly available on-line (<http://e-institutor.iiia.csic.es/islander/pub>). More than one hundred copies of EIDE have been distributed in courses, conferences, demos and upon request.
- *Contacts with potential user firms.* In January 2005 we organized a meeting in Madrid with firms that are working on the problem domains we are interested. The meeting served to exchange experiences and consider possible joint activities. We are also preparing a technology transference contract with a software house to develop an EI-platform.
- *Contacts in the European space.* The group members have been very active in this sub-task. Most actions are listed below – here we only outline the most significant ones. The *Web-i(2)* partners co-sponsored and headed the local organization of the European Conference in Multi-agent Systems (EUMAS04); co-organized and co-sponsored a round table meeting on virtual organizations and organized two workshop on electronic institutions that are co-located with large international conferences. Group members participated in the organization of several workshops and meetings whose content is associated with this project, and are part of the agent-related European networks of excellence. Both partners are involved in VI Framework Program projects that are closely related to the *Web-i(2)* subjects. Both groups have stable academic relationships with foreign universities and research groups, and have exchanged several visits over the last twenty months.

- *General dissemination activities.* Group members taught seminars and short courses on *Web-i(2)* subjects in the European Summer and Spanish schools on agents (EASS-04, 05; AgentCities.ES-05) and in universities in the UK, Holland, Spain and New Zealand. There was a significant number of papers presented in international conferences, students attended courses on topics related to the project's content and there were demonstrations of EI developments in four international conferences (ECAI-04, AAMAS-04, AAAI-04, MATES-04). The project sponsored two international events and received public recognition for it.

4 Result indicators

This section summarizes the results obtained until July 2005, i.e. the first 20 months of the *Web-i(2)* project lifetime.

4.1 Scientific and technological production

Publications. At the time of this writing, 43 publications have been realized within the *Web-i(2)* project:

- 9 books (edited): [18, 6, 17, 19, 9, 10, 11, 39, 16]
- 12 book chapters (Springer, Kluwer, etc): [30, 21, 23, 13, 8, 20, 26, 28, 4, 42, 43, 25]
- 7 articles in international journals: [24, 22, 33, 41, 1, 36, 38]
- 9 papers at international conferences (ACM, IEEE, etc): [32, 3, 34, 12, 37, 5, 7, 27, 40]
- 6 other publications: [2, 31, 14, 15, 35, 29]

Software developments. One software platform, *EIDE* (with several tools: *AMELI*, *aBuilder*, *ISLANDER*, *SIMDEI*, *EIMONITOR*); the *EI in 3-D* visualization software; the RICA-J specification and visualization tools; *IBundler* combinatorial auctions server and an *AMELI*-compatible norm language interpreter prototype.

4.2 Education of human resources

Theses. The following seven PhD theses are linked to the *Web-i(2)* project.

- Eva Bou. Dynamic and reconfigurable electronic institutions. Under development.
- Alberto Fernández. Semantic service coordination in open environments. Under development.
- Andres García-Camino. Norm-based electronic institutions.
- Andrea Giovannucci. Combinatorial auctions. Under Development.
- Ramón Hermoso. Agent-based social simulation. Under development.

- Armando Robles: EI-based corporate information systems.
- Sergio Saugar. Coercive multiagent infrastructures. Under development.
- Juan Manuel Serrano. Pragmática de los agentes software: análisis y diseño de lenguajes de comunicación artificiales. (URJC, Jul 2004).

In addition, several undergraduate thesis have been carried out within the project. Recently, the IIIA team received a grant from CSIC for funding PhD research assistantships on electronic institutions. Four students will be chosen from the more than one hundred candidates who submitted CVs for those assistantships.

Courses taken. PhD students of the *Web-i(2)* teams have enrolled in the following advanced courses:

- AAI-2004, (S.José, CA), [Andrea Giovannucci]
- AAGTLSN-2004 on complex systems, co-organized by the EXYSTENCE European network of excellence (Santorini) [Jorge San Martín].
- AAMAS2004 Americas' School on Agents and Multiagents Systems (New York) [Andrea Giovannucci]
- EASSS-2004 on agent technologies, AgentLink III (Liverpool) [Eva Bou, Andrea Giovannucci, Andrés García, Sergio Saugar].
- EASSS-2005 on agent technologies, AgentLink III (Amsterdam) [Ramón Hermoso].
- ECAI 2004, (Valencia) [Andrea Giovannucci]
- Escuela Española de Agentes, AgentCities.ES (Sevilla) [Andrés García, Ramón Hermoso].

Courses taught. The research performed within the project has found its way into several graduate and final-year undergraduate lectures. In addition, the following courses have been taught by senior members of the teams

- Agent Mediated Interactions, PRIMA (New Zealand) [Carles Sierra].
- Agent-mediated Electronic Commerce, EASS04 (Liverpool) [Juan Anonio Rodríguez].
- Agent technology applied. Escuela Superior de Administración y Dirección de Empresas (ESADE) [Juan Antonio Rodriguez-Aguilar]
- Desarrollo de Sistemas Multiagente, Ikerlan (Mondragón) [Marc Esteva and Juan Antonio Rodríguez].
- Engineering open environments with electronic institutions (University of Aberdeen) [Juan Antonio Rodriguez-Aguilar]
- Instituciones Electrónicas, Escuela Española de Agentes (Sevilla) [Josep Lluís Arcos].

4.3 Relations with the socio-economic context

Technology transference.

- Contract proposal with a software house, Grupo TCA.
- DMR grant for applied research (DMR Decision Engineering Lab)
- Contacts with Telefónica, Barcelona City Government, Blanes City Hall, AUTEK, World Trade Organization, Mazars Consulting, Grupo TCA.
- More than 150 downloads of the EIDE platform from the *Web-i(2)* site and more than two hundred cd-copies of it distributed.

Participation in related projects with industrial participation.

- Context-Aware Business Application Service Coordination in Mobile Computing Environments (CASCOM). Funded by the 6th FP of the EU as STREP. 2004-2007
- Ever-growing global scale-free networks, their provisioning, repair and unique functions (EVERGROW). Funded by the 6th FP of the EU as IP. 2004-2007
- OK (Open Knowledge). EI-based P2P web-services. Funded by the 6th FP of the EU as STREP. 2006-2009

Participation in networks

- European network on agent technology (AgentLink III)
- European network on complex systems (EXYSTENCE)
- Spanish network on agent technology (AgentCities.ES)

4.4 Relations with European and international teams

International collaborations The project has greatly helped establishing and consolidating links with other research groups. These links have materialized on joint publications, joint organization of events, and joint projects. The following is a list of the main researchers and groups that the *Web-i(2)* teams are currently collaborating with:

- Huib Aldewereld (U. Utrecht, NL)
- Ron Ashri (U. of Southampton, UK).
- Anton Bogdanovych (U. of Technology Sydney, AS).
- Paul Davidsson, (Blekinge Institute of Technology, SE)
- John Debenham (U. of Technology Sydney, AS).
- Frank Dignum (U. of Utrecht, NL)

- Les Gasser (U. of Illinois Urbana, US)
- Mark d’Inverno (U of Westminster, UK)
- Matthias Klusch (DFKI, DE)
- Michael Luck (U. of Southampton, UK)
- Ronaldo Menezes, (Florida Institute of Technology, US)
- Marcos Oliveira (U. of Otago, NZ)
- Andrea Omicini, (U. of Bologna, IT)
- Julian Padget, (U. of Bath, UK)
- Sarvapali Ramchurn (U. of Southampton, UK)
- Wamberto Vasconcelos (U. of Aberdeen, UK)

4.5 Other dissemination activities

Organization of international events.

- ACM SAC-2004 Special Track on Coordination Models, Languages and Applications (Mar 04, Nicosia) [Sascha Ossowski]
- Agent Link II. Technical Forum Group in Trust (Jun 04, Rome) [Juan Antonio Rodriguez-Aguilar]
- AAMAS04. (Jul 04, New York) [Carles Sierra]
- AMEC-VI 2004. (Jul 04, New York) [Juan Antonio Rodriguez-Aguilar]
- ATT 2004 (Jul 04, New York) [Sascha Ossowski]
- ECAI 2004 (Aug 04, Valencia) [Carles Sierra]
- ECAI Workshop on Coordination in Emergent Agent Societies (Aug 04, Valencia) [Sascha Ossowski]
- Eighth International Workshop CIA 2004 on Cooperative Information Agents (Sep 04, Erfurt, Germany) [Sascha Ossowski]
- EUMAS04 European Conference on Multiagent Systems (Dec 04, Barcelona) (with *Web-i(2)* sponsorship) [Pablo Noriega]
- ACM SAC-2005 Special Track on Coordination Models, Languages and Applications (Mar 05, Santa Fe) [Sascha Ossowski]
- Barcelona Round Table on Virtual Institutions and Legal Theory: The confluence of legal and multi-agent systems perspectives (May 05, Barcelona) (with *Web-i(2)* sponsorship) [Pablo Noriega]

- XXII World Congress of Philosophy of Law and Social Philosophy IVR 2005. Workshop on AI and LAW: The regulation of electronic social systems. (May 05, Granada) [Pablo Noriega]
- AAMAS-2005 Workshop on Agents, Norms and Institutions for Regulated Multiagent Systems (ANIREM) (Jul 05, Utrecht) [Sascha Ossowski]

Invited talks

- PRICAI 2004, (Auckland, NZ) Electronic Institutions: Methodology of Multi-agent Systems development [Carles Sierra];
- I-Sourcing Forum, (Barcelona) *Tendencias Futuras en I-Sourcing* [Juan Antonio Rodríguez];
- Foro Tecno-atlántico 2004 (Vigo) *MASFIT y subastas intermediadas por agentes* [Pere Garcia];
- ESAW 2004, (Toulouse) *Electronic Institutions an Explorer's Notebook* [Pablo Noriega];
- ANIREM 2005 (Utrecht) *Fencing the Open Fields: Empirical Considerations on Electronic Institutions* [Pablo Noriega].

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