

mWater: a Sandbox for Agreement Technologies

Antonio GARRIDO^a Adriana GIRET^a and Pablo NORIEGA^{b1}

^a *Universitat Politècnica de Valencia*

^b *IIIA, Artificial Intelligence Research Institute
CSIC, Spanish Scientific Research Council*

Abstract. The management of natural resources is an intricate and consequential task. In particular, water management is at the forefront of public policy priorities in many countries because of its growing scarcity and its considerable economic and social implications. At the core of water policy is the need to foster a more rational use of the resource, and one way of fostering efficiency might be the creation of an agile market of water rights. However, the design and operation of such a market is not an easy endeavor because it needs to coexist in a complex social and legal framework that has evolved to address the different and often conflicting objectives of the many stakeholders involved.

We are approaching this problem by building an open multi-agent system, *mWater*, that is designed as a regulated environment where autonomous agents trade rights for the use of water in a closed basin. *mWater* is intended as a sophisticated simulator of the demand component of a basin for the design and testing of water management policies, as a test case for a potential actual market and as a sandbox for the development of agreement technologies. This paper outlines the aims of the *mWater* system, describes its core institutional components and indicates its potential use for the development and testing of technologies involved in the processes of reaching and fulfilling agreements.

Keywords. Agreement technologies, e-market, electronic institutions

1. Introduction

Agreement is one of those basic social concepts that help humans cope with their social environment and is present in most human interactions. In fact, agreement is fundamental to cooperation and, ultimately, to the emergence of social systems. It is likely to be crucial for artificial social systems as well.

With that possibility in mind, it makes sense to approach the notion of agreement from a technological perspective, and hence study the computer-supported tools and practices with which agents—that may be human or software entities—interact with one another in order to come to mutually acceptable agreements, and put them in practice. Thus, negotiation, argumentation, collective decision making, knowledge modelling, virtual organizations and learning technologies are evidently involved in agreement pro-

¹Correspondence to: P. Noriega. IIIA - CSIC. Campus UAB, Bellaterra, 08193 Barcelona. SPAIN.

cesses, but ontology matching, normative reasoning and social sanctioning mechanisms play a significant role as well. We shall refer to all these tools and practices as *agreement technologies* and focus the term even more onto the use of these technologies in the context of agents that are autonomous. In fact, this is the rationale behind an ongoing research project on agreement technologies, AT, funded by the Spanish Government (Consolider-Ingenio 2010 CSD2007-00022, [11]), for which *mWater*, the system we discuss in this paper, is a 'demonstrator'.

In this paper, we discuss one of the demonstrators of the AT project, *mWater*, an ideal on-line water market scenario. A sandbox that, as a whole, constitutes a rather complex regulated open multi-agent system.

The paper is organized as follows. We first motivate the pertinence of a market for water rights (Section 2) and argue for a proposal of an ideal electronic market (Section 3). In Section 4 we present a specification of an institutional framework for that e-market, and in Section 5 we outline how it is to be used for testing agreement technologies, to conclude with some indications of future work in Section 6.

2. A market for water rights

Environmental policies have received increasing attention over the past few years and water management, in particular, is at the core of the public agenda. In most countries water scarcity is a major concern, 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. It is not surprising, then, that planning and policy design of water management is given high political priority to reorient current practices in order to prepare water users for unprecedented actions.

In countries like Spain, and particularly in its Mediterranean coast, there is a high degree of public awareness of the main consequences of the situation just sketched: the need of investment and legislation, the unavoidability of conflicts and the urgency of adequate assessment of actual and potential water use. Thus, both government and society are taking preparatory and corrective actions, including new water management mechanisms. Two of these mechanisms 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'. In fact, 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)— 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 right in cases of drought or other severe scarcity problems.

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 [9], sustainable planning of water volumes [3,7], or the use of shared visions for negotiation and conflict resolution [8]. 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 these lines but one may point to

the NEGOWAT project (<http://www.negowat.org/ingles/inicio/Inicio.htm>), whose goal was to help negotiations between stakeholders in peri-urban catchment areas when water conflicts arise. Closer to our own approach, the recent effort in 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. Our focus is on demand and, in particular, on the type of legal and market mechanisms that may have an incidence on that it, so that water use is efficient. We further focus our attention in the role that regulation, coordination, negotiation, reputation or trust play in the decisions these agents make. To cap it all we are also interested in the use of software agents in that type of context.

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 [4,10,12]. 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 [6]. Moreover, a straightforward extension to other types of stakeholders would promote trading for industrial uses, aquaculture, leisure or navigation, not only irrigation, thus improving market conditions and hence efficiency of water use [4]. Ideally, such institutional framework should add flexibility without increasing the number or complexity of disputes. Actually, international experience in USA (particularly California), Chile, Australia and Mexico has demonstrated that (formal) water markets can improve the economic efficiency of water use and stimulate investment [10,12]. There exist several scenarios for implementing water markets, the more salient are water banks [4] and water brokers (see www.waterfind.com.au) that mirror the economic policies of traditional stock markets, and there is no reason why those ideal market would not be an electronic market provided it fully addresses the unavoidable complexities of the water rights trading practices. We propose to implement such a market with a regulated open multi-agent *mWater* whose main features we discuss below.

3. The *mWater* proposal

We have three main objectives for building the *mWater* prototype. First, *mWater* may be used as a demonstrator for AT and, as such, to provide a testing environment for conceptual proposals and the tools thereof. Second, the prototype may be used as a visualization and experimentation environment to explore the interactions between the basin hydrographic resources and infrastructures and the use of water as it is being modulated by market mechanisms and policy directives and regulations. Third, given the possibility of the eventual creation of an actual market for water rights or analogous public goods, *mWater* would constitute a first proof of concept version to build upon.

Our scenario is an idealized version of an intra-basin water rights market. It is not intended to correspond entirely to the trading practices and regulations currently established by the Spanish National Hydrological Plan and forthcoming Basin Hydrological Plans, because it intends to capture the components of an electronic market where water rights are traded with great flexibility through multiple price-fixing mechanisms and the exchange of water rights proper is supported by some ancillary activities around the management of contracts and grievances among right-holders. Our proposal includes richer

and more elaborate trading and agreement management processes than the ordinary ones because: i) we presume software agents may be active participants in the electronic market, ii) we want to make trading more efficient, and iii) we want to have a powerful environment for trying and inspiring agreement technologies.

Legislation in each basin is guaranteed by its Basin Authority (“Organismo de Cuenca”), which guarantees the entitlement of users to trade rights and is also involved in the formalization and publication of transfer contracts and in settling disputes. In the current implementation we have reflected these roles through staff agents. In future implementations we will elaborate more.

The structure of the prototype is based on territorial components for water right exchanges within a basin. More particularly, a basin is organized as districts, generally represented as geographical regions with a network of rivers, a number of district-specific water sources and springs, storage and transport infrastructure like dams, canals and pumping stations, and administrative jurisdictions. We abstract the system and model each territorial component as a directed weighted graph. Each node represents a location where water may be available a, whereas links represent transport conditions (capacity, cost and ownership) between nodes.

Although current legislation defines some components of a water right, in order to make trading agile we add more components to that definition and relax some trading conventions. We admit non-conventional right-holders trading in the market. We allow a right to be transferrable for any water use that has a priority higher, or equal than the original; to split water rights into sub-rights and also to assemble new (single) rights from existing ones, regulating how these operations may be achieved. Finally, we assume human and software agents will be involved as traders, staff and peripheral market players.

4. *mWater*: the institutional framework

Our goal is to establish an institutional framework for an on-line market of water rights. In this paper we only sketch the institutional framework that regiments trading and the main ancillary activities. Hence, it is institutional in the sense that we set the conventions that determine: i) what actions are valid within the market, ii) what are the conditions these actions must satisfy, and iii) what are their intended effects. For the construction of that framework we follow the IIIA *Electronic Institution* (EI) conceptual model [1] where an institution is specified through two main blocks: one that deals with ontological components (the *dialogical framework* that specifies ontology, language, roles and information model) and another for deontological components (the *performative structure* for interaction models and procedural prescriptions and *rules of behavior* for commitment-making conventions). For the actual specification and implementation of *mWater* we use

the EIDE platform.² The following sections describe its roles, its dialogical structure, and the ISLANDER specification of its performative structure.

4.1. Ontological components

These are the core roles and concepts of the *mWater* dialogical structure:

The *Guest* role is for agents that want to enter the *mWater*. *Guest* may be specialized into *Water User*, a water right-holder of the basin, and eventually as *Buyer*, *Seller* and as (an affected) *Third party*. There are two governing roles involved in grievances and contract validation processes: *Basin authority* and *Referee*. Finally, the *Staff* role represents institutional agents who run standard market activities, for example set up a trading table or mediate a face-to-face negotiation.

Definition 1 A *basin* is a directed graph $\Lambda = \langle N, E \rangle$, where N is a set of places where water may be extracted, introduced or re-conducted; E is a set of edges, where an edge between two nodes indicates that one node receives water from the other by means of a transportation resource (river or canal).

Definition 2 A *water-right* is a tuple $\omega = \langle \lambda, u, v, t \rangle$, where λ (subgraph of Λ) is the basin district where the water-right can be executed (at least one node in λ must be a water source node); u is the usage allowed; v represents the maximum quantity of water allowed to be extracted there; and t is the time interval during which the water-right may be executed.

Definition 3 A *water-right bid* is defined as the tuple $\beta = \langle o, \{\omega, \perp\}, t, t_\beta \rangle$, where an offer o can take a *Put* label to represent a bid to sell, or a *Call* for a bid to buy; when $o = \text{Put}$, ω is the water-right associated with the bid, when $o = \text{Call}$, there is no water right associated, so this component is null; t is the time interval during which the water-right would be used; t_β is the deadline of the bid.

Definition 4 An *agreement* is a tuple $\alpha = \langle s, b, \omega', p, d, st \rangle$, where s is the seller of the right; b is the buyer; ω' is the new water-right derived from the agreement negotiation (this water-right will be granted to the buyer by means of a contract); p is the agreed economic compensation; d is the agreement date; st represents the stage of its life-cycle where the agreement is.³

²EIDE is a development environment for Electronic Institutions developed at the IIIA, <http://e-institutor.iiiia.csic.es/eide/pub/>. It is composed of a set of software tools that support all the stages of an Electronic Institution (EI) engineering. ISLANDER is the tool for EI specification. aBUILDER supports the automatic generation of agent (code) skeletons based on graphical specifications of agent behaviors. The real execution of the institution is supported by the AMELI middleware and SIMDEI is a testing and monitoring tool.

³Possible stages are: *Public*, when it is registered by the buyer and seller and it is waiting for the Basin Authorities endorsement; *Contested*, when it is contested by a third party who claims his rights are affected by the agreement; *Authorized*, by the Basin Authorities; *Suspended*, by the Basin Authorities due to an exceptional drought situation or a misuse of the transfer; *Valid*, the water-right transfer is being executed; *Done* the water-right transfer was executed and the time-period has expired.

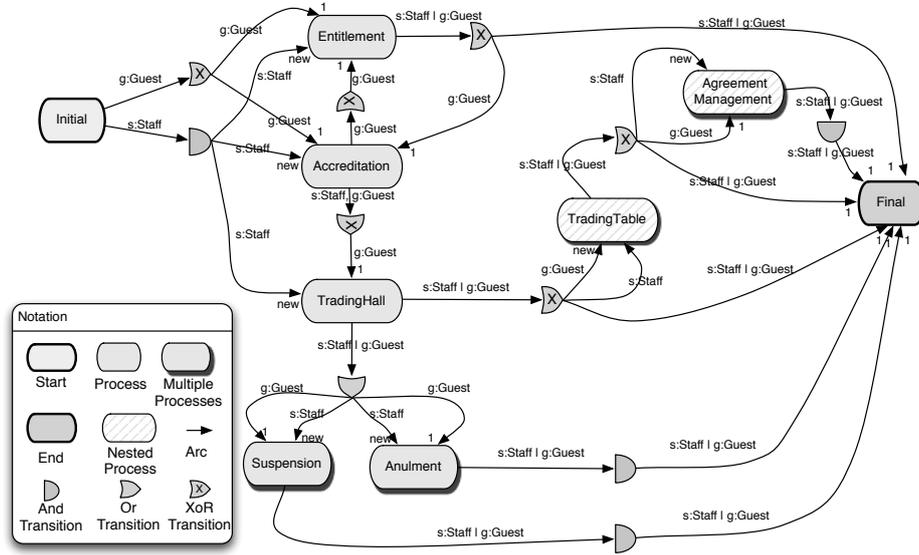


Figure 1. *mWater* performative structure.

Definition 5 A *contract* is the signed agreement among the contracting parties. It is defined by the tuple $\kappa = \langle A, K, U, d, O, C \rangle$, where A is the set of related agreements (a set of multiple water transfer agreements may be signed in a single contract); K is the set of related sub-contracts, for example transportation resource contracts (if there is no related sub-contracts it is an empty set); U is the set of users that sign the contract; d is the agreement date; O is the set of observation commitments to execute the contract; C is the set of conditions for conflict resolution.

4.2. Deontological components

Procedural conventions in the *mWater* institution are specified through a nested performative structure (Figure 1). The top one, *mWaterPS*, describes the overall market. It includes two other performative structures, *TradingTablesPS* and *AgreementManagementPS*. For lack of space, in this paper, we only give a brief account of the essential functions of their constitutive process (scenes).

Since only bona fide right-holders may trade water rights in the market, there needs to be a process through which an individual proves to be the rightful holder of a given water right and, thus, entitled to trade it. There are two means of becoming the owner of a right, one when an existing right is legally acquired from its previous owner outside of *mWater* (through inheritance or pecuniary compensation for example). The other when a new right is created by the *mWater* authorities and an eligible holder claims it and gets it granted. In both cases, there must be some legal document that proves that a potential trader is in fact entitled to trade that right. This process is carried out in the *Entitlement* process of *mWater*.

The *Accreditation* process, in turn, makes it possible to "jump start" a market and to introduce new rights and traders. Once a market is open, this scene allows legally

entitled right-holders to enter and trade by registering their rights and individual data for management and enforcement purposes. Staff has to validate admission conventions and right-holder variables are given default variables.

Actual trading starts by entering the *Trading Hall* process, where existing tradeable rights as well as ongoing deals and active contracts are listed. There, right-holders become aware of the market activity, get invitations to trade or initiate a trade process. Thus, a right-holder may ask a staff member to open a *Trading Table* or enter one that is accessible to his/her. Currently, a right-holder may opt to trade a water right in a standard double auction exchange, through closed bids or face to face negotiations, but other mechanisms may be added as needed. In order to accommodate different trading mechanisms, we expand the trading table scenes as a performative structure, *TradingTable*, where each trading mechanism is given a scene.

Once an agreement on transferring a water right has been reached it is 'managed' according to the market conventions. This, again, may be a rather elaborate process and it is thus reflected as another performative structure, *AgreementManagement*. First of all, *mWater* staff check whether or not the agreement satisfies some formal conditions. If the agreement complies with these, a transfer contract is agreed upon and signed by both the buyer and seller, and then the agreement becomes active. Once an agreement is active it may be executed by the new right-holder and, consequently, other right-holders and some external stakeholders may initiate a grievance procedure that may overturn or modify the transfer agreement. Even if there are no grievances that modify a contract, parties may not fulfill the contract properly and there might be some contract reparation actions. If things proceed smoothly, the right subsists until maturity.⁴

Two final scenes take care of the (permanent) *Annulment* and (temporary) *Suspension* of rights.

The current *mWater* implementation reflects normative requirements in different ways through the standard EI constructs. Some non-procedural conventions are reflected in the dialogical framework. Some others as variable constraints or pre- and post-conditions of speech acts in the specification of scenes. Still some more in the decisional models of internal (staff) agents. Thus, for instance the strict total order on water uses imposed by the NHP as well as our own rules for splitting and joining rights are checked by staff agents in many *Trading Table* scenes and in the *Agreement ManagementPS Validation* and *Grievance* processes. Sometimes a set of conventions gives rise to a whole scene, like *Entitlement* to allow for new types of right holders and the introduction of new rights into the market.

5. Playing in *mWater* with agreement technologies

The previous section sketched the core institutional framework for *mWater*. That establishes the “rules of the game” we may now list some of the games we would like to play with those rules or, properly speaking, the topics we want to explore in the regulated environment provided by *mWater* context:

⁴Technically speaking, *Trading Hall* is a stay-and-go scene and right-holder *alteroids* are spawned for each negotiation and ensuing agreement management processes when applicable. One scene instance of the subperformative structures is activated for each alteroid.

Norms. One topic is the way to represent and use the normative frameworks involved in the water market. Current regulations impose certain constitutive restrictions, (like the total order on seven very specific types of water use), that may be readily regimented into the institutional specification. Likewise for procedural requirements, (for instance, the Ministry's acknowledgement before a transfer becomes active). As noted, we also include new constitutive regimentations, (like the 5-tuple representation of a right or the composition and decomposition of rights) that may be readily regimented with the IIIA's EI model and tools. However, there are regulations that should not be regimented that way and should be expressed in declarative form in order to guarantee some formal properties, and comply or enforce them after some situated reasoning. Then, there is the problem of expressiveness: the type of norms we have dealt with so far have straightforward formal representations that are amenable for formal and computational manipulation but, as the literature in the field shows, questions and alternatives abound. Linked with these concerns, obviously, is the discussion of architectures for norm aware agents, on one side, and different means (logic, coherence theory, satisfying thresholds, etc.) to deal with norm internalization, adoption and compliance. Another related topic is electronic contacting: archetypes, negotiation, adoption, follow-up. Likewise, the structure and management of concurrent and subsidiary agreements and contracts.

Institutional aspects. From a theoretical perspective we want to break loose from the procrustean limits of the IIIA's EI model in two directions: alternative enforcement mechanisms (in addition to internal agent enforcers which are already available) and the evolution of regulations (beyond parameterized protocols and re-usable scenes). For the *mWater* environment proper, we are also interested in developing further the current performative structures with generic add-ons, particularly with new types of water rights negotiations and with many on-line dispute resolution mechanisms. Of particular interest is the presence of collective actors in these add-ons, as we mention below.

Organizational issues. In the current stage, *mWater* is not explicitly incorporating collective roles and collective actors. One immediate extension is to capture all those roles currently recognized by legislation that have any impact on trading and agreement management, specially in grievances and conflict resolution. Subsequently we want to deal with ad-hoc and dynamic coalitions to trade and to intervene in conflicts and with a special focus on the by-laws, goal-oriented groupings and goal-achievement features of such organizations. Similarly, we want to study the roles and operations of non-trading organizations that somehow affect demand (e.g., water treatment plants, water distribution companies, municipality services, water transport firms and infrastructure).

Collective decision-making. We are currently working in three main lines: Argumentation (logical formalisms; domain-specific values, terminology, appeals; rhetorical and strategic aspects); Judgement Aggregation (not only from the social choice perspective) and Multi-party Negotiation (negotiation involving more than two parties, multiple-stages, reconfiguration of parties, mediating roles,...)

Social norms and non-institutional coordination. Reputation and prestige. Word-of-mouth-based negotiation seeking.

Tools. We have been using the IIIA's electronic institutions development environment (EIDE) to specify, run and test *mWater* but we need to improve these tools. One line, already mentioned, is to have declarative norms with weaker enforcement mechanisms that may be situated in a scene and an agent's governor along the lines of [5]. Further developments include a more robust information model for a better handling of privacy and collective speech acts: a systematic treatment of scene splicing (to have modular add-ons); proactive interventions in AMELI, so that prohibitions, obligations and the invitation and expulsion of agents may be instrumented through scene managers; and a generic human interface service that map governor interactions with an external agent into a human-web-user interface.

6. Future Work

The *mWater* version presented in previous sections is intended as the institutional foundation for further developments along the three modes of potential use of the MAS. Although our immediate efforts concentrate on the test-bed conventions and functionalities, we will be keeping an open disposition towards the policy-simulation requirements. Thus, in future versions we will be including those functionalities that might be worth having in a policy-simulation environment—at the pace and depth the AT agenda indicates—but, for the time being, we neither intend to add simulation capabilities beyond those already available in SIMDEI and in the EIDE simulation service extensions (cf. [2]), nor to merge *mWater* with conventional basin models. With respect to the market prototype, our strategy is to manage it as a by-product of the test-bed and simulation developments until the need or opportunity for an actual product arises. The reason is that we are building the *mWater* test-bed around a realistic institutional core with multiple functional add-ons that may be readily adapted to eventual regulations on one hand, and market-design and testing requirements, on the other.

In the next version of the core institutional framework, we plan to move along three principal lines. Firstly, want to look into collective roles and agents with collective legal identity (firms, associations, municipalities). We plan to incorporate first all the collective roles who according to the legislation intervene in trading and in the management of agreements, and enable their interactions fully in the institutional framework; next we will bring in those that show promise for agreement games. For the test-bed purposes we will also look into the type of water-right negotiation that would involve multiple players and forms of argumentation and judgement aggregation.

Secondly, we intend to put substantial effort in the normative aspects of the *mWater* testbed. We plan to move in two complementary directions in the next few months. One is the function of norms in the exchange of rights and surrounding activities, from an institutional perspective. The other is from the agent's perspectives. Thus we plan on elaborating an inventory of norms, the exploration of alternative representations and the study of norm dynamics for the institutional and agent's perspectives.

Thirdly, we plan to work on tool making and development. In this sense we will be working with extensions of the EI model that allow other forms of governance alongside the engineering aspects of having inference resources inside scenes and governors. Another line has to do with ergonomic aspects of the *mWater* infrastructure and here we are working on three dimensional representations of the market and the deployment of

a human interface that is automatically generated by the EIDE tools from ISLANDER specifications.

We believe this ambitious program is feasible because the AT project is defined in an appropriately long term research horizon and involves a numerous group of researchers with highly complementary expertise; and more significantly, because the *mWater* demonstration is designed to draw on the results of the other workpackages of the project.

Acknowledgements

This paper was partially funded by the Consolider programme of the Spanish Ministry of Science and Innovation through project AT (CSD2007-0022, INGENIO 2010)

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