D8.2.3.P2 Report: *mWater* prototype review

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Abstract.
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The mWater prototype #2 review is detailed in this report. This document reviews (and extends) the document for the mWater prototype #1
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Executive Summary

Water scarcity is becoming a major concern in most countries, not only because it threatens the economic viability of current agricultural practices, but because it is likely to alter an already precarious balance among its many types of use: human consumption, industrial use, energy production, recreation, etc. Underneath this emergent situation, the crude realities of conflict over water rights of use and the need of accurate assessment of water needs and use become more salient than ever.

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*.[1]

It has been sufficiently argued that more efficient uses of water may be achieved within an institutional framework where water rights may be exchanged more freely, not only under exceptional conditions but on a day to day basis [Cal06, RGL04, Tho97]. It has been claimed that if farmers cannot sell their extra water allotment, they have no incentive to use the allotment efficiently and it may become wasteful [HR07]. Moreover, a straightforward extension to other types of stakeholders would promote trading for industrial uses, aquiculture, leisure or navigation, not only irrigation, thus improving market conditions and hence efficiency of water use [Cal06]. We propose to implement such a market with a regulated open multi-agent system, *mWater*. mWater is a software demonstrator developed in the Agreement Technologies Project. It is a Multi-Agent System (MAS) application that implements a market for water rights, including the model and simulation of the water-right market itself, the basin, users, protocols, norms and grievance situations. mWater plays a vital role as it allows us to define different norms, agents behaviour and roles, and assess their impact in the market, thus enhancing the quality and applicability of its results as a decision support tool.

This document reviews (and extends) the document provided in the mWater prototype #1 and also gives further uses of mWater, such as its mechanism for generic negotiation

[1] 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.

and its direct application for policy-making, which is part of our ongoing work.

Contents

Chapter 1

mWater as a decision support tool for water-right markets

1.1 Introduction

Water scarcity is a significant concern in most countries, not only because it threatens the economic viability of current agricultural practices, but because it is likely to alter an already precarious balance among its different types of use: human consumption, industrial use, energy production, navigation, etc. Underneath this emergent situation, the crude reality of conflicts over water rights and the need of accurate assessment of water needs become more salient than ever.

Good water management involves a complex balance between economic, environmental and social factors. These balance is partially determined by physical conditions like rainfall, water supply and distribution infrastructure, population distribution, land use and main economic activities. However, actual water demand is the determining balancing condition, and actual water use is the outcome to measure the success of a water management policy. A policy maker has little control over the hydrographical features of a basin but (s)he has legal power to regulate water user behaviour to a larger extent by means of: i) government laws, ii) basin or local norms, and iii) social norms. Therefore, one aim of a policy maker is to design appropriate water laws that regulate users' actions and, in particular, give users the possibility of exchanging water resources.

It has been sufficiently argued that more efficient uses of water may be achieved within an institutional framework, akin to a traditional goods market, where water rights may be exchanged, not only under exceptional conditions but on a day-to-day basis. In hydrological terms, a water market can be defined as an institutional, decentralized framework where users with water rights (right holders) are allowed to voluntarily trade them with other users, complying with some pre-established norms and in exchange of some compensation [CG06, Tho97]. Water-rights markets allow rapid changes in allocation in response to changes in water supply and demand, and ideally allow to stimulate investment and employment when users are assured access to secure supplies of water. Because of water's unique characteristics, however, such markets do not work everywhere, they cannot be homogenous since they operate under different organizational and institutional schemata, nor do they solve all water-related issues [MK99, Tho97]. Nevertheless, international experience in the USA (particularly California), Chile, Australia and Mexico has demonstrated that (formal) water markets can improve the economic efficiency of water use and stimulate investment [CG06, HR07, RR94, Tho97].

The willingness of irrigators to buy or sell water highly depends on the difference between the price of water and net revenue each farmer expects to earn by irrigating, and similarly for other stakeholders like utility companies or municipalities. However, it is not always a matter of price expectations alone what motivates users to trade water rights. Policy makers may wish to promote trading that favours outcomes that may not necessarily be directly associated with price expectations; for instance, to foster trading that guarantees the public good entailed by a healthy environment, or trading that fosters equilibria among different stakeholders (farmers, municipalities, leisure users and power utilities). But formulating market regulations that have the intended effects is a difficult and delicate task. There are many aspects that may be regulated and many parameters involved, and therefore the consequences of the many combinations difficult to foresee, not to mention the oftconflicting interests of the many stakeholders. Because of this inevitable complexity, policy-makers have traditionally tended to follow the cautious strategy of making conventions rigid, so that their enforcement is straightforward and outcomes are easy to foresee.

Some experiences have shown that more flexible regulations may be desirable but policy-makers need means and methodologies that allow them to visualize the potential consequences of new regulations and fine-tune them before enacting them, in order to avoid undesirable outcomes. In many countries, water regulation tends to be too strict. In the case of water-right trading, Spanish regulation, for instance, does not allow final stakeholders to intervene in the basin resource management plans, nor in a water-right trading process. In particular, the Water Law of the National Hydrological Plan 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, but *only* in cases of drought or other severe scarcity problems.[1] This means that the number of (legal) water-right transfers is practically non-existent. Also, in some tentative scenarios aimed at forming water markets the results were unsatisfactory because: i) water-right holders were reluctant to participate in the market, and ii) regulation and legally binding conditions were too tight. It should also be mentioned that from a performance standpoint, it is unclear which is the best quality indicator of water management, because it cannot be measured in terms of just one factor; performance is a multi-objective function

[1] See the 2001 Water Law of the National Hidrological Plan (NHP) —'Real Decreto Legislativo 1/2001, BOE 176' (www.boe.es/boe/dias/2001/07/24/pdfs/A26791-26817.pdf, in Spanish)— and its 2005 amendment.

that comprises multiple criteria based on differing objectives, responsibilities and interests among the stakeholders and institutions involved in the market. Furthermore, many outcome functions have singularities that are hard to identify and testing and visualizing limit conditions require analytical tools beyond the ones provided by the type of models mentioned above.

This document reviews our current water policy-making decision-support framework, build on top of a regulated open Multi-Agent System (MAS), *mWater* [BGG+10, GGG+11], that models a flexible water-rights market. Our simulator focuses on the effect of regulations on demand and thus provides means to explore the interplay of norms and conventions that regulate trading (like trader eligibility conditions, tradeable features of rights, trading periods and price-fixing conventions), the assumptions about agent behaviour (individual preferences and risk attitude, or population profile mixtures) and market scenarios (water availability and use restrictions). A policy-maker would then assess the effects of those interactions by observing the evolution of the performance indicators (efficiency of use, price dynamics, welfare functions) (s)he designs.

1.2 Our Approach

Agent technology and multi-agent systems have been successfully applied to problems such as manufacturing [GB04a, GB04b, GB06, GV09], medicine, aero-space, e-commerce, etc. One promising applications domain of MAS is the simulation of complex real life systems that emulate social behaviour and organizations, where a MAS is used to mimic the behaviour of autonomous rational individuals and groups of individuals [SHS09]. In this way, complex behavioural patterns are observed from simulation tests in which autonomous entities interact, cooperate, and/or compete to achieve a set of goals. This offers several advantages: i) the ability to model and implement complex systems formed by autonomous agents, capable of pro-active and social behaviour; ii) the flexibility of MAS applications to add and/or delete computational entities, in order to achieve new functionalities or behaviours in the system, without altering its overall structure; and iii) the ability to use notions such as organization, norms, negotiation, agreement, trust, etc. to implement computational systems that benefit from these human-like concepts and processes among others [SBO11].

Literature abounds in examples of sophisticated basin simulation models, particularly decision support systems for water resources planning [ACS96, RN05], sustainable planning of water supply [CLM04, MdSODO+07], and use of shared visions for negotiation and conflict resolution [PWMW99, SHS09]. From a hydrological perspective, these works have successfully bridged the gap between the state of the art in water-resource systems analysis and the usage by practitioners at the real-world level. However, the gap is still wide from a social perspective. The need is not only to model hydraulic factors, such as river basins, soil permeability, water requirements, distribution flows, etc., but also norm typology, human (mis)conducts, trust criteria and users willingness to agree on water-right trading, which may lead to a win-win situation in a more efficient use of water.

Most water management models are based on equational descriptions of aggregate supply and demand in a water basin [MdSODO+07], only a few include an agent-based perspective. Under this perspective, we explore an approach in which individual and collective agents are essential components because their behaviour, and effects, may be influenced by regulations. Our work takes inspiration from the MAELIA (`http://www.iaai-maelia.eu`) and NEGOWAT projects (`http://www.negowat.org`) that simulate the socio-environmental impact of norms for water and how to support negotiations among stakeholders in areas where water conflicts arise.

From a technical perspective, there are several approaches to implement MAS applications [SJR+02, JB04, AGV+04a, APA+07, BJC+06, GJR+10, HGPRG+09]. Some approaches are centered and guided by the agents that will populate the systems, while others are guided by the organizations that the constituent agents may form (for an overview, see [AGV+04b]). Other approaches rely the development process on the regulation that defines the MAS behaviour, which is usually encoded as an Electronic Institution (EI) [Est03, Nor97, RA01]. We are interested in this latter approach due to the requirements imposed by the environment. In particular, *mWater* —from the perspective of a MAS simulation tool— implements a regulated market environment as an EI, in which different water users (intelligent agents) trade with water rights under different basin regulations. With such a tool, water-policy makers can visualize and measure the suitability of new or modified regulations for the overall water market, i.e. more transfers, fewer conflicts, increased social satisfaction of the water users, etc., before applying them in an actual basin. All in all, *mWater* is not only an aid for a better understanding of the demand dynamics of the water-resource system in question, but it is also a tool for data organization and for communication and negotiation among the different stakeholders of a basin.

mWater uses a multi-tier architecture, as depicted in Fig. 1.1 [GGG+11]. In addition to the three typical tiers of presentation, business and data persistence, we have a module that represents the EI for *mWater*. This way, the construction of *mWater* consists of four stages: i) modelling the system as an EI; ii) designing the information system based on a database of the entire electronic market and basin structure (persistence tier); iii) implementing the agents (business tier); and iv) creating the GUI for simulation tool (presentation tier), which are described next.

1.2.1 Modelling the System as an EI

Electronic Institutions (EI) are computational counterparts of conventional institutions and represent a set of conventions that articulate agent interactions [Est03, Nor90]. 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. EIs are engineered as regulated open MAS environments in

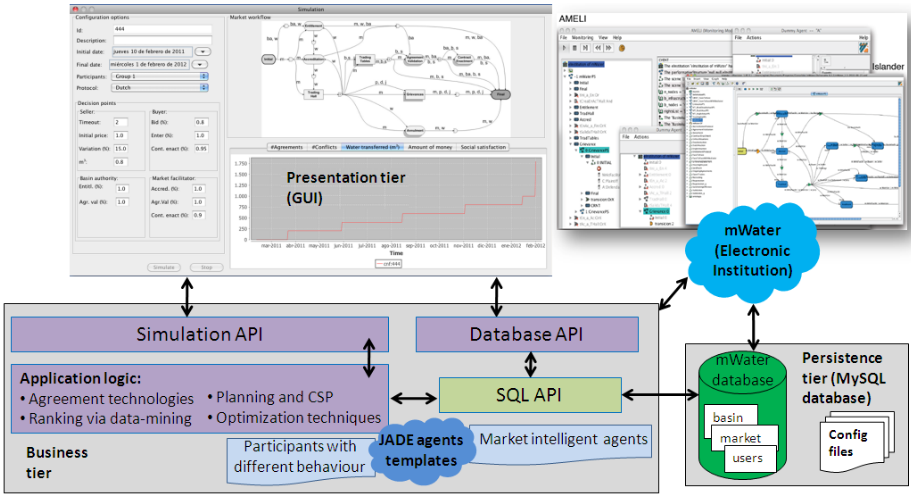

Figure 1.1: Multi-tier architecture of the *mWater* decision support tool

the sense that: i) the EI does not control the agents' decision-making processes, and ii) agents may enter and leave the EI at their own will, which is essential in a market.

The *mWater* institution is specified through a nested performative structure with multiple processes, as depicted in Fig. 1.2. A detailed description of this institution is included in the document for the mWater prototype #1.

The essence of our market relies on the Trading Tables and Grievances structures. The former implements the trading process itself, which entails the participation of the buyer/seller and staff agents. The latter is necessary to allow normative conflicts to be solved within the *mWater* institution, particularly when the agreement execution turns conflicting with third party agents. In our approach, we include a framework for conflict resolution based on grievance protocols in which alternative dispute resolution (ADR) mechanisms are included in order to settle the conflicts internally in the market [SKKLB01]. In this framework, any grievance process primarily involves negotiation like in any Trading Table (with or without mediation) and an arbitration procedure, or a combination of both. This way, the result of a conflict resolution can be an agreement among the conflicting parties by which they voluntary settle the conflict, or a decision from the arbitrator (a neutral third party) which is final, and binding to both conflicting parties.

1.2.2 Persistence Tier: Database Design

mWater implements the persistence tier by means of a MySQL database with over 60 relational tables in which historical data is stored. In essence, we have three views that comprise the basin, market and grievance structure (see Fig. 1.3). In the first view we model all the information about the nodes, connections, users, norms and water-right definition. In the second view we model information related to the entire market, in-

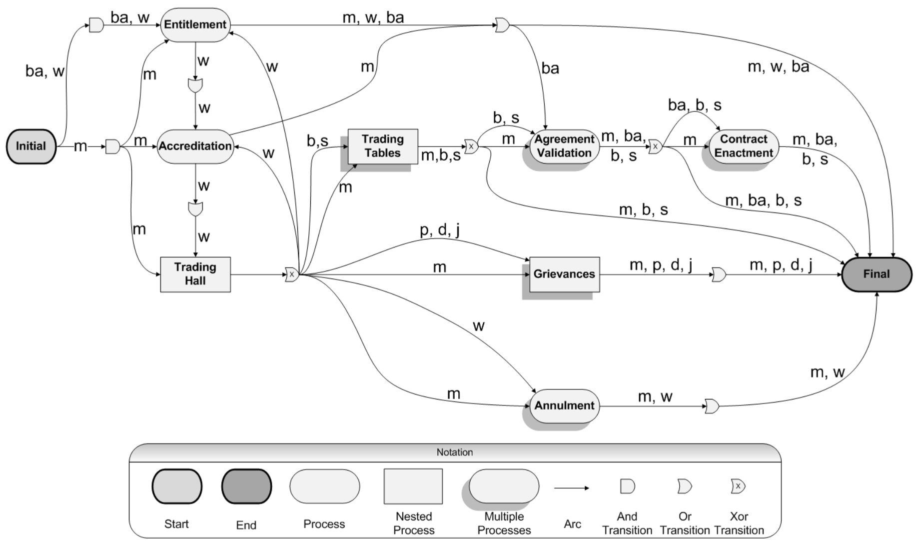

Figure 1.2: *mWater* performative structure. Participating roles: *g* - guest, *w* - water user, *b* - buyer, *s* - seller, *p* - third party, *m* - market facilitator, *ba* - basin authority. See [BGG+10] for further details

cluding the trading tables and their protocols, the water rights to be traded, participants, agreements and contracts that can be signed. Finally, in the third view we model the information about the legislation and conflicts that may appear after an agreement or contract and the mechanisms for solving such a conflict, that is the negotiation stage or arbitration procedure. This way, policy makers can run the whole market with real and simulated data for drought periods, rainfall, norms and users, and analyse how they affect the final results and the number of grievances. Furthermore, all the changes in the market are registered in the database to provide statistical information and/or distributions to the policy makers, which are essential in a decision-support tool.

1.2.3 Business Tier: Implementation of Agents

mWater implements a schema of agents that include both the internal and external roles. There is a JADE (Java Agent DEvelopment Framework, `http://jade.tilab.com`) definition for each class that represents the roles in the scenes. The generation of the Java classes is done in an automated way, thanks to the tools provided by the EIDE development environment. More particularly, the mapping that is used to generate the agents implementation is shown in Fig. 1.4. In particular, one Java class is created per valid role (guest, water user, buyer, seller, third party, market facilitator and basin authority) and per scene in which each role can participate. Intuitively, this can be seen as a basic template for an agent participating in a given scene. It is important to note that not all roles participate in all the scenes —recall the definition of the *mWater* EI in Fig. 1.2—, so there are roles that are translated into more classes than others.

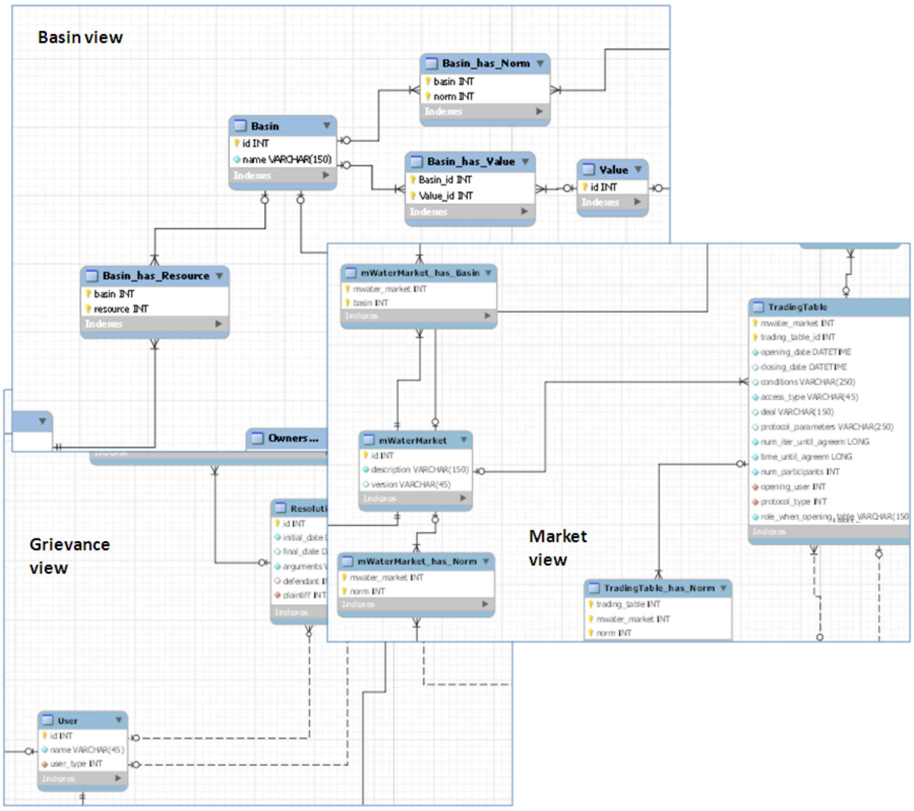

Figure 1.3: Fragment of the database: basin, market and grievance views

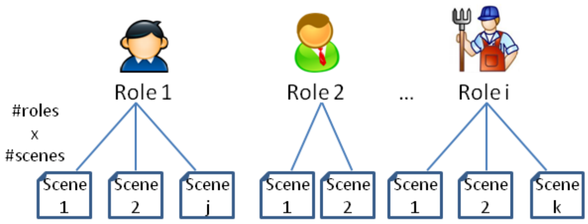

Figure 1.4: Schema of the agents implementation. The mapping proceeds by generating one Java class (template) per role in each scene it can be involved

Once the templates have been automatically generated, we can extend them by implementing new classes that represent different behaviours, which is interesting from a simulation perspective. Basically, we override methods to change the original behaviour that allows the agent to move from one state to another, i.e. to execute a transition, or send a message (interact) to other agents. Additionally, we have placed some decision points that rely on random distributions (inputs of the GUI, see section 1.2.4) to make the simulation more realistic.

Our implementation introduces an explicit intelligent management into the market in the form of market facilitator. This role has demonstrated very helpful to improve and facilitate the internal behaviour of the institution. The market facilitator must be aware of the organizational conventions, the rules of the market and the negotiation structure. But more importantly, (s)he offers intelligent capabilities to help the users under three basic scenarios: i) to decide about opening a new trading table, ii) to decide what user is going to be invited to join that table and why (preliminary process of invitation), and iii) to help within the negotiation (trading) process. First, the facilitator must be aware of the current context of application that may forbid or allow the opening of the most adequate trading table based on the current legislation. Similarly, the market facilitator may offer advice during the grievance procedure, thus making it more efficient. Second, the market facilitator sends invitations to users to join the table by using data mining rankings that assign a priority to each user for being invited to each table —this involves an intelligent deliberative process based on the user's reputation and trust in previous transactions. Third, the facilitator must obey the particular rules of the protocol to be used within the negotiation, which are usually domain-dependent —different protocols require the application of different sequences of steps—, to make the protocol more agile or to converge more rapidly.

Note that we have also two alternatives for norm enforcement [CAG$^+$10, CAJB09, CAB09, CAB10, CJBA10]. The former is to implement this reasoning process in the institution side, making it impossible for an agent to violate the norms. Although this provides a trustful and safe environment, it is less flexible and forces the implementation of the agents to be more aware of the legislation of the institution. Moreover, in real life problems, it may be difficult or even impossible to check norm compliance, specially when the violation of the norm cannot be directly observable. And perhaps, it might be preferable to allow agents to violate norms, since they may intend to improve the organization functionality, despite violating or ignoring norms. On the contrary, the second alternative moves the norm reasoning process to the agent side, thus making the system more open and dynamic. In this case, the intelligence of the agent can make it more or less law-abiding in order to obtain a higher personal benefit. If a norm is violated and a third party is affected, the grievance mechanism activates and the conflict resolution stage modelled in the EI is launched.

All in all, and as shown in Fig. 1.1, this tier includes several techniques to deal with agreement technologies, selection procedures based on data mining processes, intelligent agents that can reason on norms, and planning+CSP methods for navigating through the

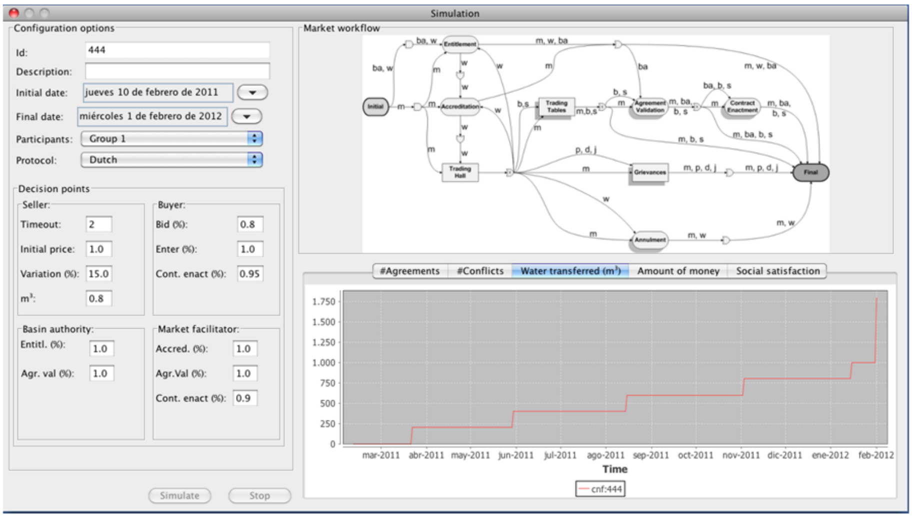

Figure 1.5: The *mWater* simulator in action for a given configuration.

mWater EI, while also trying to find optimal solutions in terms of the amount of water transferred and/or the social satisfaction of the participants.

1.2.4 Presentation Tier: GUI Simulation Tool

The interface of *mWater* as a simulation tool is simple and intuitive, as shown in Fig. 1.5. The idea is to offer a straightforward and effective way in which the user configures and runs simulation with the following data: i) the initial and final date for the period to be simulated; ii) the participants, i.e. water users, that will participate in the market (different groups/type of water users lead to different results; e.g. a group in which water users do not trust other members of the group results in a low number of agreements and a high number of conflicts); iii) the protocols to be used during trading, which represent the regulation to be applied in the current simulation; and iv) several decision points to include some random behaviour when users (seller, buyer, basin authority and market facilitator) need to take some decisions. The tool outputs graphical statistical information that indicates how the market reacts to the input data in terms of the number of transfer agreements signed in the market (historical data including information about real or simulated users), number of conflicts generated, volume of water transferred, amount of money, etc. Apart from these straightforward parameters, the tool also shows different quality indicators based on “social” functions in order to asses values such as the trust and reputation levels of the market, or degree of water user satisfaction, among others. This is important to evaluate the quality of the market from the stakeholder’s point of view, and not only from a mechanistic standpoint based just on the number of agreements or water transferred, among other.

1.2.5 Analysis of the Results

One essential part of a simulation tool to assist in decision making is to be able to compare the results of different simulations, executed under different configurations. Having this in mind, and aiming at providing as much valuable information as possible, we have also implemented in the GUI a specific decision tier for comparing and analysing simulations. The idea is easy but very effective: the user chooses some simulations from those previously executed and stored in the database, the tool plots them together and extrapolates the best result for each unit of time (day, week, month and so on). For example, if we plot the number of agreements of two simulations, e.g. configurations #337 and #347, and the objective is to maximize this number, a third graphic is added which always shows the highest number of agreements over the timeline (extracted from #337 and #347), as shown in Fig. 1.6. This is helpful for policy-makers, as it allows them to find out which *part* of the simulation (and, consequently, which input values for participants, protocols and decision points) leads to the best results in a particular time window, even if the same values are not that good in other windows. In other words, the simulator gives us more precise information on the best result over very particular time units; e.g. the input values for one configuration lead to a higher number of agreements during summer, but the input values for another configuration are better for winter, though none of the configurations in itself is clearly better than the other for a whole year. In particular, in Fig. 1.6 we can see that configurations #337 and #347 are very similar until May 2011, but afterwards configuration #347 is better —it represents the optimal solution of both configurations. Although the reader may think that this simply puts some sugar on the result simulation form and the user could do this by him/herself, it is important to note that policy-makers run dozens (and even hundreds) of simulations for periods that may range from one month to many years. So, doing this analysis by hand and independently for each simulation becomes prohibitive in most scenarios.

From the experts' point of view and their advice, we can conclude that a model+simulator like this provides nice advantages: i) it successfully incorporates the model for concepts on water regulation, water institutions and individual behaviour of water users; ii) it formally represents the multiple interactions between regulations, institutions and individuals; iii) it puts strong emphasis on user participation in decision making; and iv) it finally provides a promising tool to evaluate changes in current legislation, and at no cost, which will surely help to build a more efficient water market with more dynamic norms. Note, however, that the simulation tool is currently mainly policy-maker-oriented rather than stakeholder-oriented. The reason for this is that we have focused on the possibility of changing the norms within the market and evaluate their outcomes —which is the policy makers' labor—, but not in the participation of stakeholders to change the model of the market itself. But clearly, in a social context of water-right management it is important to include tools for letting stakeholders themselves use the system. In other words, the framework should be also able to incorporate the participation of relevant stakeholders, thus helping validate results, which is part of our ongoing work.

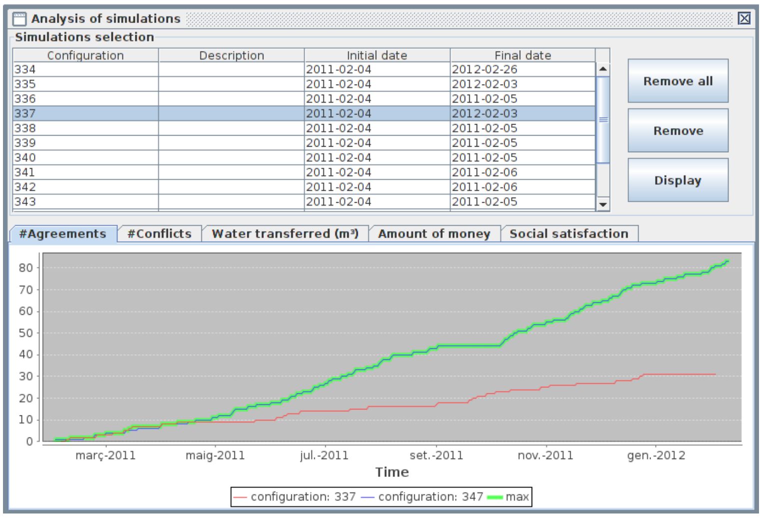

Figure 1.6: Analysis of different simulations. Thick line represents the optimal solution, in this case the max number of agreements.

Chapter 2

Further uses of *mWater*

In this chapter we present two further uses we have found for our *mWater* case study. In particular, we have extrapolated our water-right market to a generic negotiation framework that comprises both the trading and the conflict resolution process. After this, we introduce a preliminary work on how this type of MAS can be used to enhance policy-making simulation.

2.1 A Formal Framework for Generic Negotiation

Picture the water-right market (or any other produce market) where customers are involved in face-to-face negotiation or participate in auctions that must obey different policies. Picture, also, the various ways that conflicts among the users of water resources of a single basin are being solved. These are just two examples of institutions that share some standard features that can be captured in a generic negotiation framework with common roles. And they can be easily extrapolated from our *mWater* platform.

2.1.1 Performative Structures

As can be foreseen from the previous chapter, in most institutions there are several negotiation scenarios, e.g. price-fixing encounters or solving conflict resolution, each with a specific negotiation protocol that expresses how scenes are interrelated and how agents playing a given role move from one scene to another. While most tables restrict access, there is a large public hall —the market floor or the legislative environment of a hydrographic basin— where participants exchange information, request to open or enter a table, invite participants or are invited/requested, and where they reconvene after leaving a negotiation table. For this last purpose, they may go to another private encounter to carry other institutional businesses, like enacting agreements, creating/dissolving coalitions, etc. We can capture this global arrangement as a generic institution for negotiation, as shown in

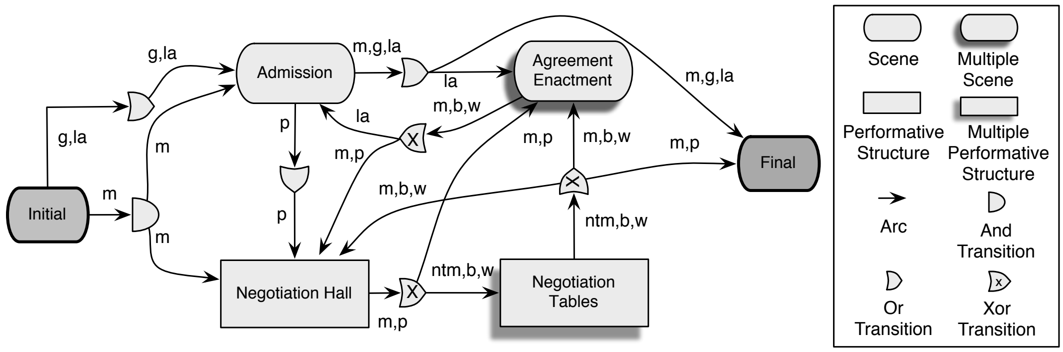

Figure 2.1: Performative structure of a generic electronic institution for negotiation. Roles: *g* - guest; *p* - participant; *b* - black; *w* - white; *m* - mediator; *ntm* - negotiation table manager; *la* - legal authority.

the ISLANDER specification[1] of Fig. 2.1. Procedural conventions in the generic negotiation institution are specified through a main performative structure which includes two other performative structures: the *NegotiationHall* and *NegotiationTables* (see Fig. 2.2), plus two supporting scenes, *Admission* to register guests as bona-fide negotiating parties and *Agreement Enactment*, to handle post-negotiation actions. *NegotiationHall* captures the public activity that surrounds negotiation, that is where participants become aware of any activity by exchanging information, initiate concurrent activities and deal with critical situations. On the other hand, *NegotiationTables* is the core of the institutional framework because it mirrors the conventions and policies that allow different protocols (e.g. auction mechanisms) to negotiate about a deal and co-exist. Specificity is embedded in the negotiation tables and gets propagated all the way to the main performative structure of Fig. 2.1 by the generic negotiation framework. Once negotiation tables are specified in the detail, the end product would be one specific electronic institution for some type of negotiation.

2.1.2 Users and Roles

In our generic negotiation framework there are seven roles, which are depicted in Fig. 2.1. This number is not arbitrary as it represents the natural interaction of the institution. First, the guest role (g) is the user that wants to enter the process. After admission, the guest may be specialized into a participant (p), which is later specialized as black and white (b and w, respectively) to differentiate the parties that are acting within negotiation. Finally, there are three types of staff roles for start, overall and end the negotiation. The

[1] At a glance, each scene represents an atomic process and/or interaction, a performative structure represents complex interaction models and procedural prescriptions. The dynamic execution is modelled trough arcs and transitions, by which the different participating roles of the institution may navigate synchronously (AND transitions) or asynchronously (OR/XOR transitions). See [AEN$^+$05] for further details on this type of notation.

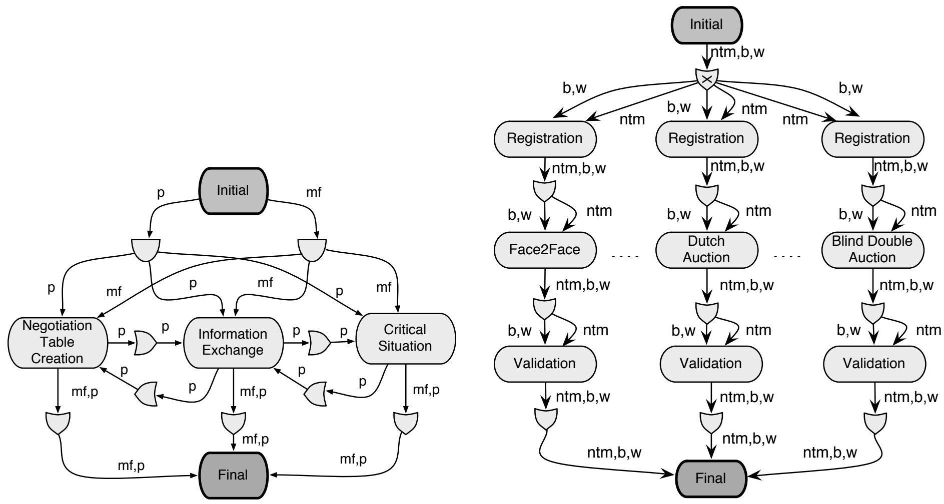

Figure 2.2: *Negotiation Hall* and *Negotiation Table* performative structures.

mediator role (m) represents institutional agents who start the negotiation activities, such as managing the users data, the specific parameters of the negotiation protocols, etc. The negotiation table manager role (ntm) represents institutional agents who execute activities that are specific of a given negotiation policy, e.g. accept valid negotiators, mediate in the negotiation process, etc. Finally, the legal authority role (la) represents institutional agents who are in charge of the last activities, such as agreement enactments that are executed as a result of a successful negotiation process.

2.1.3 Discussion

Interactions among agents are everywhere. They usually co-exist, collaborate and agree, but sometimes they compete with one another. Interestingly, the common denominator in all these situations is a negotiation process. And a standard negotiation framework is the basis for modeling virtual institutions (such as markets) as multi-agent-based specifications.

All in all, *mWater* has established the foundations for the specification of an agent-based negotiation framework that handles multiple negotiation protocols in a coherent and flexible fashion. Although it may be used to implement one single type of agreement mechanism —like a blind double auction or argumentation-based negotiation— it has been designed in such a way that multiple mechanisms may be available at any given time, to be activated and tailored on demand (on-line) by participating agents. This framework is generic enough so that new protocols may be easily added; the underlying objective is to have a generic electronic institution that may be tailored to specific needs and grafted into other electronic institutions and as a by-product create a repertoire of light-weight agreement mechanisms that may be used as ”scene-modules” in other electronic institutions and in particular as stand-alone interaction plug-ins in peer-to-peer architectures.

2.2 A MAS for Policy Simulation

2.2.1 Introduction

Policy-making is a hard task. Designing and taking legal decisions involves a complex balance among different factors, such as economic, social, administrative or environmental aspects. Also, factors usually change throughout time due to variations in economic situation, population distribution and physical conditions. Finally, to make things even more complex, the outcome to measure the success of a given policy is not always straightforward or possible.

Let us consider regulation policy on water management as an example. Needless to say that good water management is a complex endeavour. Water policy is determined by physical conditions like rainfall, water supply, distribution infrastructure, land use and economic activities. And the main outcome cannot be just measured by the actual water demand. But policy makers have a direct influence on supply and demand, and on how to foster an efficient use of water. In other words, a policy maker has little control over the hydrographical features of a basin but (s)he has legal power to regulate water user's behaviour to a larger extent by means of: i) government laws, ii) basin or local norms, and iii) social norms to design appropriate water laws that regulate users' actions.

Finding the best norms and taking the best decisions on the design of new policies and their application are rather difficult, expensive and delicate tasks. It is, therefore, essential to have mechanisms and/or simulation tools in the early phases of the policy cycle, i.e. before the legislators fix the legislation —and policies are really applied in the real world—, to analyse the impact and assess the expected success. In this line of work, *mWater* has shown as an open environment that implements (negotiation) regulations and is enabled with tools to specify performance indicators, to spawn agent populations and allow humans as well as software agents to participate in simulations of virtual trading [BGG+11, GGG+11].

2.2.2 Discussion

As discussed in the previous chapter, *mWater* is implemented as a component of a larger institutional framework designed as a demand module for water management modelling based on an electronic market of water rights. More specifically, we have provided the decision-support tool constructed around such a market that integrates a wide range of subcomponents to: i) represent all the elements of the market, such as basin, trading and conflict resolutions processes, water users, protocols, norms and legislation, among others; ii) model the entire system as an EI; iii) design the information system on a *mySQL* database of the entire electronic market and basin structure; iv) implement the agents that provide the *simulated reasoning*; and v) create the GUI for simulation tool. This is very useful in modelling policy-making. One of the key problems is policy content analysis and modelling, particularly the gap between on the one hand policy proposals and formulations that are expressed in quantitative and narrative forms. On the other hand, it is also difficult to find formal models that can be used to systematically represent and reason with the information contained in the proposals and formulations. *mWater* offers a tool designed so that policy makers may explore, monitor and visualise the interplay between: i) market regulations, ii) trader profiles and market composition, iii) the aggregated outcomes of trading under those set conditions, and finally iv) the impact of these multi-agent policy simulations (and arguments about policies) on the outcomes of the market at no real cost.

When the *mWater* simulator is in action (see Fig. 1.5, 1.6), it allows the water policy maker to choose different input values that involve simulation dates, participants, legislation (in the form of protocols used during the trading negotiation) and some decision points that can affect the behaviour of the participants[2]. We have also implemented a specific decision tier for comparing and analysing simulations, as described in section 1.2.5. To sum up, from the experts' evaluation, we can conclude that a tool like this provides an advantageous mechanism to evaluate changes in current legislation, which will surely help to build a more efficient water market with more dynamic norms. We are working on a more precise elaboration of *mWater* from the policy-making perspective.

[2]In our current implementation, these additional decision points rely on a random basis, but we want to extend them to include other issues such as short-term planning, trust, argumentation and ethical values.

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