# Using Multi-Agent Systems and Role-Playing Games to Simulate Water Management in Peri-Urban Catchments *

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**Abstract**

Pert-urban catchments are characterized by their complexity (hydrological, sociological and geographical processes) as well as their dynamics. Their dynamics depend on the multiplicity of stakeholders, with differing and often conflicting land use representations and strategies. In order to simulate these, it is necessary both innovative methods and computer tools to support their coordination and mediation processes, aiming at an improved, more decentralized and integrated natural resources management. Multi-Agent Systems (MAS) and Role-Playing Games (RPG) are methods that have been used for some years to represent this dynamics. Computer tools are implemented using MAS and RPG to integrate the conceptual modelling, allowing to represent and to explore functioning and dynamics through testing of different scenarios. The pert-urban interface provides specific hydrological functions of a city and supports groundwater recharge zones and absorbs rainwater. An example of pert-urban catchment is the Metropolitan Region of Sáo Paulo, that is studied in the Negowat Project (Negotiation of Land and Water Conflicts in Latin America). We have developed a prototype of a computer tool to integrate water management and the actions of the stakeholders. This prototype, called "JogoMan", links MAS and RPG, and its implementation is based on Corms [7], a Multi-Agent Simulator developed at CIRAD (Agricultural Research Developing Countries of France). JogoMan is a simplification of the real phenomena of interaction between the several actors, and it is used as a means of learning and analysis. The goal of Negowat Project is to define a complete conceptual model of the area and its implementation in two levels: local and catchment. In first level, the focus is in the negotiation and interaction of stakeholders, and in the second level, the focus is in multi-agent simulations and its effect in the quality of the water. For both levels, the project researchers will need to have strong linking with the local communities, who can supply many information about the real situation, and therefore being crucial for model construction. One of the project objectives is to use representative groups of people to better understand the functioning of the social and politics processes, and as consequence research will need a direct interaction with local communities. Some interesting questions related with this modelling and its implementation arises, like how one should model social processes in such an approach.

**K e y w o r d s**

Agent Based Modelling; Role Playing Games; Simulation

## 1 I n t r o d u c t i o n

Multi-Agent Systems (M AS) is characterized by the study, design and implementation of societies of artificial agents. Logic-based and cognitive science approaches have contributed considerably to its development [6].

Another approach the study of social interaction are the Role-Playing Games (RPG). They have their constitution in social sciences and intend to reveal some aspects of social relationships, allowing the direct observation of interactions among players.

By combining together both MAS and RPG, one can join the dynamic capacity of MAS to the capacity of generating discussions by RPG techniques [3].

MAS has been tested in natural resources management [3]. Traditional tools for teaching and training purposes, as RPG, have been successfully used in certain phases of negotiation over water and land-use planning and they have proved to be efficient in facilitating communication on complex real scenarios.

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The Negowat Project uses a combination of MAS and RPG, applied to the context of conflict resolution and negotiation for land and water management in the peri-urban catchment of a metropolitan area.

The peri-urban interface provides specific hydrological functions to a city (a catchment area and space for drinking water reservoirs) and supports groundwater recharge zones and absorbs rainwater. Its dynamics thus affect the hydrological processes of large areas through the alteration of the natural hydrological network, the expansion of the impermeable surface, and the pollution of surface and subterranean aquifers through industrial activities and inadequate sanitation/wastewater management.

This paper is organized in 7 sections. In Section 3 and 3 it is shown a review about RPG and MAS, respectively. Section 4 presents Peri-Urban Catchments and int Section 5 the use of RPG and MAS in water management is described. In Section 6, we present how we have developed these techniques in Negowat Project. Finally, conclusions and further work is presented in Section 7.

## 2 Role-Playing Games

In-between games and theater, Role-Playing Games (RPG) are group settings that determine the roles or behavioral patterns of players as well as an imaginary context. A RPG is the performance of a roughly defined situation that involves people with given roles. Players genuinely use RPG as a "social laboratory" It is a way for them to experiment with a variety of ways of positioning themselves in a group with presumably few consequences in the real world [2].

Psychologists have analyzed RPG and its implications on players's behavior, because there are significative relationships between RPG and a kind of psychotherapy called psychodrama. In this kind of therapy, the patient lives a controversial or psychologically problematic situation from different points of view from his own, to better understand them and live a cathartic experience [1, 9].

RPG can be used for three different purposes: training, research or policy making. The first one is more predominant, with training tools, often used by professionals in training session. In this tool type, the roles are strictly defined by the teacher's knowledge. In some cases, it is possible that more experts players use their experience to have a better situation in game, as in real practice.

A study area of social sciences is the potential synergies between RPG and models. Some work explores this potential synergy, in thematic sessions, where the issue is to, in these tools in the specific context of negotiation and dialogue processes.

RPG has focused in the interaction among the individuals, i.e., people that participate in the game. It is an old technique, that in 1980s began to be very used in computer science, mainly in games.

## 3 Multi Agent Systems (MAS)

The field of Multi-Agent Systems (MAS) is a well-established research domain in Artificial Intelligence (AI), which has emphasis in the resolution of problems by a society of agents. The distribution in several agents is necessary because these problems can be complex or too large to be solved by a single process, or even, they can need knowledge of several domains.

MAS researchers look for 'autonomy', because the more autonomous the system is, the more efficient the task distribution and execution, and the lower the computational load of the overall system. However, a MAS comprises the formalization of the coordination, hierarchical relationships and communication between agents [6].

The MAS field is increasingly characterized by the study, design and implementation of societies of artificial agents. If the logic-based and cognitive science approaches have contributed considerably to developments of MAS, the inverse does not happen (the social sciences have been less influenced) [6]. Just in the economics and game theory area, there is a huge quantity work in the MAS field (see Gastel franchi and Conte, 1995 [5]. In these areas, MAS is essentially used by economists and game-theorists to the study of the evolution of cooperation from local interactions among self-interested agents.

## 4 Feri-urban Catchments

Peri-urban catchments are characterized by their complexity (hydrological, sociological and geographical processes) as well as their dynamics. Their dynamics depend on the multiplicity of stakeholders, [1] with differing and often conflicting land use representations and strategies. To simulate these, it is necessary both innovative methods and computer tools to support their coordination and mediation processes, aiming.

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**[3] The terms "atakeholder" or "intereated party" are used concerning the active involvement level. This category of actor integrates any person, group or organization with an interest or "stake" in an issue either because they will be affected or because may have some influence on its outcome [12].**

at an improved, more decentralized and integrated natural resources management. Most of the poverty in less-developed countries can be found in the immediate surrounding areas (the peri-urban interface) of their rapidly growing cities where already most of their populations are concentrated. This is the case of many cities in Latin America, where 70 percent of the population is concentrated. Peri-urban interface can be characterized by [10]:

1. a "patchwork structure" in terms of functions, values, strategies of occupation of the territory, or appropriation and transformation of natural resources;
2. a dynamic pattern with a wide range of transformation and flows (people, goods, income, capital, natural resources such as water, energy, and building materials);
3. the new economic opportunities it provides to pert-urban such as land speculation, or informal activities linked to mineral extraction, etc.

This "patchwork" structure applies to the type of land-use occupation that ranges from urban infrastructure to strictly rural and agricultural uses. Thus, land-use changes combine different processes: conversion from non-urban (rural and/or natural) to urban activities; loss of farmland; and development of special infrastructure, due to appropriation of land and changes in property rights.

On the other hand, urban water competes with other needs such as irrigation or environmental/recreational use. In the developing world's rapidly growing cities, competition for access to land and water in pert-urban areas tends to be exacerbated, because of the wide range of users, the rapid growth of shantytowns with inadequate sanitation arrangements, the difficulty of access to running water, and increased polluted run-off. These processes directly affect the water quality in drinking water reservoirs and aquifers [10, 11].

## 5 RPG and MAS in Water Management

Within the context of complex systems, the negotiation process in the management of natural resources is a very important topic because it deals with many different agents, groups of interest and institutions which interact with the ecosystem [4].

One of the main reasons why the area of agent-based modelling is becoming more popular in the developing field of research dealing with modelling artificial societies is its ability to conceptualize entities in natural resources management [3]. Traditional tools for teaching and training purpose (RPG, for example) have been successfully used in certain phases of negotiation over water and land-use planning and they have proved to be efficient in facilitating communication on complex real scenarios. According to D'Aquino et al. [8], RPG have already been used to support land use management. The games, which depend upon the prior diagnosis of the situation by experts, help players to share their analysis and to draw upon some improvements based on them.

Figure 1 presents as RPG and MAS are usually integrated in this context. The sequence of steps of this integration is the following:

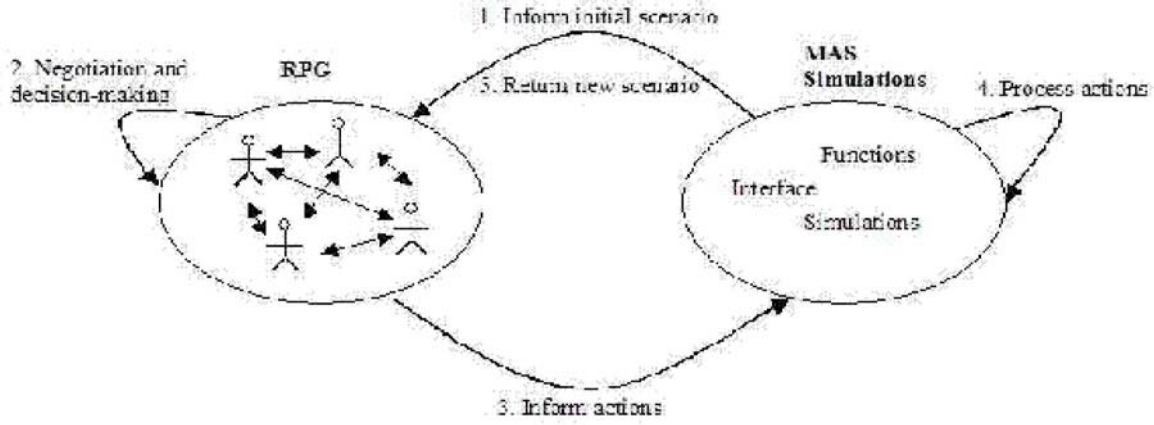


Figure 1: RPG and MAS Integration.

1. Players need to know all rules of the game, which consists the role that each player will play, and the initial scenario defined in MAS simulations;
2. The negotiation and decision-making between players occurs. Usually, the duration of this step is defined before starting the game (for example, 10 minutes). At the end of this step, each player will choose an action to perform;

3. Players inform to the MAS simulations which were the chosen actions;
4. Data is computed by MAS simulations (process actions). These actions will modify the initial scenario (first round complete);
5. MAS simulations return new scenario, if the time of the game is not exceeded or the maximum number of rounds has not been achieved, return to step 2.

Agent-based models are interesting tools to develop a joint representation of the dynamic processes in the initial stages of the negotiation processes. The modelling work is viewed as a way to structure both representations and exchanges, and to facilitate discussion and learning processes. These models, many times based on object oriented languages, are part of the developing field of research dealing with modelling virtual societies. They are based the representation of agents, considered as autonomous decision making entities. To combine agent-based model and RPG is a way to join the dynamic capacity of the agent-based model and the capacity to generate discussion of RPG techniques [3].

Aiming to model all aspects in natural resources, is important to use representative groups of people, to understand the functioning of the social and political processes. In this "social management", there is a gap between social and natural sciences, because it is necessary to cope with the current challenges of sustainability and integration in the natural resources and environmental domain [12]. For many years, the problems were examined exclusively from the angle of "a natural system subject to anthropic disturbance" or from the angle of "a social system subject to natural constraints". In the first case, a dynamic of the resource is done carefully and the social dynamics are summarized in a type of resource exploitation. In second case, the study is concentrated on the problem of resource usage, as to maximize the benefits obtained from a restricted resource [4].

According to Maurel [12], a new concept have been created, called Social Learning, that combine contributions from different social sciences and try to solve this gap. In order to do so social learning refers to social processes (information, knowledge, actors) and technical processes (models, tools). Both can not be treated separatelly, because they must be combined to identify problems, to make diagnostics, to search solutions, etc. All task are implemented and monitored in a social environment, as a result of interactions between different actors with different representations of the reality (different representation techniques).

## 6 Negowat Project

The Negowat Project (Negotiation of Water Ressources)[2] uses a combination of MAS and RGP, applied to the context of conflict resolution and negotiation for land and water management in the peri-urban catchment of a metropolitan area. The project goal is to elaborate, to structure and to test a methodology combining these two approaches in order to facilitate the negotiation /discussion over land and water management in the specific context of the urban fringe in metropolitan upstream catchments in Latin America (Brazil and Bolivia) (see Ducrot et al. [11]).

This research aims thus to provide:

- a conceptual tool that will allow to analyze land and water management in peri-urban upstream catchments;
- a methodology (including computing tools) and its guidelines for its implementation to facilitate negotiations.

One of the scientific objectives of the project (include in first item above described) is to develop a conceptual framework of the land and water management issues in peri-urban upstream catchment areas linking the dynamics of land and water resources (water quality, water availability and land access), land and water use patterns, and roles of the various stakeholders.

A conceptual framework means to define a conceptual model, where all information has the same semantics for a same concept. For example, all players must have the same understanding for potable water. In order to develop the conceptual framework, we divided it in two parts: in the first moment, we are modelling all aspects, with the participation of the society groups and the researchers groups, because both can give information about the real situation of the studied areas. The second step is to implement this model. The MAS simulation is developed in Cormas [?], a multi-agent tool created to realize simulations in land and water management The complete conceptual model of the area and its implementation is divided in two levels: local and catchment. In first level, the focus is in the negotiation and interaction of stakeholders, and in the second level, the focus is in multi-agent simulations and its effect in the quality of the water.

[2] **Negowat Project: Facilitating negotiations over land and water conflicts in Latin American peri-urban upstream catchments: combining multi-agent modeling with role game playing.**

### 6.1 Negowat Domain in Brazil

In Brazil, the study focus is São Paulo, the most populated and industrialized region of Latin America. The Metropolitan Region of Sao Paulo has some 18 millions inhabitants in 39 adjacent cities. It represent an area of 8.050 km2 of which 1.500 km2 are urbanized. In this area, the water management depends on many aspects, as urban expansion associated with the growth of shantytowns and inadequate sanitation arrangements [11]. Therefore, the biggest problem, in a city as São Paulo, is to know how long the unlimited access to safer water will be tolerated.

However, this management involves the concept of "Social Learning" as well as a model of social processes. We believe that only with public participation our work can be possible, in order to understand the gap between social and natural sciences.

### 6.2 Case Study: JogoMan

We have developed a prototype of peri-urban catchment, called JogoMan. It uses RPG and MAS, and represents a simplification of the real phenomena of interaction between the several actors, used as a means of learning and analysis. This prototype involves, specifically, land and water management problems in different cities, in order to better understand the problems in the scope of the project.

Figure 2: Interface of first RPG developed in Negowat Project. Left figure presents cities division (3 cities, each with a different color). Right figure presents infrastructure division or land occupation, the numbers represent the owners of each portion of space and the colors the type of land occupation (industry, agriculture, etc.).

Each portion of space has a different occupation, as agriculture or forest, and an owner. There are three types of adminstrators: the cities, the water company and the private owners. This test were implemented in Cormas and Figure 2 shows its interface (a 8x8 grid, with 13 players: 3 mayors, 1 water company administration and 9 private owners).

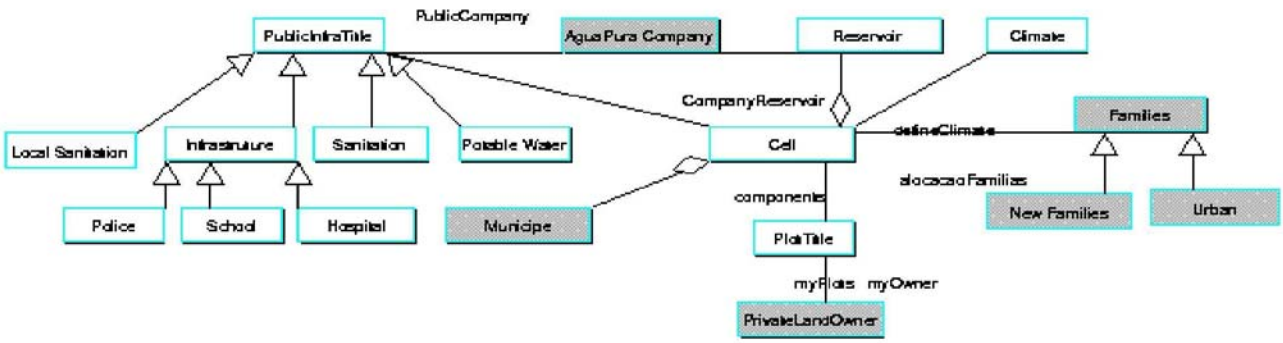


Figure 3: UML class model of JogoMan to Agents.

Figure 3 presents the UML class model of JogoMan. In gray, the classes represent the agents and in white, the classes represent some system functionality. The agents and their functions (actions) in JogoMan are described below:

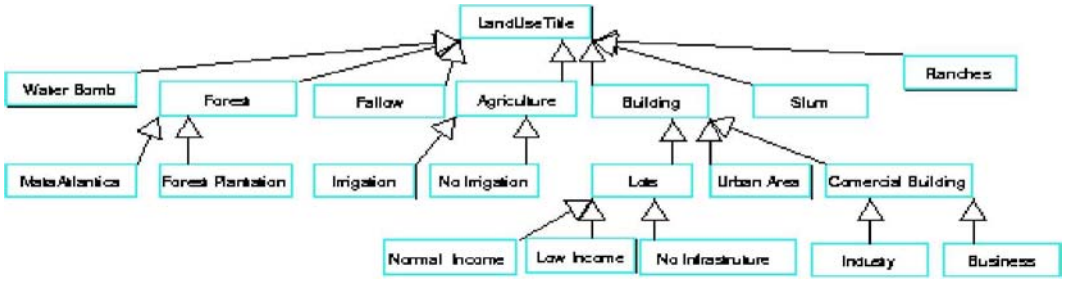


Figure 4: UML class model of JogoMan to Land Use.

- **New Families:** Each year, 200 new families come to live in the cities. The mayors, the Private-LandOwners and the AguaPura Company must decide where these families will be allocated.
- **Urban:** The initial configuration, there are 3-800 urban families. They live in an urban area, consume water and pay taxes. However, the families do not have a role in RPG.
- **Private LandOwner:** Each owner has 5 private areas. These areas, initially, can be: MataAtlantica (Forest), No Irrigation Agriculture and Ranches. For each different area type, there are different values to maintenance and financial return. Owners can sell or buy private areas or they can change the land use of these areas (in Figure 4, there are other possible land use for areas).
- **Municipe (Mayors):** There are three cities, each one has a main activity (urban, agricultural or preserved area (with Mata Atlantica)) Each mayor must preserve it, each mayor has a different objective They can invest on public infrastructure, as portable water net or to build a school. In RPG (negotiation process), Private LandOwners should demand to mayors the construction of infrastructure in their municipes
- **AguaPura Company:** It is a public company and it has the same characteristics of Municipes regarding water (make portable water and sanitation net).

Each player chooses his actions individually, but he/she should know that these actions have influence in other players, because the quality and quantity of water depends of the land use. For example: if a mayor decides to decrease the land taxes for private owners that preserve the forests, various private owners can decide to maintain their areas with forest or even decide to plant forest (reforestation). This action influences every players, because the water quality probably will get better. Other example of players action is when a private owner decides to build a industry. The industry profit is larger, but the water pollution is larger too.

We have already done two tests of this game: one with Negowat Project staff, and an other with "Guarapiranga Technical Chamber" [3]. These tests were very important, because many suggestions and modifications were proposed, in order to obtain a game more similar to the reality. These alterations were inserted into game and they have helped us to define a better framework.

In order to build a conceptual framework, we need to define the conceptual model. Therefore, we have done several meetings with each sub-group of the project. These meetings were a way to discuss many aspects, and to better understand the different points of view of the researchers. The sub-groups were divided in: hydrology, rural, land, actors or stakeholders and social-water aspects. The first three sub-groups work on natural resources. The fourth one works on the social aspects, and the last works in the connection between social and natural aspects. There have been some difficulties to structure together all information presented by sub-groups, each of those having different semantic of common concepts, but we believe we have done a first step in the right direction.

## 7 Conclusion

RPG is a way to experiment a variety of players positions in a group with presumably few consequences in the real world It is original by a "social laboratory" and it can be used in many activities. MAS can provide interesting tools to develop a joint representation of the dynamic processes in the initial stages of the negotiation processes.

[3] **A group of public participation with municipal and stakeholders representatives.**

On the other hand, the competition of water should increase and the conflict resolution tends to be difficult in the institutional landscape of water management in pert-urban areas, characterized by the traditional dual (urban/rural) focus of the institutions, the disconnection between land and water management policy, institutions, and intervention levels, and the implementation of specific protective legislation and rules, in a context of uncoordinated metropolitan planning.

Water management is a very important topic, because ecosystems involve a great amount of groups and institutions. RPG as well as MAS have been tested in natural resources management, as water or land. The Negowat Project has used a combination of them applied in the context of land and water management in the pert-urban catchment of metropolitan area. In Brazil, as other Latin American places, this management depends on the co-ordination between public and private institutions, with support of local population {stakeholders, for example).

The project is in its first step and many question still do not have an answer. Our prototype helped us to better understand the problems in the scope of the project, giving us some clues about how we will build the conceptual framework and how we will structure information between social and natural sciences.

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