D8.2.3 Report: *mWater* prototype review

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Abstract.
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The mWater prototype review is detailed in this report.
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Executive Summary

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*, whose main features we discuss in this paper.

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.[2] We are therefore interested in the institutional framework that defines the "rules of the game" that may allow one to study the role that regulation, social environment, coordination, conflict resolution mechanisms, reputation or trust play in the decisions participating agents make and their aggregate results. Ideally, the institutional framework should add flexibility to cur-

[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.

[2]Considerable effort has been invested in the development of sophisticated basin simulation models and in improvement and innovation of water use practices. Literature abounds in examples of decision support systems for water management [RN05], sustainable planning of water volumes [CLM04, MdSODO^{+}07], or the use of shared visions for negotiation and conflict resolution [PWMW99]. We explore an alternative approach in which individual and collective agents are an essential component because their behavior (and effects) may be influenced by policy-making. There are few projects along this line but one may point to the NEGOWAT project (http://www.negowat.org/ingles/inicio/Inicio.htm), whose goal is to help negotiations between stakeholders in peri-urban catchment areas when water conflicts arise. Closer to our own approach, the recent effort is project MAELIA (http://www.iaai-maelia.eu), that involves simulation of socio-environmental impact of norms for water and other renewable natural resources and the environment.

rent water use practices without increasing the number or complexity of disputes. In such a framework we shall profit from agreement technologies to understand the behaviour of participating agents and the collective effects of their behavior.

As a whole, *mWater* constitutes a rather complex regulated open multi-agent system. The work we report in this deliverable provides the prototype review. This report includes the results from the mWater Advisory Board review report from the mid 2010 meeting in Valencia.

Contents

Chapter 1

A decission support tool for Water-Right Markets

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 different types of use. 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.

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 [Tho97], similarly to a traditional goods market. 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, always fulfilling some pre-established norms, to other users in exchange of some compensation, economic or not [Tho97]. Additionally, when there exist incentives for an efficient use of water allotment, it is time for a straightforward extension to other types of stakeholders that promote trading for non-irrigation uses, such as industrial uses, aquiculture or leisure, thus improving market conditions and efficiency in water use. This paper concerns the application of a regulated open Multi-Agent System (MAS), *mWater*, that uses intelligent agents to simulate a flexible water-right market. Our simulator focuses on demands and, in particular, on the type of regulatory (in terms of norms selection and agents behaviour), and market mechanisms that foster an efficient use of water while also trying to prevent conflicts among parties. In this scenario, a MAS 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.

1.1 Problem Overview and its Current Limitations

Water-right markets allow rapid changes in allocation in response to changing demands for water and stimulate investment and employment, as users are assured of access to secure supplies of water. Because of water's unique characteristics, such markets do not work everywhere, they are not homogenous as present different organisation schemata, nor do they solve all water-related issues [Tho97]. So it is essential to design appropriate water laws and regulate, either privately or publicly, the users' actions, interactions and their eventual trade.

The willingness of irrigators to buy or sell water initially depends on the difference between the price of water and net revenue each farmer expects to earn by irrigating. Thus, for a given price of irrigation water, a farmer would be willing to purchase water if (s)he expects a unit of water to generate more incomes than it costs. If another farmer expects a unit of water to earn less that (s)he could sell it for, (s)he might want to sell it thus originating the trading process. But it is not always a matter of price expectations, but also of regulation. The emphasis on regulatory aspects is motivated by the fact that the main objective policy makers have in mind is to achieve an adequate behaviour of users to ensure the success of the market. And regulation is the main tool that policy makers have to modify behaviour by means of laws, local and social norms. In practice, users are prone to achieve "order without law" or, at least, to preserve their practices within the established regulation, whereas policy makers adapt regulation to guide users in a constantly changing environmental and political media. Also, as the result of enforcing norms in a water market is unknown a priori, a MAS-based simulation tool shows very appealing to analyse the impact in the users, the market itself and its success.

Literature abounds in examples of sophisticated basin simulation models, particularly decision support systems for water management [ACS96, RN05], sustainable planning of water volumes and hydraulic resources [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. Clearly, operational management has benefited from the advances in computing and its applications, particularly in modelling, software engineering and simulation techniques, thus helping improve the operating rules for efficient water allocation. However, the gap can still be considerably narrowed from a social perspective, which is an important limitation nowadays. The underlying idea is not only to consider hydraulic factors, such as river basins, water demands, pumping flows, etc., but also different norms 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. This requires the use of intelligent agent technology, including trust, cooperation, argumentation and, in general, agreement technologies (see `http://www.agreement-technologies.org`). Agreement is a crucial concept that helps human agents to cope with their social environment and deal with any type of human interactions. And how to support and promote agreements in water markets is missing in current approaches, which is also an indication of ineffectiveness.

An additional limitation is imposed by current legislation. In many countries, the norms and their regulation are very strict, which do not allow a full and flexible market. For instance, Spanish regulation is too restrictive; 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. This means that the number of water-right transfers is practically nonexistent in reality, and limited to very short periods. 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 strong.

Finally, from a performance standpoint it is unclear which is the best quality indicator of the market because it cannot be measured in terms of just one factor; we need a multiobjective analysis that comprises multiple criteria based on differing objectives, responsibilities and interests among the stakeholders and institutions involved in the market. Factors such as economic development, social welfare, environment preservation, agricultural self-sufficiency and financial feasibility must be considered. All in all, these issues can be achieved at a high global cost which is based on industry structure, population, quality standards, investment for new treatment plants, and policy for water allocation among agriculture, industry and domestic sectors.

In this paper, the simulation tool provides the foundations for the study of that interplay among agents, rule enforcing and performance indicators. In particular, we simulate and test how regulations and norms modify the users' behaviour and how it affects the quality of the market.

1.2 Why Use a MAS as a Simulation Tool?

Agent technology and multi-agent systems have been successfully applied to problems such as manufacturing, medicine, aero-space, etc. One of the most promising domain applications of MASs is the simulation of complex real life systems that emulate social behaviour and organizations, where a MAS is used as a powerful tool that mimics real world behaviours of individuals and societies [SHS09, SJR+02, GB04a, JB04, GB04b, AGV+04, GB06, APA+07, BJC+06, HGPRG+09, GV09, GJR+10]. In this way, complex behavioural patterns are observed from simulation tests in which autonomous entities (agents) 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 entities that interact, and 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.

On the other hand, in the specific domain of water-right management there is a need to foster a more rational use of the resource. And it is agreed that this may be addressed by creating an efficient market of water rights that coexist in a complex, social and legal framework [Tho97]. Although 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 regulation and policy-making. The idea is to follow the thread of 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.

Our approach, as a MAS simulation tool, implements a regulated market environment, in which different water users (intelligent agents) trade with water rights under different basin regulations. With such a tool, water-policy makers can easily predict and measure the suitability and accuracy 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 into the real floor. At the same time, it is a tool to manage the water resource in an effective way, both in the short and medium term. All in all, not only is it an aid for a better understanding of the physical and management aspects of the water-resource system in question, but it is also a good tool for data organization and communication among the different teams of the basin administration.

There are a lot of approaches to implement MAS applications. Some approaches are centered and guided by the agents that will inhabit the systems, while others are guided by the organizations that the constituent agents may form (for a literature review please refer to [**?**]). Apart from these approaches there are another group in which the development process is centered on the regulations that defines the MAS behavior. We are particularly interested on those methods due to the requirements imposed by the environment of mWater. In the following section we introduce the Electronic Institution approach used to develop mWater.

1.2.1 Electronic Institutions

Electronic Institutions (EI) are computational counterparts of conventional institutions [Nor97, RA01, Est03]. Institutions are, in an abstract way, a set of conventions that articulate agent interactions [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. *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.

1.3 Our Approach

mWater uses a multi-tier architecture, as depicted in Fig. 1.1. In addition to the three typical tiers of presentation, business and data persistence, we have a module that represents the Electronic Institution (EI) for *mWater*. This way, the construction of *mWater* consists of four stages: i) modelling the system as an electronic institution; 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) deploying the GUI for simulation tool (presentation tier), which are described next.

1.3.1 Modelling the system as an EI

We have followed the IIIA EI conceptual model [AEN$^+$05], whereas for the actual specification and implementation we have used the EIDE platform[1]. The *mWater* institution is specified through a nested performative structure with multiple processes, as depicted in Fig. 1.2 (see Deliverable 8.2.1 for further details). There are five agents' roles: i) guests, i.e. users before entering the market; ii) water users, i.e. the guests that have valid water rights; iii) buyer/seller, thus representing the particular role the water user currently joins

[1]EIDE is a development environment for Electronic Institutions, implemented at the IIIA (`http://e-institutor.iiia.csic.es/eide/pub`). It consists of a set of tools that support all the stages of EI engineering, namely: i) ISLANDER, a tool for EI specification; ii) aBUILDER, a tool to support the automatic generation of agent (code) skeletons from ISLANDER specifications; iii) the AMELI middleware that handles the enactment of the institution; and iv) SIMDEI, a testing and monitoring tool.

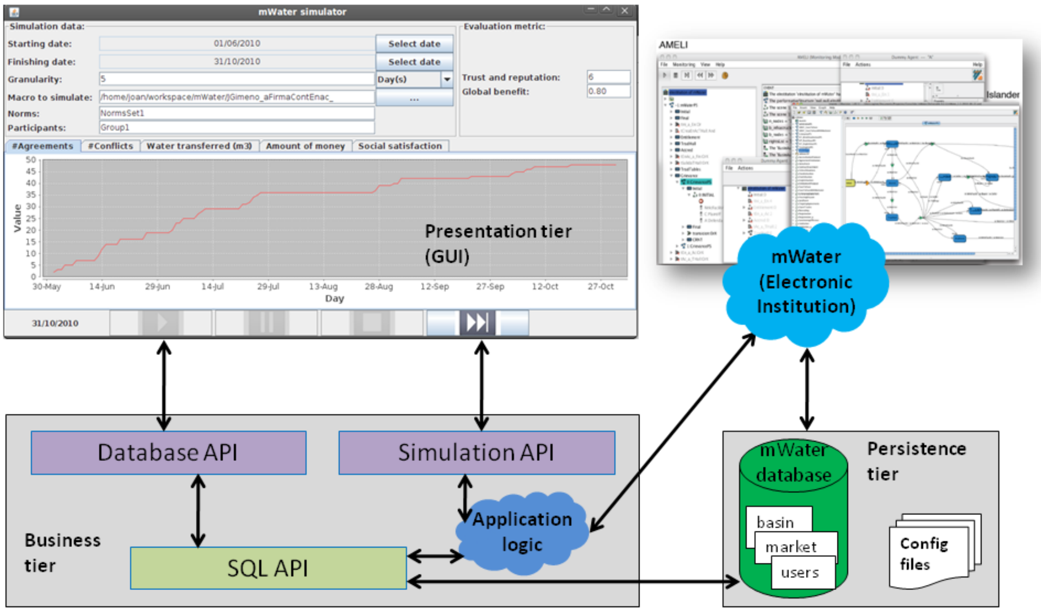

Figure 1.1: Multi-tier architecture of the *mWater* decision support tool

for the market; iv) third parties, i.e. those water users that are direct or indirectly affected by a water transfer —usually conflicting parties; and v) market facilitator and basin authority, thus representing the governing roles of the market. The top structure describes the overall market environment and includes the following elements:

- Entitlement, which represents the bootstrap routine to give access to the market to those water-right holders who prove they are entitled to trade because: i) they have an existing right, or ii) a new right is created by the *mWater* authorities and an eligible holder gets it granted.
- Accreditation, which allows legally entitled water-right holders to trade by registering their rights and individual data for management and enforcement purposes.
- TradingHall, which represents a nested performative structure. It basically provides information about the market and, at the same time, allows users and trading staff to initiate trading and ancillary operations.
- TradingTables, which represent a nested performative structure and the core of our market. It allows a market facilitator to open a new trading table whenever a new auction period starts (i.e. automatically) or whenever a right-holder requests to trade a right (i.e. on demand). Our implementation accommodates different trading mechanisms and negotiation protocols, such as Dutch auction, English auction, standard double auction and blind double auction with mediator negotiation, but new negotiation protocols can be easily included.
- Agreement Validation, which validates agreements on water-right transfers according to the market regulation. More particularly, staff have to check whether the agreement satisfies formal conditions and the hydrological plan normative conventions.
- Contract Enactment, which represents the signature among parties involved in a norm-abiding agreement, thus making the agreement active.
- Grievances, which represent a nested performative structure. It allows external stakeholders to initiate a grievance and conflict resolution procedure that may overturn or modify an active agreement. Even if there are no grievances that modify a contract, parties might not fulfill the contract properly and there might be some contract reparation actions.
- Annulment, which deals with anomalies that deserve a temporary or permanent withdrawal of water rights.

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. Since the agreement execution may eventually turn conflicting with third party agents, the grievances structure is necessary to allow normative conflicts to be solved within the *mWater* institution.

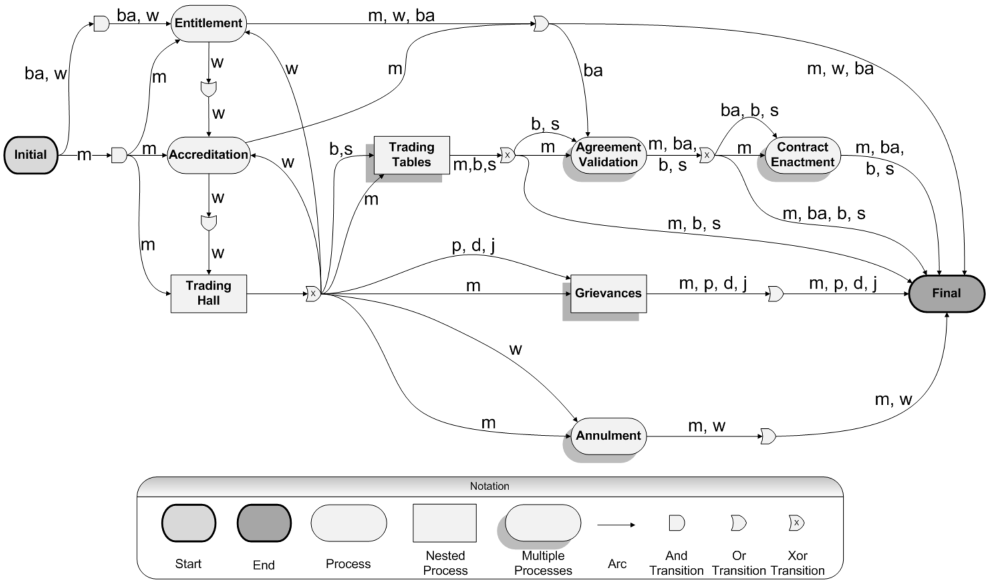

Figure 1.2: *mWater* performative structure. Participating roles: *g* - guest, *w* - water user, *b* - buyer, *s* - seller, *p* - third party, *m* - market facilitator, *ba* - basin authority

1.3.2 Storing the Information. Database Design

mWater implements the persistence tier by means of a MySQL database with over 50 relational tables in which historical data is stored (see Fig. 1.3). In essence, we have three views that comprise the basin, market and grievance structure. 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, including 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.

1.3.3 Implementation of Agents

mWater implements a schema of agents that include both the internal and external roles. Broadly speaking, there is a JADE (Java Agent DEvelopment Framework, `http://jade.tilab.co` 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 devel-

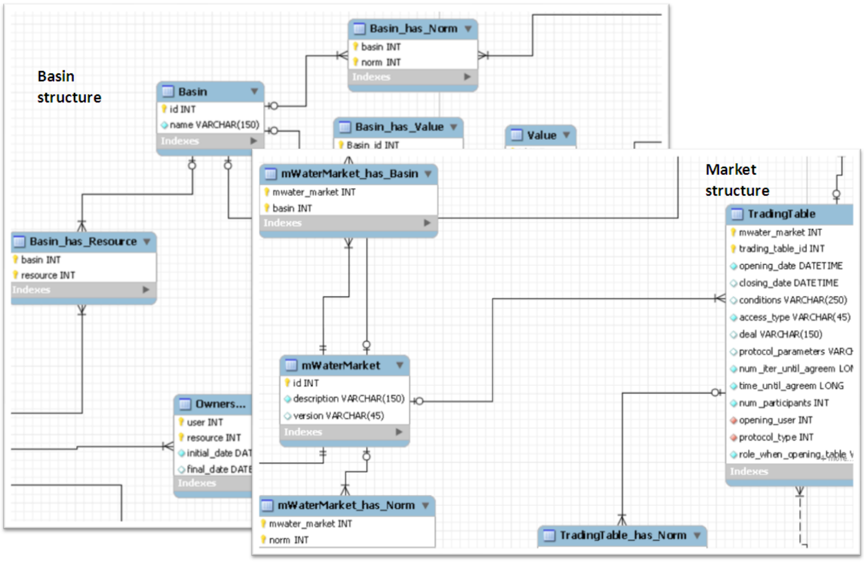

Figure 1.3: Fragment of the database: basin and market structure

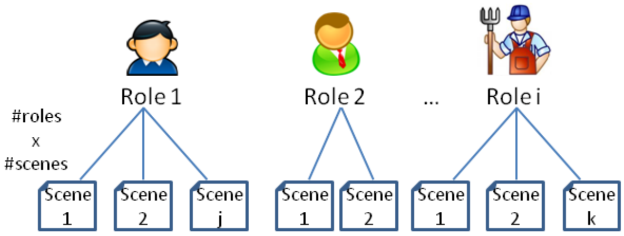

Figure 1.4: Schema of the agents implementation. The mapping proceeds by generating one Java class per role in each scene it can be involved

opment 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 —see the definition of the *mWater* EI in Fig. 1.2—, so there are roles that are translated into more classes than others. The main idea with this is to offer open and flexible templates to implement different agents and norms, which provides more opportunities to the user to evaluate the market indicators under different regulations and types of agents.

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 can 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. For instance, in the case of the buyer/seller we have implemented a *favourable* and *unfavourable* behaviour. In the former, the agent is always in favour of achieving an agreement to trade and follow the norms of the market, whereas the latter is always against it and does not follow the rules. Note that we have also two alternatives for norm enforcement [CAB10b]. 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.

Additionally, we have currently working on the implementation of more behaviours that use agreement technologies features. Instead of relying the decisions on a random basis, we take decisions in terms of trust, cooperation, short-term planning, argumentation and ethical values. In any case, the advantage here is that we can implement as many different agents (with different behaviours) as necessary and analyse their impact in the market.

1.3.4 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 a given simulation with the following data: i) the starting and finishing date for the period to be simulated; ii) the 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); and iii) the regulation to be applied in the current simulation. 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), volume of water transferred, number of conflicts generated, 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.

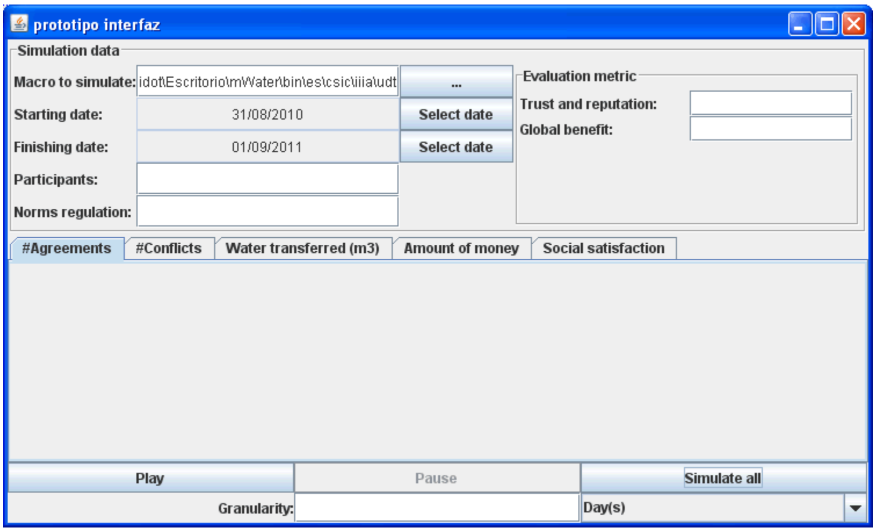

Figure 1.5: The *mWater* simulator in action.

1.4 Results: the Simulator in Action

Figure 1.5 shows a snapshot of the mWater simulator in action2 . This interface allows the user, i.e. the water policy maker, to choose different input values that involve simulation dates, participants, norms (in the form of protocols used during the trading negotiation) and some decision points that can affect the behavior of the participants3. From the expertsÕ point of view and evaluation, 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 behavior 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 [CAB10b, CAB10a, CJBA10, CAJB09, CAB09].

Chapter 2

Review

Te review report of the mWater Advisory Board is attached in the following pages.

mWATER ADVISORY BOARD REPORT

– January 2011 -

INTRODUCTION

"Agreement Technologies" is a research project that proposes to use Multi Agent Systems (MAS) methodology and technologies for analyzing and understanding the performance of social systems by using an artificial computer based institute. As part of the project, three application areas are being used for testing and demonstrating the value of this approach: mWater, eProcurement and mHealth.

mWater deals primarily with the interactions between agents who propose to sell and buy water rights, in a market whose rules are set by a central regulator. Individual transactions that are conducted in this market are simulated, one-by-one, following a sequence of activities that include entering the market, making a proposal, bidding and negotiations, successful or abandoned agreements, complaints and contestation, and arbitration of contested activities. All outcomes of the individual activities are recorded in a data base, which is then used to summarize, analyze and present the outcomes. The analysis yields various "measures of performance", that are in fact multiple objectives – from the perspective of the authority (e.g., efficiency, sustainability) and of the agents themselves (e.g., equity, preservation of nature – which is a joint objective of the authority and of the "green" agents that should be added to the institute). In the project, there is a planned application of the mWater demonstrator to the 7,421 square kilometer area of the aquifer of Mancha Oriental in the south-east of the Iberian Peninsula.

The ultimate objective of the system is to provide information that is useful in assessing for comparison and decision making different sets (alternatives) of "market conditions, rules, laws, regulations, and procedures". In the project, two different possible applications of the resulting system are envisaged:

- as a tool for supporting the operation of an actual water market

- as a test bed for designing and testing the effects on the market of certain changes in its organizational or regulatory framework.

ABOUT THE ADVISORY BOARD

The members of the Advisory Board (AB) that attended the meeting and contribute to the present report are:

- Prof. Uri Shamir, from Technion - Israel Institute of Technology

- Prof. Luis Garrote, from Universidad Politécnica de Madrid, Spain
- Dr. Manuel Echevarría, from Centro de Estudios y Experimentaciones del Ministerio de Fomento (CEDEX), Spain
- Prof. Joaquín Andreu, from Universitat Politècnica de Valencia, Spain

Most members of the AB are not expert in Computer Science in general and in Agent Based methodology in particular. Our expertise is primarily in water resources systems, including the use of management models that employ simulation and optimization methods, and we have a range of experience in actual management of real-world water systems. Our report should be viewed with this in mind, i.e., from the perspective of how the system can represent a reasonable reality in the domain of water and be a useful tool in aiding decision making. It should not be viewed as a critical review of the CS tools being used.

ABOUT THE MEETING

Prior to the meeting, the UPV team in charge of the mWater demonstrator in the Agreements Technologies project sent information about the work performed (Report and scientific paper) to the Advisory Board.

The meeting took place the 9th of November 2010, at UPV, and the main presentations were:

- Overview of the Agreement Technologies project
- mWater: Task 8.2 of the Agreement Technologies Project
- mWater: a decision support tool

During and after the presentations, there were questions raised by the AB members, and discussions with the Project Team. And, finally, there was a private meeting of the Advisory Board.

In the private meeting of the AB, it was agreed that a single report will be produced based on individual contributions of the members of the AB.

This report is designed to present the observations and comments from the AB with respect to the current situation of the mWater demonstrator, and the recommendations and suggestions for future development and improvements.

CURRENT SITUATION OF mWATER

The system has been modeled using the EIDE platform (development environment for electronic institutions, implemented at IIIA). The elements included in the water market Electronic Institution are:

- Entitlements

- Accreditations
- Trading Hall
- Trading Tables
- Agreement Validation
- Contract Enactment
- Grievances
- Annulments

The database has been designed by means of a MySQL database with over 50 relational tables in which historical data can be stored an the agents have been implemented using a JADE (Java Agent Development Framework). According to the mWater developers, they are working on allowing several implementations of each agent so as to represent different behaviors.

The simulation tool has a very simple interface allowing the user to configure a simulation defining the starting and finishing date for the period to be simulated; the groups/type of water users that participate in the market; and the norms (regulation). It also displays other items such as the "Granularity" and the "macro to be simulated". It gives as results two "Evaluation metric variables" dealing with Trust and Reputation levels of the market, and Global Benefit. It also provides, for the period being simulated, graphs showing time series of Number of Agreements signed, Number of Conflicts generated, Water transferred, Amount of Money, and Social Satisfaction.

OBSERVATIONS AND COMMENTS FROM THE ADVISORY BOARD

1.- About the current version of the demonstrator:

- The basic elements of the system seem to be in place, and initial (hypothetical) testing of mWater has been carried out. The AB observed a demo of this application and received copies of the power-point presentations. So far, it seems that the demonstrator is not yet dealing with the case of study of Mancha Oriental aquifer. It is clear that the system in its current form is a somewhat primitive "robot" that seems to be making certain "moves". It is only through continued development and testing that the system will be able to prove its usefulness. In a perspective of several years into the future, what is currently a "primitive robot" has the potential of becoming more realistic.

- We think that mWater can be a good demonstrator for the Agreement Technologies project. It successfully incorporates many novel approaches in an innovative way to build a software application which simulates the performance of a water market. It incorporates the concepts of water regulation, water institutions and individual behavior of water users. It is very interesting that the emphasis is placed on social notions as opposed to mechanistic simulation, The multi-agent structure is perceived as a successful formalization of these concepts and leads to an acceptable working simulator which can be used to explore the implications of changing the regulations or user behavior through policy actions in order to improve the global efficiency of the system.

- We also found the graphic user interface too simple: the only outcomes are graphs representing quantities such as the number of agreements, conflicts or the amount of money in transactions, and it is very difficult to draw conclusions on the effect of policy measures by analyzing only those outcomes.

- Other questions are the following:

  - We find it strange that among the data provided for the simulation of the Water Markets there is no mention of economic functions that express the economic value of water for the water users, as these are surely important considerations in the individual decision process to buy or sell water rights..

  - The allegation (grievance) activation process is not sufficiently clear: how does a stakeholder discover that he/she is or may be affected by an agreement?

  - What arguments are allowed to support the presentation and decision in a Hearing Dispute?

  - The results of the simulation tool should be better displayed and explained. A clear and easily understood presentation of the results is critical for assessing the relative advantages of different market management policies/strategies.

2.- About the relationship between the virtual market in mWater and reality:

- The real system that is depicted in mWater is a market of water rights in which individuals are allowed to enter transactions under a specified set of market regulating norms and regulations. A most important duty of the work in the project is to ascertain that it is indeed a reasonable depiction of the situation in the field, in particular in the Mancha Oriental Aquifer. By this we mean that one should be convinced that the outcomes generated by mWater are a reasonable outcome, a result that could have happened in the field. It is clear that calibration against past performance is not possible, since there is no body of past experiences to calibrate against. Still, persons with real experience in this area – including farmers, farmers' unions, local water managers, environmentalists, government officials - should be able to say whether the outcomes of different simulations look possible, even reasonable. And, in addition to observing the aggregate behavior of the market, individual behavior of a not-too-large yet sufficiently representative set of individual agents should also be examined. This is another examination of the reasonableness of the system.

- Moreover, real water markets tend to be very imperfect because they are strongly constrained by the availability of water infrastructure, which limits the possibility to store or transport water. Water is not a homogeneous good.

Different sources of water have different quality and value for different user types.

- User and/or group behavior is also very difficult to model because there are many factors outside the modeling scope of mWater which play a role, such as political influences (in Spain there can be many); Lobbies, that condition individual behavior; irrational behavior (customs, inertias, indolence, etc.); effects of Court's appeals and interferences.

- Also, relationships between water markets and other physical, and/or economical, and/or production factors, such as Hydrology (rain), European Agricultural Policies, Crop markets and prices, Weather and natural hazards (freeze, floods, plagues, ...), and Energy prices, can play roles influencing water market decisions, and are not included in mWater.

- The time dimension also requires a deeper treatment, since negotiations take time to complete and user behavior can change significantly over time, especially in the agricultural sector.

All these factors limit the capability of mWater to reproduce a real water market, and therefore also limit its applicability to analyze the effect of water policies in a concrete water market.

From our perspective as researchers in water management, we think that a number of difficulties need to be overcome before mWater could be used for practical purposes. From mWater documentation and from the presentation which was made to the Advisory Board we gather that the mWater represents a "virtual world" which corresponds to an ideal formalization of a water market. From this perspective it could be used as a software laboratory to carry out virtual experiments to characterize the effect of water polices on water markets.

RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER DEVEOLPMENT AND IMPROVEMENTS

1.- About information to be incorporated into the model:

The dynamics of operation of an actual market of any kind is strongly conditioned by the quantity and the quality of the available information. Both, the access to the information and its associated certainty (and uncertainty) are key elements for qualifying a market. Some of the elements of information more directly linked to a water market are: future availability of water resources, profit expectations associated to different crops, eventual maximum or minimum price of water, economic characterization at macro and micro scale, etc. The elements of information that are the major key factors for decision making of farmers, as main actors in a water rights exchange market, should be selected and represented explicitly in the model. The introduction of these elements would provide a more detailed control over the operation of the system.

The degree of certainty of the information and even the different level of access to it for different groups of agents, are factors that condition their decisions and, hence, the operation of the market. Therefore, taking into account these factors in the model would add a greater approach to actual market operation.

2.- About farmers behavior:

- The behaviour of different individual (or collective) farmers faced by identical situations of the market conditions presents a high degree of variability and heterogeneity. The ideal behaviour would be one characterized by a fully rational process of decision making based on the available information. Perhaps the variability observed in the actual decisions issued by individual farmers could be introduced in the model as a distribution around that ideal behaviour. As was sated earlier, as yet there is no sufficient data base of actual cases upon which to “adjust/fit” a distribution of individual decisions on selling or buying water in the context of a water rights exchange market. There is, however, more information regarding observed reactions of farmers faces by similar situations, such as water scarcity, changes in expected produce/crop prices, etc. This knowledge could suffice to characterize the decisions that would resemble the ones that would be issued by farmers in a water market context. The information should be used to test if the model reacts in the right direction in different situations.

- Different types of farmer individuals (e.g.: small farms, big farms), and their behavior (e.g.: influenced only by agricultural production economic arguments, or by its overall economical circumstances, including personal) should be considered. Is there an expert in behavior analysis in the mWater team? If not, then a social scientist and/or social psychologist who has good familiarity with the specific area being simulated and its population should be added to the research team (or at least consulted). The absence of this professional capability is a significant deficiency of the project as it currently stands.

4.- About model calibration and/or validation

- As mentioned above, persons with real experience in this area – including farmers, farmers' unions, local water managers, environmentalists, government officials - should be able to say whether the outcomes of different simulations look possible, even reasonable. We recommend that presentations of such results/outcomes be made to selected individuals and groups. It is suggested that the simulations should be conducted under a relatively broad set of parameters, such that outcomes of different simulations should be quite diverse, to enable examination of the "response" of the system to different conditions.

5.- About consideration of other aspects, e.g. multiple objectives, long-term sustainability, physical system operation and behaviour.

We refer here to elements of the mWater system that should be added/expanded.

- An additional "layer" should be considered "above" the currently planned system, in which the multi-objectives whose values are generated by the simulation are evaluated for decision making. This can be done with multi-objective decision making procedures and graphical and tabular outputs that facilitate comprehension of the tradeoffs between non-commensurate objectives. The various objectives must first be defined clearly and then the tradeoffs among them are presented, to form a platform for decision making.

- Long-term sustainability of the regional water resources system should be introduced - as constraints (on amounts being extracted, on groundwater levels, on environmental flows into rivers, etc.) and as an objective (e.g., the state of the system at the end of the simulation). Without these, there is a danger that the water users will ignore non-market aspects and potentially also deplete the aquifer towards the end of the planning period.

6.- About increasing the capacity of the users, decision makers and stakeholders to interact with the system.

- If the final goal of mWater is to become eventually a computerized decision support tool, further developments would still be required. If the model is to be used outside a research context, a solid methodology for model construction, calibration and validation must also be developed. The ultimate end user would need guidance in defining the relevant model parameters, in order to adapt them to a specific case. So far, no work has been done along these lines, because model structure and model parameters have been configured together by the same team. These are perceived as a set of graphs depicting interaction among agents and a database of basin structure. Which of those features are “persistent” (valid for all markets) and which are parameters (specific to Mancha Oriental Aquifer)?. It is claimed that the simulation tool will allow the user to change and impose more norms and try a new market with them, but it has not been clarified how the user can do this without having to change the model structure.

- The goal should be to increase the capacity of a user to manage the program in a predictable way, improving its control over the market system and being able to understand its outputs. The achievement of this goal would provide the users greater confidence in the system operation.

- The graphic user interface should provide more meaningful results in order to assess the effectiveness and quality of the water market and its influence on improving water resource management. It should also provide better access to internal model behavior, which could be used to draw conclusions regarding how to improve the model.

- In this first version, mWater has limited application for decision support in water management problems. Water management is an area with a long tradition in using quantitative tools to support decisions. These tools are being continuously developed over time with the main goal of reproducing the behavior of real systems under different management actions. To do so, model formulation must be carefully selected to incorporate the essential features according to the objectives of the modeling effort. In addition to that, the user must be provided with guidance on how to set up a model for a specific case study and how to analyze its results. All these features are missing in the current version of mWater.

- An effort should be made to provide guidance to the user on how to build a model of a water resources system and to adapt it to a specific case study: how to incorporate relevant legislation, how to describe existing actors, how to formalize their behavior, etc.

7.- Other suggestions.

- An effort should be made to distinguish between water rights and water supply. Having a water right does not always warranty that water will be obtained and be available for use.

- It was not clear during the presentations whether some legitimate "agents" were or were not represented - notably nature and ecology. This was not raised at the meeting, and is now posed as a question and a suggestion to add to the agents.

- Lessons should be learned together with the other two applications – eProcurement and mHealth. While each domain has its own characteristics and peculiarities, it is precisely these differences, and how they are dealt with in each of the other two applications, that can provide ideas and insights.

- Even though this is not exactly the research and development area of the members of the AB, some of them have had experience in related areas, such as decision making in multiple objective and multiple decision makers framework using game theory concepts, and applying them in a participative process fostered by the use of a jointly developed Decision Support System (DSS) representing the real basin and including the main components (i.e.: infrastructure, water rights and priorities, operating rules, and water pricing policies), using the results of the DSS depicting the tradeoffs between the objectives. Both approaches could converge.

- Some references about works that could be related to mWater, and may be worth to review, if they have not yet been reviewed, are the following:

Barreteau, O., Bousquet, F., Millier, C. and Weber, J. (2004), Suitability of multi-agent simulations to study irrigated system viability: application to case studies in the Senegal river valley. Agricultural Systems, 80(3): 255-275.

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Bousquet, F., Bakam, I., Proton, H. and Le Page, C. (1998), Cormas: common-pool resources and multiagent systems, Tasks and methods in applied artificial intelligence. Springer, Berlin / Heidelberg, pp. 826-837.

Schlüter, M. and Pahl-Wostl, C. (2007), Mechanisms of resilience in common-pool resource management systems: an agent-based model of water use in a river basin. Ecology And Society, 12(2).

Van Oel, P.R., (2009) "Application of MAS to depict spatiotemporal interdependencies between water use and water availability in a semi-arid river basin", by. In R.S. Anderssen et al. (eds), 18th IMACS World Congress - MODSIM09 International Congress on Modelling and Simulation. ISBN: 978-0-9758400-7-8, pp. 3287-3293.

CONCLUSIONS

mWater introduces a novel approach for software development which opens a new field in the area of simulation of complex systems. Although there are several examples of water models that incorporate human behavior, especially in the area of water demand modeling, mWater is an application that focuses its design on formal representation of the multiple interactions between regulations, institutions and individuals. Recent developments in public water policy have placed strong emphasis on user participation in decision making, and the mWater approach seems a promising one to formalize this process.

As a demonstrator for the Agreement Technologies project we believe it is an excellent application, with many novel concepts in the area of behavioral simulation, which opens a new way to develop software applications to assist in water policy formulation. It is an adequate framework to simulate social dynamics of water markets. As a first prototype, it requires further work, specially related to the interface with simulation of the physical system.

As a virtual laboratory for experimentation on water resources management it has strong potential, but needs to be improved in a number of ways, including calibration or adaptation to a specific water market and validation with real-life processes. As a tool for decision support in water management, it is still very far from being useful, because no methodologies are being offered for model construction, calibration or validation, and especially decision support methodologies. Also, the user interface is still very basic.

As these are first attempts using MAS and AT approaches, they have to be taken as such, and have reasonable expectations on the outcomes of the research. mWater has to be contemplated as a first generation platform that can provide valuable help to raise and explore questions related to water markets that are now included in the development, but not as a definitive tool able to include and give immediate answers to all type of questions, like complex influences of external physical, economical, and social factors, and/or complex behaviors.

Therefore, the AB considers the Agreement Technology project an interesting and potentially useful research, and mWater a worthwhile application. Our observations and suggestions above are designed to help in improving the system itself and its application to a water rights market.

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