JogoMan: A Prototype Using Multi-Agent-Based Simulation and Role-Playing Games in Water Management

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Abstract
The NEGOWAT project has as one of its goals to facilitate the negotiation process between several stakeholders over water conflicts in peri-urban catchments. In this work, we present the main characteristics of the JogoMan prototype, which uses a combination of Multi-Agent-Based Simulation and Role-Playing Games techniques to solve this problem.

Keywords*:* Multi-Agent-Based Simulations; Role-Playing Games; Natural Resources Management.

1. Introduction

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, with differing and often conflicting land use representations and strategies. In order to simulate these, it is necessary innovative methods and

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computer tools to support their coordination and mediation processes, aiming at an improved, more decentralized and integrated natural resources management [13].

Multi-Agent-Based Simulation (MABS) and Role-Playing Games (RPG) are methods that have been used for some years to represent natural resources management [10] [4]. Computer tools are implemented using MABS and RPG to integrate the conceptual modelling phase, allowing to represent and to explore the functioning and dynamics through testing of different scenarios. Combining MABS and RPG is a way to join the dynamic capacity of the MABS and the capacity to generate discussion of RPG techniques [3].

An example of peri-urban catchment, that is studied in the Negowat Project[1], is the Metropolitan Region of São Paulo. In this context, we have developed a prototype, called JogoMan. This prototype is a computer tool that integrates both water management and the actions of the stakeholders. It links MABS and RPG, and its implementation is based on Cormas [8], a Multi-Agent Simulator developed at CIRAD (Centre de coopération internationale en recherche agronomique pour le développement).

JogoMan is a simplification of the real phenomena of interaction between the several actors, and it is used as a means of learning (environment education) and analysis. This prototype involves, specifically, land and water management problems in different cities with urbanization pressure, in order to better understand the problems in the scope of the Negowat Project.

The focus of this paper is to present all the steps carried on to develop this prototype: UML model, Cormas implementation (some scenarios) and result analysis. In JogoMan, players decide their actions, during a RPG session, and MABS processes these actions.

This paper is organized in 7 sections. In Section 2, Peri-Urban Catchments are briefly presented. In Sections 3 and 4, we show a brief review about RPG and MABS, respectively. In section 5 the use of RPG and MABS in water management is described. Section 6 presents how we structure our prototype, JogoMan, as well as the first preliminary results of its use. Finally, conclusions are presented in Section 7.

[1] Negowat Project: Facilitating Negotiations Over Land and Water Conflicts in Latin American Peri-Urban Upstream Catchments: Combining Multi-Agent Modelling with Role-Playing Games. The project is financed by the INCO Program of the European Commission - grant number ICA4-CT-2002-10061 and by the FAPESP, Brazil - grant number 02/09817-5.

2. Peri-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[2] 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 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 [13]:

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. new economic opportunities provided to peri-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 peri-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 [13, 14].

2 The terms "stakeholder" or "interested 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 [18].

Such a complex environment needs to be simulated by using non-conventional computer techniques. In the context of this work, we have chosen to use a combination of two different techniques, described in the next two sections.

3. 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, 12].

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 reach a better situation in the game, as in real practice.

One 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 join these tools in the specific context of negotiation and dialogue processes [3].

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 [9].

4. Multi-Agent-Based Simulation (MABS)

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 large to solve by an only process, or still, they can need knowledge of several domains. One goal of these systems is to release the researchers from lowlevel technical-operational problems, allowing the researcher to concentrate his/her efforts on the relevant domain application level.

The computer simulation of social phenomena is a promising field of research at the intersection between social, mathematical and computer sciences. The first developments in computer simulation in social sciences coincided with the first use of computers in academic research, in the early 1960s. In this time, computer simulation was essentially used as a powerful implementation of mathematical modelling [16].

Multi-Agent-Based Simulation (MABS) is the union of MAS and Simulation and is specially valuable to conciliate different interdisciplinary perspectives. It, typically, involves researchers from various scientific areas, such as social psychology, computer science, social biology, sociology and economics. The interdisciplinary character of MABS is an important challenge faced by all researchers, while demanding a difficult interlacement of different theories, methodologies, terminologies and points of view [17].

The MABS field is increasingly characterized by the study, design and implementation of computational platforms to simulate societies of artificial agents. If the logic-based and cognitive science approaches have contributed considerably to developments of MABS, the inverse does not happen (the social sciences have been less influenced) [7]. An exception is the economics and game theory area (see Castelfranchi and Conte, 1995 [6]). In these areas, MABS is essentially used by economists and game-theorists to the study of the evolution of cooperation from local interactions among self-interested agents.

MABS has provided architectures and platforms for the implementation and simulation of relatively autonomous agents and it has contributed to the establishiment of the agent-based computer simulation paradigm. The agent-based approach enhances the potentialities of computer simulation as a tool for theorizing about social scientific issues. In particular, the notion of an extended computational agent, implementing cognitive capabilities, is giving encouragement to the construction and exploration of artificial societies, since it facilitates the modelling of artificial societies of autonomous intelligent agents [7].

5. RPG and MABS 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 [5].

One of the main reasons why the area of agent-based modelling is becoming more popular is its ability to conceptualize different entities envolved 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. [10], 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.

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 on the representation of agents, considered as autonomous decision making entities. By combining agent-based models and RPG, one can join the dynamic capacity of the agent-based models and the capacity to generate discussion of RPG techniques [3].

Aiming to model all aspects in natural resources management, one needs 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 [18]. For many years, these 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 [5].

In this paper, the integration of RPG and MABS is called GMABS (Games and Multi-Agent-Based Simulation) methodology. Figure 1 presents how GMABS is used in this context. The sequence of steps of this integration is the following:

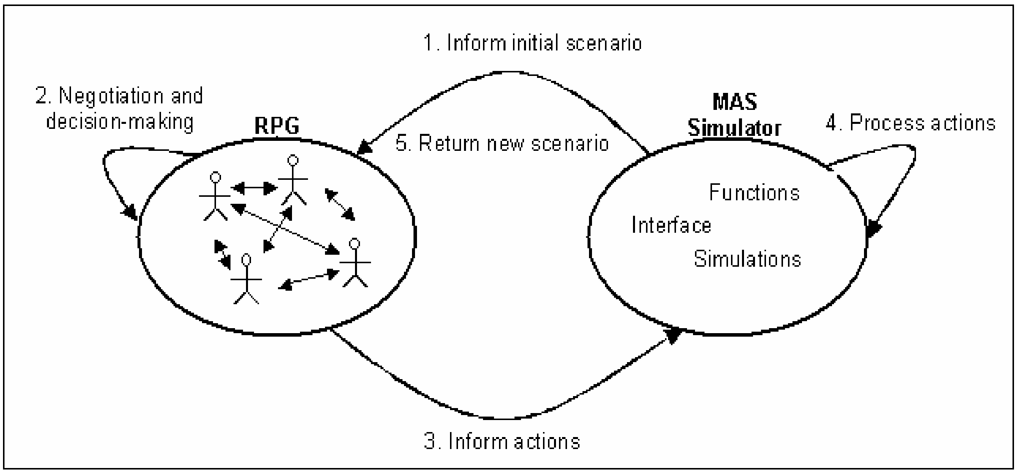

Figure 1: GMABS Methodology.

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 simulator which were the chosen actions;

4. Data is computed by simulations (process actions). These actions will modify the initial scenario (first round complete);

5. MAS simulator returns 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.

6. The JogoMan Prototype

JogoMan is a prototype constructed according to GMABS methodology, which simulates the managenent of a particular peri-urban catchment, located at Bacia do Alto Tietê, in São Paulo, Brazil. This game represents a simplification of the real phenomena of interaction between the several actors, used as a means of learning and analysis. In this section, we will explain all steps carried on to develope this prototype: the game idea (rules and players), a practical use of GMABS methodology in JogoMan, the UML model, the implementation, the developed scenarios and the first tests and preliminary results.

6.1 The Game Rules

The specific objective of this game is to determine quality and quantity of water in a peri-urban catchment. It involves, specifically, land and water management problems in different cities. The game environment is a grid divided in portions (parcels). These portions have a land use (as agriculture or forest) and an owner (a player). Players can change land use, put infrastructure, sell/buy their portions. However, the different players have different goals in the game. There are four types of players:

- *Land Owner*: Each player owns some portions of space, with a land use type. For each different land use type, there are different values to maintenance and financial return. Owners can sell or buy private areas or they can change land use of these areas ;
- *Mayors*: There are different cities, each one with a main activity (urban, agricultural, etc.). The mayors can invest on public infrastructure, as portable water and sewerage (sanitation) net or to build schools, hospitals or police stations. During RPG, Land Owners should demand to mayors the construction of infrastructure in their cities;
- *AguaPura Company Administrator*: This player can invest on public infrastructures to water quality: portable water and sewerage net;
- *Migrant Representative*: This player has a special function in the game, because he/she must allocate a number of new families. These families will arrive in the cities (urbanization pressure), and they can be allocated in settlement or in slums.

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 and infrastructures. For example, if a mayor decides to decrease the land taxes for land owners that preserve the forests, various land owners can decide to maintain their areas with forest or even decide to plant forest (reforestation). This action influences every player, because the water quality probably will get better. Other example of players action is when a land owner decides to build a industry. The industry profit is larger, but the water pollution is larger too.

6.2 GMABS Methodology in JogoMan

In section 5, we explained the GMABS methodology. However, when this metodology is applied, the integration between the players (RPG) and the system (MABS) can occur in many ways. For example, each player can access the system by Web and inform which are the chosen actions for the round. In JogoMan, only a person (operator of the system) is responsible to input the data into MABS. The players choose their actions and they write in a specific paper form, as shown in Figure 3 (the mayor paper form). This form is given to the operator. Another function of the operator is to inform the new scenario (next round) to the players, as shown in Figure 4 (information about all changes in the first round to Mayor). Figure 2 presents the pratical application of GMABS methodology in JogoMan.

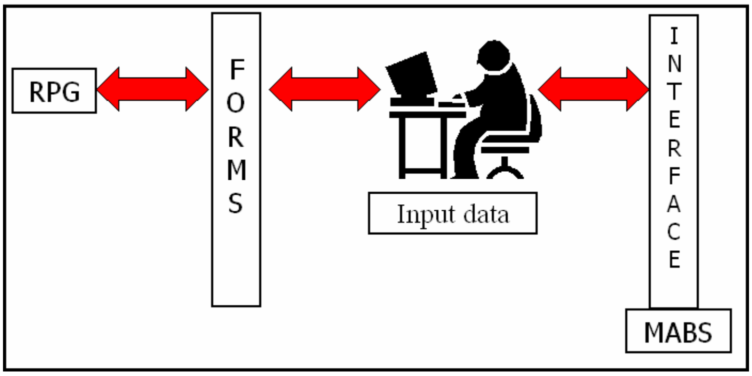

Figure 2: Practical operation of the GMABS methodology in JogoMan.

PREFEITO **MUNICÍPIO** _______ **Rodada Num°** _______

COLOCAR INVESTIMENTO DE INFRAESTUTURA

LOTE	TIPO DE INVESTIMENTO
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FLUXO DE CAIXA

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FINAL			

TRANSFORMAR ORCAMENTO DO MUNICIPIO

TIPO	VALOR	PARA QUEM
☐ Transferir Dinheiro		
☐ Transferir Dinheiro		

ALTERAR LISTA DE PROPRIEDADE

AÇAO	LOTE N°	PREÇO	EM FAVOR JOGADOR N°	PARCELADA
☐ Vender ☐ Alugar				
☐ Vender ☐ Alugar				
☐ Vender ☐ Alugar				

MODIFICAR IMPOSTO

USO	NOVO VALOR

DESCONTO

USO	NOVO VALOR

MODIFICAR USO DO TERRENO

LOTE	NOVO USO DO ESCOLHIDO								
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	☐ Agricultura	☐ Plantação	☐ Floresta	☐ Campo	☐ Sitio	☐Agricultura Irrigada	☐ Loteamento	☐ Industrial	☐ Comercial
	☐ Agricultura	☐ Plantação	☐ Floresta	☐ Campo	☐ Sitio	☐Agricultura Irrigada	☐ Loteamento	☐ Industrial	☐ Comercial

Figure 3: Paper form to Mayors (in portuguese).

6.3 The UML Model

According to Barreteau *et. al* [3], the modelling work is viewed as a way to structure both representations and exchanges, and to facilitate discussion and learning processes.

Figure 5 presents the UML class model of JogoMan. This figure is divided in three levels:

- white classes represent possible land uses (for example, Industry or Forest) and infrastructures (for example, Hospital or Sanitation Network);
- gray classes represent spatial units, where Plot means the portion of space and Municipality and Reservoir are aggregations of plots;
- the darkest classes represent all social agents in system. However, only AguaPura, MigrantRepresantative, LandOwner and Mayor classes are represented in RPG by real players. The GroupOfFamily class represents

families that MigrantRepresentative will allocate during the game (they are social agents, but they do not have a real player that represents them).

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Log Valores Economicos Prefeito: 1
Cashbox Inicial: 30000
--------RODADA: 1 ---------
--------LOTES: ---------
Número: 1  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
Número: 2  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
Número: 9  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
Número: 10  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
Número: 17  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
Número: 18  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
Número: 25  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
Número: 26  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
Número: 33  Uso: #Urban  Custo Manutenção: 0  Taxas Mun.: 6800
--------GASTOS---------
Gastos com Infra-Estrutura: 0
Gastos com Pagamentos de Taxas a Prefeitura: 0
Gastos com Manutenção dos Lotes: 0
Gastos com Pagamentos de Tarifas a AguaPura: 0
Gastos com Pagamentos de Alugueis de Lotes: 0
Gastos com Tarifas Especificas: 0
--------GANHOS---------
Ganhos com Atividade dos Lotes: 0
Ganhos com Infra-Estrutura dos Lotes : 0
Ganhos com Tarifas Especificas: 62900
Ganhos com Recebimento de Alugueis de Lotes: 0
Cashbox Final: 92900.00s
Indice Social (Fator F): 0.7
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Figure 4: Informations about the new scenario to Mayor (in portuguese).

The development process of UML diagram class was very iterative. In Figure 5, it is presented the final version of this model. However, we developed some other models until reaching this version, because during the discussion process, some functions were not represented in the first models and some mistakes were found.

The idea of UML class model is to represent all rules presented in Section 6.1. For example, concerning the MigrantRepresentative, the function of this player is to allocate new families. In the UML model class this is represented by a link between GroupOfFamily and MigrantRepresentative classes, and the local where these families will be allocated is represented by the link between GroupOfFamily class and Housing or Favela (Slum) classes, because the new place where these families will be allocate depends of the quantity of money that they will have. For the other players described in the Section 6.1, there are more links and different classes to represent them.

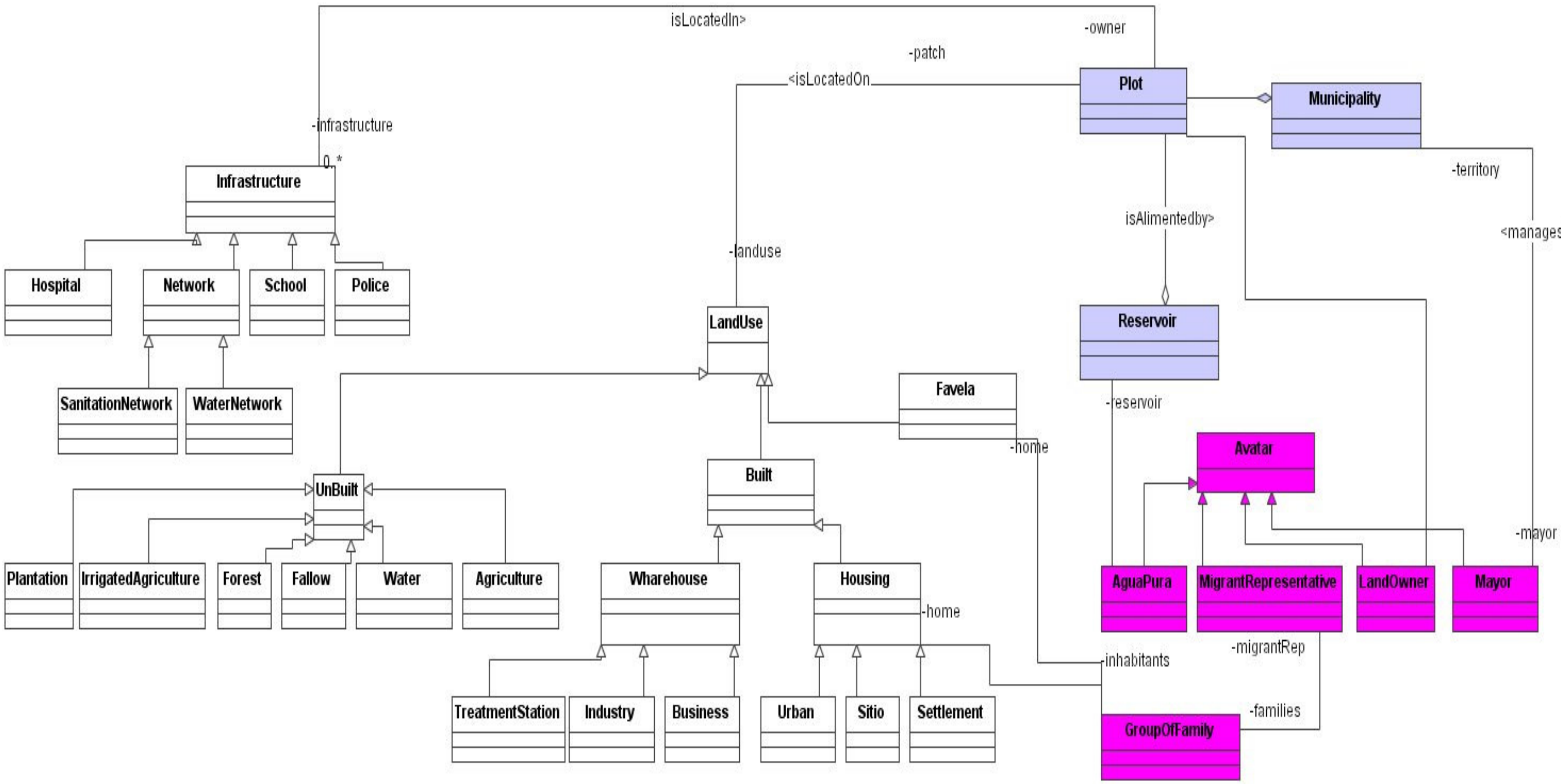

Figure 5: UML class model of JogoMan.

6.4 Implementation and Some Scenarios

JogoMan was implemented using the Cormas system (COmmon-pool Resources and Multi-Agent Systems) [8], a Multi-Agent Simulator developed at CIRAD, for simulation of natural resources. Cormas is based in an object-oriented language, SmallTalk [19]. In management of natural resources, spatial localization is very important, because some natural dynamics are easier to represent for a spatial level, and the social agents (stakeholders) are extremely related with the spatial localization [5, 13, 10]. In Cormas, all agents can be located in a spatial grid, and in JogoMan prototype, as shown in UML class model by Plot class (Figure 5), the spatial unit is important, because it represents the portion of space, having a land use, an infrastructure and an owner.

We defined three different scenarios in JogoMan, using the same spatial area (a 8x8 grid). These scenarios are important to obey a specific situation. For example, in a scenario where there is a larger number of land owners, the migrant representative player can better negotiate where he/she will allocate the new families. However, where there are less land owners, the negotiation is more difficult. The three scenarios are the following:

- *First scenario*: it consists of 14 players, where one represents the water company administrator, three represent city mayors, nine represent private land owners and one represents the migrant representative). It is the most complete scenario of JogoMan, where negotiations between every player are more complex (see in Figure 6, the first scenario interface);
- *Second scenario*: it consists of 8 players, where one represents the water company administrator, three represent city mayors, three represent private land owners (one by city) and one represents the migrant representative. It is a subset of the first scenario and negotiation of private land owners are reduced;
- *Third scenario*: it consists of 8 players, where one represents the water company administrator, two represent city mayors, four represent private land owners (two by city) and one represents the migrant representative. It is a subset of the first scenario too, but the negotiation of private land owners are more complex.

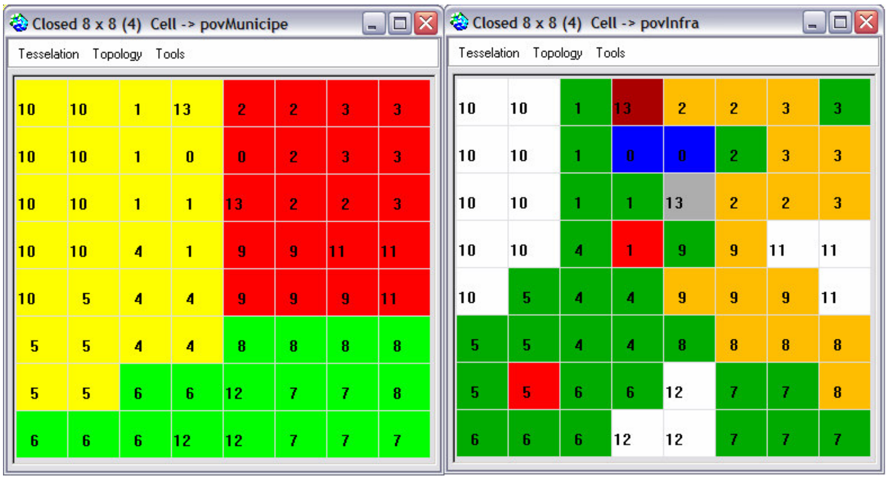

Figure 6: Interface of first scenario of JogoMan. Left figure presents cities division (3 cities, each with a different color). Right figure presents land occupation, the numbers represent the owners of each portion of space and the colors the type of land occupation (industry, agriculture, etc.).

6.5 First Tests and Preliminary Results

Several tests were accomplished with the JogoMan prototype. The first ones (four tests) were carried on with the Negowat Project staff (researches and graduate students) and the other ones (three tests) with students of several universities of the São Paulo area. The next tests will be applied with community groups in São Paulo peri-urban catchment.

According to Egenfeldt-Nielsen [15], one of the main problems of presenting test results is that the evaluation methods in relation to games is a problem in itself: it has been questioned if we can use traditional methods for measuring learning outcomes. In our tests, the results are qualitative, not quantitative. It means that we did not use a mathematical method to determine the game results. We can only observe the game evolution and ask the players about the game, using, for example, questionnaires to obtain more information.

The tests described here used the First scenario (with 14 players) and the sequence of steps to its application were the following:

1. A general explanation was given for all participants of the game, presenting its objectives and roles (possible players);
2. Each person has choosen a role (a player);
3. For each different player, specific information were given. For example: mayors know how many money they have and actions that they can execute;
4. The first round was stayed. Usually, the first play is longer, because the players do not have knowledge of all the actions that they can execute and the benefits/damages that these actions can cause. A time of 30-40 minutes was defined for the first round;
5. Players informed to the MABS operator which were the chosen actions;
6. Actions were computed by MABS. These actions modifed the initial scenario (first round complete). The operator has then informed the new scenario to the players;
7. When the rounds finish (normally 3 or 4 rounds), we did a debriefing, to verify doubts and suggestions by a questionnaire. This step is extremely important, because it has helped us to define a better prototype.

Debriefing is an indispensable step, because it is an important element to learn about the game. It is a way to increase reflection about games. It is a natural step in a learning process, and it is quite surprising that research into written debriefing is almost non-existing [15, 11].

Some suggestions/information appointed by players in the debriefing questionnaire (step 7 in our application sequence) were the following:

- Most of the participants found the game very interesting and realistic, and it has helped them to understand the reality in peri-urban catchments;
- The participants have also affirmed to have learned a lot about the domain, because RPG is a didactic and funny form to learn a new topic;
- The participants have highlighted that it is easy to identify the relationship between social and environmental issues, like pressure urban versus forest preservation;
- Most of the participants thought that the rules are rather complex. They suggested the creation of a game manual, to help them to decide and/or to negotiate in each round. We agree and we think that the complexity of the game demand a preparation process, previous to the game application. For example: all participants need to read the game manual and to participate in an

explanation section about which are the player roles and game rules. According to Dorn [11], games should be integrated with readings, lectures, discussion, media presentations, reaction, papers and testing and evaluation;

- The participants thought that there was too little time (30-40 minutes) for their decision-making in the first round. It is a consequence of the game complexity.

These tests were very important, because many suggestions and modifications were proposed in order to obtain a game more similar to the reality. However, we did not monitor all the actions that have occured during the negotiation processes. For example, we do not know how a player decides to buy a portion of space from other player, and this process is very important to better define our prototype.

7. Conclusions

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 as "social laboratory" and it can be used in many activities. MABS can provide interesting tools to develop a joint representation of the dynamic processes in the initial stages of the negotiation processes.

On the other hand, the water competition should increase and the conflict resolution tends to be difficult in the institutional landscape of water management in peri-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 MABS have been tested in natural resources management, as water or land. The integration of these two techniques, called GMABS methodology, can help us to define tools to support negotiation process in conflicts resolution to natural resources management.

The JogoMan prototype is an example of how to use the GMABS methodology. This prototype has helped us to better understand the real phenomena in a peri-urban catchments. All steps involved in the development process (rules and players, practical use of GMABS methodology in JogoMan, UML model, implementation, scenarios and first tests), described in Section 6, were very important, because we have the chance to discusse and learn about all prototype functions and processes.

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