Norm enforceability in Electronic Institutions?

Natalia Criado[1], Estefania Argente[1], Antonio Garrido[1], Juan A. Gimeno[1], Francesc Igual[1], Vicente Botti[1], Pablo Noriega[2], Adriana Giret[1]

[1] DSIC, Department of Information Systems and Computation, Universitat Politècnica de Valencia,
[2] IIIA, Artificial Intelligence Research Institute, CSIC, Spanish Scientific Research Council,
{ncriado,eargente,agarridot,jgimeno,figual,vbotti,agiret}@dsic.upv.es
pablo@iiia.csic.es

Abstract. Nowadays Multi-Agent Systems require more and more regulation and normative mechanisms in order to assure the correct and secure execution of the interactions and transactions in the open virtual organization they are implementing. The Electronic Institution approach for developing Multi-Agent Systems implements some enforceability mechanisms in order to control norms execution and observance. In this paper we study a complex situation in a regulated environment in which the enforceability mechanisms provided by the current Electronic Institutions implementation cannot deal appropriately with norm observance. The analyzed situation is exemplified with a specific scenario of the *mWater* regulated environment, an electronic market for water-rights transfer. After this example is presented, we extrapolate it to a more generic domain while also addressing the main issues for its application in general scenarios.

1 Introduction

In general, norms represent an effective tool for achieving coordination and cooperation among the members of a society. They have been employed in the field of Multi-Agent Systems (MAS) as a formal specification of a deontic statement that aims at regulating the actions of software agents and the interactions among them. Thus, a *Normative MAS* (NMAS) has been defined in [3] as follows:

> "a MAS organized by means of mechanisms to represent, communicate, distribute, detect, create, modify, and enforce norms and mechanisms to deliberate about norms and detect norm violation and fulfilment."

According to this definition, the norm enforcement problem, faced by this paper, is one of the key factors in NMAS. In particular, this paper faces with the enforcement of norms inside Electronic Institutions (EIs) that simulate real scenarios. EIs [21, 24, 8] represent a way to implement interaction conventions for agents who can establish commitments in open environments.

When real life problems are modelled by means of EI some of the norms are obtained by giving a computational interpretation to real legislation. In this process we have encountered two main problems:

– *Norm Inconsistency.* Usually the set of laws created by human societies in order to regulate a specific situation are contradictory and/or ambiguous. In particular, there are situations in which there is a general law (*regulative norm* [4]) which is controlled by a local law (*procedural norm* [4]). The problem arises when this local law does not ensure compliance of the more general law. This may be due to the existence of different levels of institutions which are working in the same system [12]. Thus, an elaborated process is necessary in order to determine which norms are active in a specific moment and how they are applied. Traditional methods for implementing norms in EI, which are based on the unambiguous interpretation of norms, are not suitable to overcome this problem.
– *Norm Controlling.* Even in absence of a conflict among norms, there is still the problem of norm controlling. Norm enforcement methods inside EI are based on the observation of these activities controlled by norms. In particular, there are norms whose violation cannot be observed since they regulate situations that take place out of the institution boundaries. Thus, violations are only detectable in presence of a conflict among agents.

In this paper we focus on the enforcement of these norms, which cannot be controlled by traditional techniques. Thus, we address the question of enforceability of non-observable norms inside EIs. In order to make more clear and understandable the problem addressed by this paper, it has been exemplified in the *mWater* scenario [5]. In addition, a first solution for overcoming the *mWater* concrete problem is shown. In particular, we propose the definition of a grievance scene for allowing normative conflicts to be solved within the *mWater* institution. However, this solution can be also extrapolated to generic domains.

This paper is structured as follows: the next section provides background on norm implementation, EIs and the implementation of norms inside EIs. Then a concrete example of the problem addressed by this paper is described. Finally, discussion and future works are described.

2 Background

This section firstly reviews the main methods for ensuring norm compliance in MAS and the techniques that can be employed for implementing these methods. Then, a brief description of the Electronic Institution framework is given, as well as a discussion on how norms are implemented and enforced in this framework.

2.1 Norm Implementation in Multiagent Systems

Norms allow legal issues to be modelled in electronic institutions and electronic commerce, MAS organizations, etc. Most of the works on *norms* in MAS have been proposed from a theoretical perspective. However, several works on norms from an operational point of view have recently arisen, which are focused on giving a computational interpretation of norms in order to employ them in the

design and execution of MAS applications. In this sense, norms must be interpreted or translated into mechanisms and procedures which are meaningful for the society [16]. Methods for ensuring norm compliance are classified into two categories: (i) *regimentation* mechanisms, which consist in making the violation of norms impossible, since these mechanisms prevent agents from performing actions that are forbidden by a norm; and (ii) *enforcement* mechanisms, which are applied after the detection of the violation of some norm, reacting upon it.

In a recent work [2], a taxonomy of different techniques for implementing effectively norms is proposed. On the one hand, the regimentation of norms can be achieved by two processes: (i) *mediation*, in which both the resources and communication channels are accessed through a reliable entity which controls agent behaviours and prevents agents from deviating from ideal behaviour; and (ii) *hard-wiring*, assuming that the agents' mental states are accessible and can be modified in accordance with norms. On the other hand, norm enforcement techniques are classified according to both the observer and the enforcer entity. Norms are *self-enforced* when agents observe their own behaviour and sanction themselves. Thus, norm compliance is both observed and enforced without the need of any additional party. In situations in which those agents involved by a transaction are responsible for detecting norm compliance (i.e. *second-party* observability) norms can be enforced by: (i) the *second-party* which applies sanctions and rewards; and (ii) a third entity which is an authority and acts as an *arbiter* or *judge* in the dispute resolution process. In the case of *third-party* observability, two different mechanisms for ensuring norm compliance can be defined according to the entity which is in charge of norm enforcing: (i) *social norms* are defended by the *society* as a whole; (ii) in *infrastructural enforcement* there are infrastructural entities which are authorities in charge of *monitoring* and enforcing norms by applying sanctions and rewards.

2.2 Electronic Institutions

Electronic Institutions (EI) are computational counterparts of conventional institutions [21, 24, 8]. Institutions are, in an abstract way, a set of conventions that articulate agent interactions [22]. In practice they are identified with the group of agents, standard practices, policies and guidelines, language, documents and other resources —the organization— that make those conventions work. *Electronic Institutions* are implementations of those conventions in such a way that autonomous agents may participate, their interactions are supported by the implementation and the conventions are enforced by the system on all participants. Electronic institutions are engineered as regulated open MAS environments. These MAS are open in the sense that the EI does not control the agents' decision-making processes and agents may enter and leave the EI at their own will. EIs are regulated in four ways. First, agents are capable of establishing and fulfilling commitments inside the institution, and those correspond to commitments in the real world. Second, only interactions that comply with the conventions have any consequence in the environment. Third, interactions are

organized as repetitive activities regulated by the institution and, last, interactions, in EIs, are always speech acts.

An EI is specified through: (i) a *dialogical framework* which fixes the context of interaction by defining roles and their relationships, a domain ontology and a communication language; (ii) *scenes* that establish interaction protocols of the agents playing a given role in that scene, which illocutions are admissible and under what conditions; (iii) *performative structures* that, like the script of a play, express how scenes are interrelated and how agents playing a given role move from one scene to another, and (iv) *rules of behaviour* that regulate how commitments are established and satisfied.

The IIIA model has a platform for implementation of EIs. It has a graphical specification language, ISLANDER, in which the dialogical framework, performative structures and those norms governing commitments and the pre- and post- conditions of illocutions are specified [9]. It produces an XML file that is interpreted by AMELI [10], a middleware that handles agent messages to and from a communication language, like JADE, according to the ISLANDER specification [10]. In addition, EIDE [1] includes a monitoring and debugging tool, SIMDEI that keeps track of all interactions and displays them in different modes. There is also a tool, aBuilder, that, from the XML specification, generates, for each role, agent shells that comply with the communication conventions (the decision-making code is left to the agent programmer).

2.3 Norm Implementation in EI

Norm Regimentation. In AMELI, governors filter the actions of agents, letting them only to perform those actions that are permitted by the rules of society. Therefore, governors apply a regimentation mechanism, preventing the execution of prohibited actions and, therefore, preventing agents to violate their commitments.

This regimentation mechanism employed by governors makes use of a formalism based on rules for representing constraints on agent behaviours [14]. This formalism is conceived as a "machine language" for implementing other higher level normative languages. More specifically, it has been employed to enforce norms that govern EIs. The main features of the proposed "machine language" are: (i) it allows for the explicit definition and management of agent norms (i.e. prohibitions, obligations and permissions); (ii) it is a general purpose language not aimed at supporting a specific normative language; (iii) it is declarative and has an execution mechanism. For implementing this rule system, the Jess tool has been employed as an inference engine. Jess allows the development of Java applications with "reasoning" capabilities[1].

In open systems, not only the regimentation of all actions can be difficult, but also sometimes it is inevitable and even preferable to allow agents to violate norms [6]. Reasons behind desirability of norm violations are because it is impossible to take a thorough control of all their actions, or agents could

[1] http://herzberg.ca.sandia.gov/jess/

obtain higher personal benefits when violating norms, or norms may be violated by functional or cooperative motivations, since agents intend to improve the organization functionality through violating or ignoring norms. Therefore, all these situations require norms to be controlled by enforcement mechanisms. Next, works on the enforcement of norms inside EI are described.

Norm Enforcement. The enforcement of a norm by an institution requires the institution to be capable of recognizing the occurrence of the violation of the norm and respond to it [16]. Hence, checking activities may occur in several ways: *directly*, at any time, randomly or with periodical checks, or by using monitoring activities; or *indirectly*, allowing agents to denounce the occurrence of a violation and then checking their grievances.

Regarding direct norm enforcement, the institution itself is in charge of both observing and enforcing norms. Thus, in this approach there are infrastructural entities which act as norm observers and apply sanctions when a violation is detected. In [19, 13], distributed mechanisms for an institutional enforcement of norms are proposed. In particular, these works propose languages for expressing norms and software architectures for the distributed enforcement of these norms. More specifically, the work described in [19] presents an enforcement mechanism, implemented by the Moses toolkit [18], which is as general (i.e. it can implement all norms that are controllable by a centralized enforcement) and more scalable and efficient with respect to centralized approaches. However, one of the main drawbacks of this proposal is the fact that each agent has an interface that sends legal messages. Since norms are controlled by these local interfaces, norms can be only expressed in terms of messages sent or received by an agent; i.e. this framework does not support the definition of norms that affect an agent as a consequence of an action carried out independently by another agent. This problem is faced by Gaertner et al. in [13]. In this approach, Gaertner et al. propose a distributed architecture for enforcing norms in EI. In particular, dialogical actions performed by agents may cause the propagation of normative positions (i.e. obligations, permissions and prohibitions). These normative propositions are taken into account by the normative level; i.e. a higher level in which norm reasoning and management processes are performed in a distributed manner. In a more recent work, Modgil et al. [20] propose an architecture for monitoring norm-governed systems. In particular, this architecture is formed by trusted observers that report to monitors on states of interest relevant to the activation, fulfilment, violation and expiration of norms. This monitoring system is *corrective* in the sense that it allows norm violations to be detected and reacting to them.

Mixed Approaches. Finally, there are works which employ a mixed approach for controlling norms. In this sense, they propose the usage of regimentation mechanisms for ensuring compliance with norms that preserve the integrity of the application. Unlike this, enforcement is proposed to control norms that cannot be regimented due to the fact that they are not verifiable or their violation

may be desirable. In [7] an example on the mixed approach is shown. In particular, this work shows how norms that define the access to the organization infrastructure are controlled, whereas norms controlling other issues such as work domain norms are ignored. In particular, those norms that define permissions and prohibitions related to the access to the organization are regimented through mediation, whereas obligation norms are enforced following the institutional sanction mechanism.

The ORA4MAS [17] is another well known proposal that makes use of a mixed approach for implementing norms. The ORA4MAS proposal defines *artifacts* as first class entities to instrument the organisation for supporting agents activities within it. *Artifacts* are resources and tools that agents can create and use to perform their individual and social activities [23]. Regarding the implementation of norms in the ORA4MAS framework, regimentation mechanisms are implemented in artifacts that agents use for accessing the organization according to the mediation mechanism. Enforcement of norms has been implemented using third party observability, since the detection of norm violations is a functionality provided by artifacts. In addition, norms are enforced by third parties, since there are agents in charge of being informed about norm violations and carrying out the evaluation and judgement of these situations.

However, none of the above mentioned proposals allows norms which regulate activities taking place out of the institution scope to be controlled. In this case, norm compliance is non-observable by the institution and can only be detected when a conflict arises. Thus, in this paper we propose that both a *second-party* and *third-party* can observe non-compliant behaviour and start a grievance process which takes place inside the EI. Therefore, in this paper we face the problem of institutional enforcement of norms based on second-party and third-party observability. Next section provides a concrete instantiation of this problem inside a more specific case-study.

3 A concrete sample scenario in the *mWater* regulated environment

In this section we exemplify the problem of non-regimented norm enforcement in EI with *mWater*, a regulated MAS application for trading water-rights within a virtual market. In order to get a good understanding of the overall *mWater* functioning, we first describe the motivation of *mWater* and present a brief overview of its structure. Afterwards, the sample complex situation for norm enforcement in the current *mWater* EI implementation is analyzed.

3.1 *mWater* overall description

In countries like Spain, and particularly in its Mediterranean coast, there is a high degree of public awareness of the main consequences of the scarcity of water and the need of fostering efficient use of water resources. Two new mechanisms

for water management already under way are: a heated debate on the need and feasibility of transferring water from one basin to another, and, directly related to this proposal, the regulation of *water banks*[2]. *mWater* is an agent-based electronic market of water-rights. Our focus is on demand and, in particular, on the type of regulatory and market mechanisms that foster an efficient use of water while preventing conflicts. The framework is a somewhat idealized version of current water-use regulations that articulate the interactions of those individual and collective entities that are involved in the use of water in a closed basin. The main focus of the work presented in this paper is on the regulated environment, which includes the expression and use of regulations of different sorts: from actual laws and regulations issued by governments, to policies and local regulations issued by basin managers, and to social norms that prevail in a given community of users.

For the construction of *mWater* we follow the IIIA *Electronic Institution* (EI) conceptual model [1]. For the actual specification and implementation of *mWater* we use the EIDE platform.

Procedural conventions in the *mWater* institution are specified through a nested performative structure (Fig. 1) with multiple processes. The top structure, *mWaterPS*, describes the overall market environment and includes other performative structures; *TradingHall* provides updated information about the market and, at the same time, users and trading staff can initiate most trading and ancillary operations here; finally, *TradingTables* establishes the trading procedures. This performative structure includes a scene schema for each trading mechanism. Once an agreement on transferring a water-right has been reached it is "managed" according to the market conventions captured in *AgreementValidation* and *ContractEnactment* scenes. When an agreement is reached, *mWater* staff check whether the agreement satisfies some formal conditions and if so, a transfer contract is signed. When a contract becomes active, other right-holders and external stakeholders may initiate a *Grievance* procedure that may have an impact on the transfer agreement. This procedure is activated whenever any market participant believes there is an incorrect execution of a given norm and/or policy. *Grievance* performative structure includes different scenes to address such grievances or for the disputes that may arise among co-signers. On the other hand, if things proceed smoothly, the right subsists until maturity.

3.2 Complex scenario: The registration of water-right transfer agreements

In *mWater* we have three different types of regulations: (i) government norms, issued by the Spanish Ministry of Environment (stated in the National Hydro-

[2] The 2001 Water Law of the National Hidrological Plan (NHP) —'Real Decreto Legislativo 1/2001, BOE 176' (see www.boe.es/boe/dias/2001/07/24/pdfs/A26791-26817.pdf, in Spanish)— and its amendment in 2005 regulates the power of right-holders to engage in voluntary water transfers, and of basin authorities to setup water markets, banks, and trading centers for the exchange of water-rights in cases of drought or other severe scarcity problems.

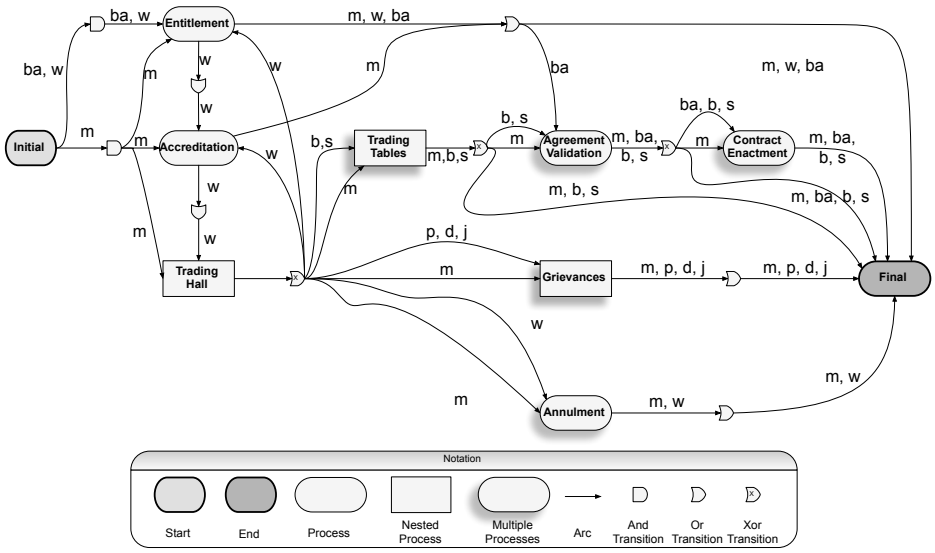

Fig. 1. *mWater* performative structure. Participating Roles: g - Guest, w - Water user, b - Buyer, s - Seller, p - Third Party, m - Market Facilitator, ba - Basin Authority.

logical Plan); (ii) basin or local norms, defined and regimented by the basin authorities; and (iii) social norms, stated by the members of a given user assembly and/or organization. The interplay among different norms from these three groups brings about complex situations in which there are non-regimented norms and, moreover, the non-compliance of the norm is not observable until a conflict appears. A very critical situation for the reliable execution of *mWater* appears when the following norms apply:

Government norm - (N0): A water-user can use a given volume of water from a given extraction point, if and only if he/she owns the specific water-right or has a transfer agreement that endows him/her.

Government norm - (N1): Every water-right transfer agreement must be registered within the fifteen days after its signing and wait for the Basin Authorities' approval in order to be executed.

Local norm - (N2): The registration process of a water-right transfer agreement is started voluntarily by the agreement signing parties.

Social norm - (N3): Whenever a conflict appears, a water user can start a grievance procedure in order to solve it.

Sample situation:

Let's suppose there is a water user A who has a water-right w_1 and wants to sell it. A starts a Trading Table inside the *TradingTables* process (see Fig. 1) in order to sell w_1. The water user B enters the Trading Table and, as a result, there is an agreement Agr_1 between A and B, by which B buys w_1 from A for

the period $[t_1, t_2]$, and pays the quantity p_1 for such a transfer. A and B belong to $Basin_x$, in which norms *N1*, *N2* and *N3* apply. A and B do not register Agr_1 due to norm $N2$ (in other words, A and B do not go to the Agreement Validation scene of Fig. 1). Since there is no mechanism in $Basin_x$ by which water-right w_1 is blocked from A after its selling (due to Agr_1 is not registered and w_1 is still owned by A in time periods not overlapped with $[t_1, t_2]$), A continues to operate in the market. Afterwards A starts a new Trading Table to sell w_1 for period $[t_3, t_4]$, with $t_1 < t_3 < t_2$ and $t_4 > t_2$ (the new period $[t_3, t_4]$ is overlapped with $[t_1, t_2]$). In this second Trading Table A and C sign Agr_2, by which A sells w_1 to C for the period $[t_3, t_4]$ and C pays p_2 to A. A and C belong to $Basin_x$. In this case C registers Agr_2 in the *Agreement Validation* scene, due to *N1* and *N2*, and obtains the basin approval for executing Agr_2. At time t_3 (the transfer starting time) C attempts to execute Agr_2, but there is no water in the water transportation node, since B is also executing Agr_1. At this moment C has a conflict with B, and in order to solve it he/she has to start a grievance procedure due to *N3* (Grievances performative structure of Fig. 1).

This situation[3] is an instantiated example of the one described above, in which there are non-regimented norms whose non-compliance is not observable and cannot be asserted until the conflict appears. The critical situation comes out due to the compliance procedure for agreement registration and second selling of the same water-right is not coercive.

The current development environment of EI we are using does not provide build-in support for non-coercive processes that are defined by non-regimented norms. Moreover, those situations in which it is not possible to observe the non-compliance of a norm until the resulting conflict appears are not supported either. Nevertheless, there are sample scenarios, like *mWater*, in which this behaviour is required. In the following section we analyze the EI implementation we have devised for this complex scenario.

3.3 Implementation

In this section our approach to solve the previously described complex scenario in *mWater* is described.

In order to include norm *N1* in the current EI implementation of *mWater* we have designed the *Agreement Validation* scene (see Fig. 1) as a successor scene for any Trading Table. When any water user enters this scene, the Market Facilitator verifies the constraint of fifteen days from the agreement statement process related to norm *N1*. If this constraint is satisfied the water-right transfer agreement is forwarded to the Basin Authority who activates a Normative Reasoning process in order to approve, or not, the agreement based on the basin normative

[3] The scenario presented in this section happens in practice in Spain, due to the impossibility to monitor all the water transfer negotiations that may take place among the different water users. It can be considered as a loophole in the Spanish regulations. Nevertheless we are interested in modeling it due to its complexity and in order to simulate the "real" behaviour of the basin users.

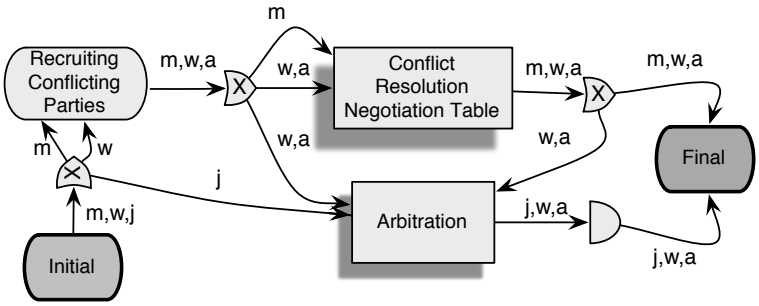

Fig. 2. Grievances performative structure

regulation. If the agreement gets approved it is published in the Trading Hall in order for every water user of the basin to be informed of the transfer agreement.

On the other hand, norm *N2* is automatically included in the *mWater* institution due to the EIDE implementation feature by which no participating agent in the electronic institution can be forced to go to a given scene. For the particular *mWater* example, neither the buyer nor the seller can be forced to go through the transition between the Trading Table scene and the Agreement Validation scene (see Fig. 1). This way, whenever the buyer and/or the seller goes to the Agreement Validation scene he/she starts the scene voluntarily, so norm *N2* is satisfied.

The implementation of norm *N3* requires a specific performative structure, named *Grievances* (Fig. 2), in order to deal with conflict resolution processes.

Finally, the observance of norm compliance is delegated to every water user. Hence, the enforceability of norm *N0* is delegated to every water user.

Fig. 2 shows the different scenes of the complex Grievances performative structure. In this structure any conflict can be solved by means of two alternative processes (these processes are similar to those used in Alternative Dispute Resolutions and Online Dispute Resolutions [26, 27]). On the one hand, conflict resolution can be solved by means of negotiation tables (Conflict Resolution Negotiation Table performative structure). In this mechanism a negotiation table is created on demand whenever any water user wants to solve a conflict with other/s water user/s, negotiating with them with or without mediator. Such a negotiation table can use a different negotiation protocol, such as face to face, standard double auction, etc. On the other hand, arbitration mechanisms for conflict resolution can also be employed (Arbitration performative structure). In this last mechanism, a jury solves the conflict sanctioning the offenses.

There are three steps in the arbitration process (see Fig. 3). In the first one, the grievance is stated by the plaintive water user. In the second step, the different conflicting parties present their allegations to the jury. Finally, in the last step, the jury, after hearing the dispute, passes a sentence on the conflict. The difference among the two mechanisms for conflict resolution is that the arbitration process is binding, meanwhile the negotiation is not. In this way if

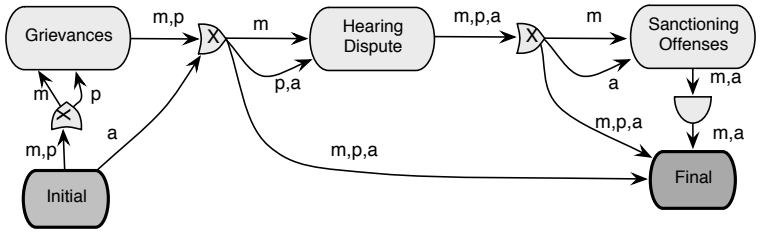

Fig. 3. Arbitration performative structure

any of the conflicting parties is not satisfied with the negotiation results he/she can activate an arbitration process in order to solve the conflict.

In the previously described complex scenario, when C cannot execute Agr_2 (because there is no water in the water transportation node), C believes that B is not complying norm *N0*. C believes there is a conflict because Agr_2 endows him/her to use the water, and moreover, there is no transfer agreement published in the Trading Hall that endows B to do the same. In order to enforce norm *N0* and to execute Agr_2, C starts a grievance procedure. In this procedure, water users C and B are recruited as conflicting parties and A as third party because he/she is the seller of w_1 as stated in Agr_2 (Recruiting Conflicting Parties scene of Fig. 2). Let's assume C chooses as conflict resolution mechanism arbitration, because he/she does not want to negotiate with B. After stating the grievance, C and B present their allegations to the jury. In this process B presents Agr_1 by which he/she believes there is fulfillment of norm *N0*. Nevertheless, in the last arbitration step, by means of a Normative Reasoning function, the jury analyzes the presented allegations and the normative regulations of the basin and deduces that there is an offense. Norm *N1* was not complied by B and A, and moreover, A has sold the same water-right twice for an overlapped time period. In this last step, the jury imposes the corresponding sanctions to A and B.

Further implementation details. *mWater* is also devised as a simulation tool for helping the basin policy makers to evaluate the behaviour of the market when new or modified norms are applied. *mWater* is implemented by tiers.

We use the typical three-tier architecture defined in software engineering, as depicted in Fig. 4, with the *mWater* electronic institution being executed in background. The persistence layer implements an information model that supports the execution of the EI and it is developed in MySQL, including the different conceptual data required for the market execution, such as basin structure, market structure and all the elements necessary for the conflict resolution process. Fig. 5 shows a fragment of this relational model in which some elements are depicted such as: basin structure, water-right definition, agreement, and conflict resolution table configuration, among others. The business layer includes all the logic of the system, and it is implemented by providing different APIs (Application Programming Interfaces) for querying the database and

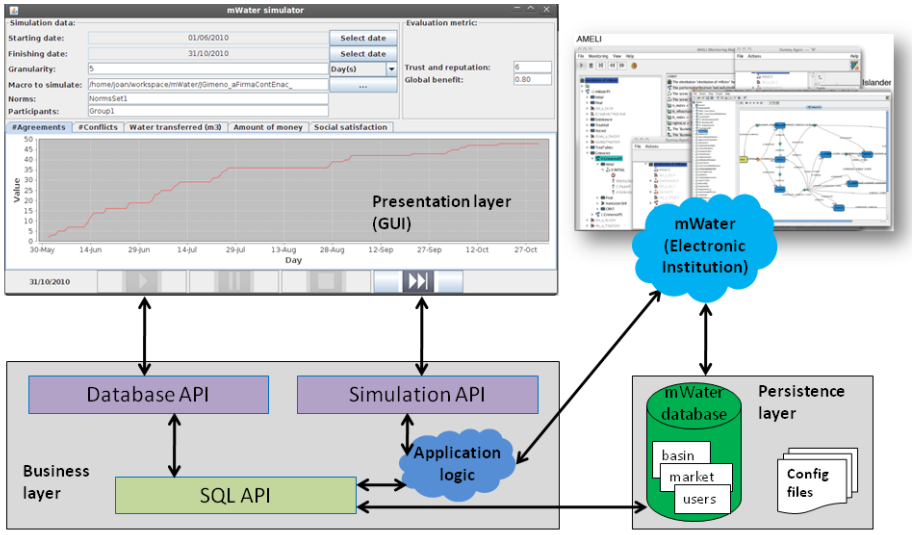

Fig. 4. Architecture of our approach for *mWater* as a simulation tool for decision-taking support

running the simulation. Fig. 6 shows a snapshot of the *mWater*'s complex scenario implementation running on the AMELI execution environment of EIDE with 3 different agents named as the example 'A', 'B' and 'C'. In each agent window we are able to identify, on the left part, a tree which is labeled with the performative tasks, transitions and scenes where the agent has passed or is staying. Note that the implementation we have devised for this complex situation in *mWater* allows us to solve the scenario described above. Moreover, when dealing with this scenario it is also possible to observe the limitations of the current EIDE platform for supporting non-observability and enforceability of non-regimented norms. The implementation of *mWater* we are discussing in this paper is developed with EIDE 2.11[4], and includes all the components described in previous sections. Finally, the presentation layer provides the front-end of the system while gives the user the opportunity to tune some parameters (selection dates, regulation to be applied and water users population) to run the market in a very intuitive way. Additionally, it provides us with very useful (graphical) information that helps stakeholders when taking decisions.

To this end, we are working on defining evaluation functions to measure the performance of the market rather than on the implementation performance itself.

[4] Available at http://e-institutions.iiia.csic.es/eide/pub/

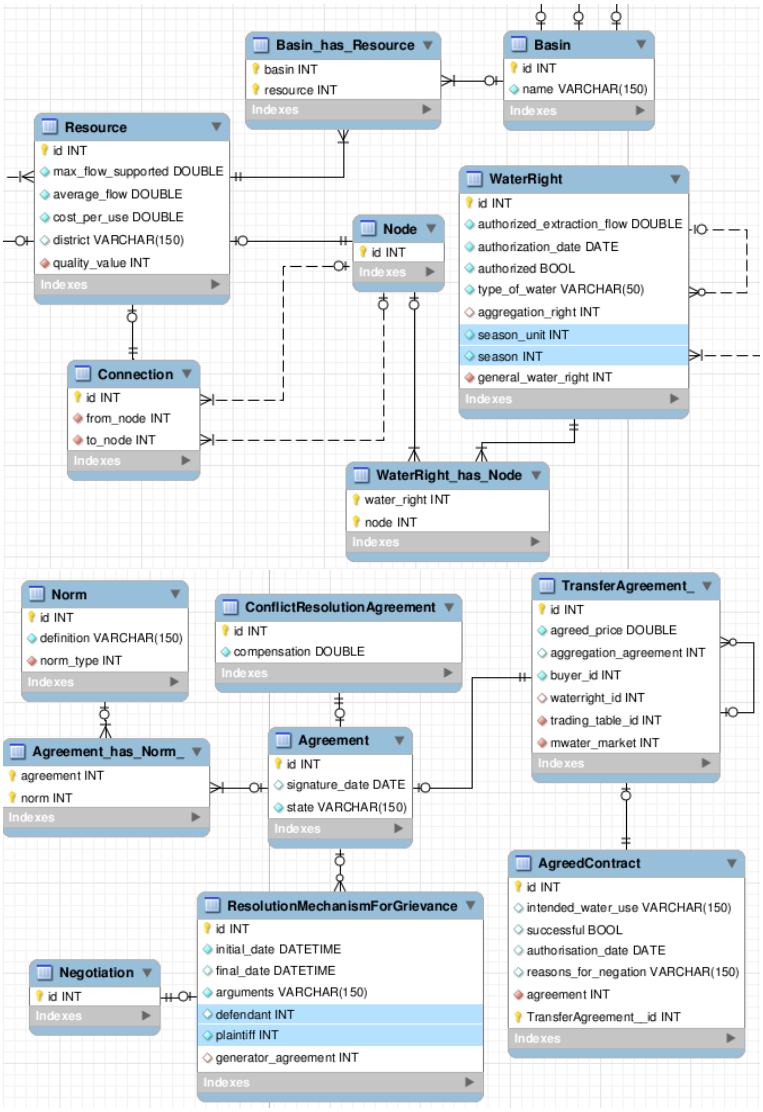

Fig. 5. A fragment of the information model of *mWater*

However, our tests do not show clear limitations in the the system performance, and the system is fast enough to simulate the market during a whole year in just a few minutes. On the other hand, the functions to measure the performance of the market include now the amount of water transfer agreements signed in the market, volume of water transferred, number of conflicts generated, etc. (see GUI in Fig. 4), but the GUI is open to deal with other indicators. Apart from these straightforward functions we are also working on defining "social" functions in

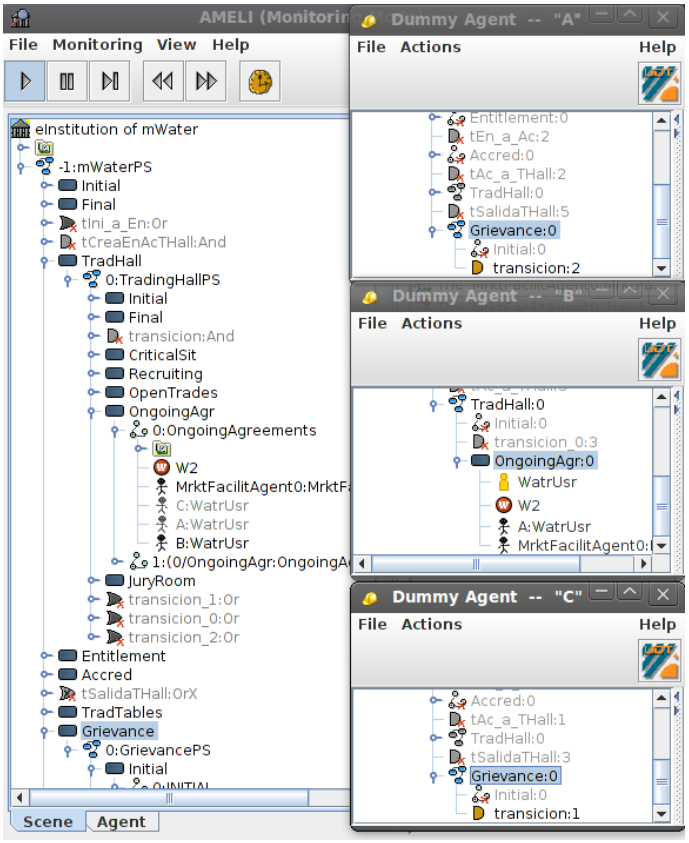

Fig. 6. A snapshot of the *mWater* electronic institution running on AMELI

order to asses values such as the trust and reputation levels of the market, or degree of water user satisfaction, among others.

4 Discussion and closing remarks

In real life problems, in many occasions it is difficult or even impossible to check norm compliance, specially when the violation of the norm cannot be directly observable. In other occasions, it is not only difficult to regiment all actions, but it might be preferable to allow agents to violate norms, since they may obtain a higher personal benefit or they may intend to improve the organization functionality, despite violating or ignoring norms. It is clear that from a general thought and design perspective of an Electronic Institution, it is preferable to define a safe and trustful environment where norms cannot be violated (i.e. norms are considered as hard constraints), thus providing a highly regimented scenario that inspires confidence to their users. However, from a more flexible and realistic

perspective, it is appealing to have the possibility for agents to violate norms for personal gain. Although this is a very realistic attribute that humans can have, it eventually leads to corruption and, consequently, the designer may think to rule it out. But again, from a norm enforceability standpoint it is always a good idea to allow this: it does not only make the environment more open and dynamic, but it also provides a useful tool for decision support. In such a thread, we are able to range the set of norms, from a very relaxed scenario to a very tight one, simulate the institution and the agents' behaviour and, finally, analyze when the global performance —in terms of number of conflicts that appear, degree of global satisfaction or corruption, etc.— shows better, which makes it very interesting as a testbed itself [5]. In all these cases, norm enforcement methods are needed, such as second-party and third-party enforcements.

This paper has highlighted the necessity for norm enforceability in Electronic Institutions. Clearly, when the agents and their execution occur outside the boundaries of the institution it is inviable to count on a simple and efficient way to guarantee a norm-abiding behaviour, as the full observability of the whole execution and environment is rarely possible. In other words, norm violations are perfectly plausible (and unfortunately common) and are only detectable in presence of a conflict among agents.

In our *mWater* scenario, we have proposed an open mechanism that comprises two main principles: (i) the generation of a grievance when one agent detects a conflict, i.e. when an agent denounces the occurrence of a violation; and (ii) an authority entity with the role of arbiter/judge to mediate in the dispute resolution process and being able to apply sanctions. The advantage of this mechanism is twofold. First, it allows different types of grievance, either when it corresponds to the execution of a previous signed (or unsigned) agreement or, simply, when it happens as an occasional event during the habitual execution of the water scenario and its infrastructure use. Second, it provides different ways to deal with grievances, as shown in Fig. 2: (i) in a very formal and strict way by means of an arbitration procedure that relies on a traditional jury, thus applying a *third-party* enforceability mechanism (with an infrastructure enforcement); or (ii) in a more flexible way that relies on the creation of a conflict resolution negotiation table, which ranges from informal protocols (e.g., face to face) to more formal ones that may need one or more mediators. In this last case, a *second-party* enforceability mechanism has been adopted. We have shown that this grievance procedure shows to be effective in the *mWater* scenario. But despite its origin in the water environment, it can be easily extrapolated to any other real problem modelled by using EIs, which represent the main contributions of this paper.

The underlying idea to deal with norm enforcement in generic domains follows a simple flow, but it needs some issues to be clearly defined. First of all, we require a procedure to activate or initiate a new grievance. This can be done from any type of performative structure similar to the *TradingHall* of Fig. 1. This operation requires the identification of the agents that will be involved in the grievance itself, so it is essential for all agents to be uniquely identified; that is, we cannot deal with anonymous agents, which is an important issue. Once

the grievance has been initiated, we also require a mechanism for recruiting the conflicting parties. Again, this is related to the agents' identification and the necessity of (perhaps formal) communication protocols to summon all the parties. Note that this step is necessary for any type of dispute resolution, both by negotiation tables and arbitration. And, at this point we have a high flexibility for solving the conflicts, as they can be solved in many ways depending on the type of problem we are addressing at each moment. Analogously to the trading tables that we have in the *mWater* scenario, we can use general or particular tables to reach an agreement and, thus, solving the conflict, no matter the real problem we have. Finally, it is also important to note that reaching an agreement when solving the conflict does not prevent from having new conflicts that appear from such an agreement, being necessary the initiation of a new grievance procedure and repeating all the operations iteratively. Although such new grievances are possible from both the negotiation table and arbitration alternatives, it is common to have situations where the decisions/verdict taken by the arbitration judges are unappealable.

Regarding the limitations of our proposal, the solution provided here is not useful *per se*. In this sense, the solution to the norm enforceability problem in EI is not complete. In particular, this paper focuses on the description of the structure (i.e the *grievance* performative structure) that allows the question of norm enforceability to be solved in case of the *mWater* scenario. However, this structure must be endowed with *arbitration* [15], *trust* [25] and *argumentation* mechanisms [28, 11] in order to become a reliable infrastructure for detecting and reacting to non-observable norm violations. Therefore, our current work of research is focused on providing a specification of these mechanisms. In particular, we are working on how the conflict resolution tables can be defined and to come up with specialized protocols for these tables. Hence, our final goal is to be able to integrate this behaviour into a decision support system to be applied to the *mWater* and other scenarios of execution. On a parallel line, we are also working on the development of a simulation tool for the water-right market that allows us to easily range: (i) the type of regulatory and market mechanisms; (ii) the number, type, group of norms and how to reason on them; (iii) the agents' population and their behaviour, in particular the way they are more or less norm-abiding; and (iv) the performance measures to evaluate "social" issues in the market behaviour. This will provide us with very valuable information about the necessity of richer normative regulation and its real impact when different types of water users interact within the market.

Acknowledgements

This paper was partially funded by the Consolider programme of the Spanish Ministry of Science and Innovation through project AT (CSD2007-0022, INGENIO 2010), MICINN projects TIN2008-06701-C03-01 and TIN2009-13839-C03-01 and by the FPU grant AP-2007-01256 awarded to N. Criado. This research

has also been partially funded by the Generalitat de Catalunya under the grant 2009-SGR-1434 and Valencian Prometeo project 2008/051.

References

1. Josep Arcos, Marc Esteva, Pablo Noriega, Juan Rodriguez-Aguilar, and Carles Sierra. Engineering open environments with electronic institutions. *Engineering Applications of Artificial Intelligence*, (18):191–204, 2005.
2. Tina Balke. A taxonomy for ensuring institutional compliance in utility computing. In Guido Boella, Pablo Noriega, Gabriella Pigozzi, and Harko Verhagen, editors, *Normative Multi-Agent Systems*, number 09121 in Dagstuhl Seminar Proceedings, Dagstuhl, Germany, 2009. Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, Germany.
3. G. Boella, L. van der Torre, and H. Verhagen. Introduction to the special issue on normative multiagent systems. *Autonomous Agents and Multi-Agent Systems*, 17(1):1–10, 2008.
4. Guido Boella and Leendert van der Torre. Substantive and procedural norms in normative multiagent systems. *Journal of Applied Logic*, 6(2):152–171, 2008.
5. V. Botti, A. Garrido, A. Giret, F. Igual, and P. Noriega. On the design of mWater: a case study for Agreement Technologies. In *7th European Workshop on Multi-Agent Systems - EUMAS 2009*, pages 1–15, 2009.
6. Castelfranchi C. Formalising the informal? *Journal of Applied Logic*, N 1, 2004.
7. N. Criado, V. Julian, V. Botti, and E. Argente. A Norm-based Organization Management System. In *AAMAS Workshop on Coordination, Organization, Institutions and Norms in Agent Systems (COIN)*, pages 1–16, 2009.
8. M. Esteva. Electronic Institutions: from specification to development. *IIIA PhD Monography*, 19, 2003.
9. M. Esteva, J.A. Rodriguez-Aguilar, C. Sierra, P. Garcia, and J. Arcos. On the formal specification of electronic institutions. *Agent mediated electronic commerce*, pages 126–147, 1991.
10. M. Esteva, B. Rosell, J.A. Rodriguez-Aguilar, and J.L. Arcos. Ameli: An agent-based middleware for electronic institutions. In *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems-Volume 1*, page 243. IEEE Computer Society, 2004.
11. J. Euzenat, L. Laera, V. Tamma, and A. Viollet. D2.3.7: Negotiation/argumentation techniques among agents complying to different ontologies. *Tech. Report. KWEB/2004/D2.3.7/v1.0.*, 2006.
12. N. Fornara and M. Colombetti. Specifying and enforcing norms in artificial institutions (short paper). In *Proc. 7th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2008)*, pages 1481–1484, 2008.
13. D. Gaertner, A. Garcia-Camino, P. Noriega, J.A. Rodriguez-Aguilar, and W. Vasconcelos. Distributed norm management in regulated multiagent systems. In *Proceedings of the 6th international joint conference on Autonomous agents and multiagent systems*, page 90. ACM, 2007.
14. Andrés García-Camino, Juan A. Rodríguez-Aguilar, Carles Sierra, and Wamberto Weber Vasconcelos. Norm-oriented programming of electronic institutions. In *Proc. International Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, pages 670–672. ACM, 2006.

15. B. Gateau and D. Khadraoui. Arbitration of Autonomous Multimedia Objects with a Multi-Agent System. *Proceeding of 2nd Information and Communication Technologies*, pages 3007–3012, 2006.
16. D. Grossi, H. Aldewereld, and F. Dignum. Ubi lex, ibi poena: Designing norm enforcement in e-institutions. In *Coordination, Organizations, Institutions, and Norms in Multi-Agent Systems II*, volume 4386, pages 101–114. Springer, 2007.
17. J.F. Hübner, O. Boissier, R. Kitio, and A. Ricci. Instrumenting multi-agent organisations with organisational artifacts and agents. *Autonomous Agents and Multi-Agent Systems*, 20(3):369–400, 2010.
18. N.H. Minsky and V. Ungureanu. A mechanism for establishing policies for electronic commerce. In *International Conference on Distributed Computing Systems*, volume 18, pages 322–331. Citeseer, 1998.
19. N.H. Minsky and V. Ungureanu. Law-governed interaction: a coordination and control mechanism for heterogeneous distributed systems. *ACM Transactions on Software Engineering and Methodology (TOSEM)*, 9(3):273–305, 2000.
20. Sanjay Modgil, Noura Faci, Felipe Rech Meneguzzi, Nir Oren, Simon Miles, and Michael Luck. A framework for monitoring agent-based normative systems. In Carles Sierra, Cristiano Castelfranchi, Keith S. Decker, and Jaime Simão Sichman, editors, *AAMAS*, pages 153–160. IFAAMAS, 2009.
21. P. Noriega. Agent-mediated auctions: The fishmarket metaphor. *IIIA Phd Monography*, 8, 1997.
22. D.C. North. *Institutions, institutional change, and economic performance*. Cambridge Univ Pr, 1990.
23. A. Omicini, A. Ricci, and M. Viroli. Artifacts in the A&A meta-model for multi-agent systems. *Autonomous Agents and Multi-Agent Systems*, 17(3):432–456, 2008.
24. J.A. Rodrıguez-Aguilar. On the design and construction of agent-mediated electronic institutions. *IIIA Phd Monography*, 14, 2001.
25. Jordi Sabater and Carles Sierra. Review on computational trust and reputation models. *Artif. Intell. Rev.*, 24(1):33–60, 2005.
26. T. Schultz, G. Kaufmann-Kohler, D. Langer, and V. Bonnet. Online dispute resolution: The state of the art and the issues. In *Available at SSRN: http://ssrn.com/abstarct=899079*.
27. WK Slate. Online dispute resolution: Click here to settle your dispute. *Dispute Resolution Journal*, 56(4):8–14, 2002.
28. S. Toulmin. *The Uses of Argument*. Cambridge Univ Pr, 1969.