Participatory Simulation for Collective Management of Protected Areas for Biodiversity Conservation and Social Inclusion

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***Abstract*— In this paper, we introduce a research project aimed at methodological and computer-based support for participatory management of protected areas, in order to promote biodiversity conservation and social inclusion. Our starting point is the "companion modelling" approach, as defined by the ComMod group, a movement of researchers created in 2003. Their method, called MAS/RPG, consists in iterations coupling role-playing games (RPG) and agent-based simulations (MAS), in order to model collective management and support negotiation between stakeholders. It has been applied to the collective management of natural renewable resources. The agent-based simulations are used to foresee, display and discuss the impact of individual actions on the environment. For obvious reasons, companion modelling does not provide stakeholders with a pre-defined solution to their conflicts.**

More recently, an evolution of the MAS/RPG approach named "agent-based participatory simulations" proved able to prompt participants to create innovative distributed solutions to complex problems. These simulations rely more heavily on computer support (distribution, logs, assistant agents) and integrate the agent-based simulation with the role-playing game, thus reducing the need for iterations.

Our objective is to propose and evaluate the use of this methodology and the associated software tools on different national parks for conservation of natural resources in Brazil. Our first case study is the Tijuca National Park, in Rio de Janeiro. It is inserted in the urban net of a great metropolis (Rio de Janeiro) and suffers from different kinds of human pressure and their impacts, e.g., illegal occupation, water contamination and social tension. This case study addresses the question of conflict resolution, one of the key questions for the participatory management of protected areas.

***Keywords*— participatory simulation, environment, protected areas, management, role-playing games.**

I. Introduction

An important and difficult challenge facing our world is the apparent dilemna between the competing objectives of environmental conservation, economic development, and social inclusion. Brazil faces such challenges, in rural but also in urban environments, as it happens with the remains of the Atlantic Forest within the city of Rio de Janeiro.

Recent initiatives to address these challenges, notably by the Brazilian Ministry of Environment, are based on bottom-up participatory approaches, that allow for building solutions using the knowledge of local actors (stakeholders) and communities. Such bottom-up approaches echo the research conducted by members of the "ComMod" (for companion modeling) movement [1]. Over the last ten years, they have developed a participatory method to support negotiation and decision-making in the field of collective management of natural renewable resources. This method consists in jointly using role-playing games involving stakeholders and agent-based simulations of the environment and associated resources.

Our project inherits from this tradition, but we propose to use a recent evolution of the ComMod methodology called participatory simulations [2], that merges role-playing games and agent-based simulation. Our main hypothesis is that such an approach favors discussions between stakeholders and the emergence of policy proposals. From a computing perspective, it also has several advantages: distribution, use of assistant agents, automatic analysis of traces.

This paper aims at describing our project, which is starting this year, its challenges, our approach, and the techniques of participatory simulation. It represents a step for testing innovative participatory approaches for management of protected areas. The project, named "SimParc", gathers French and Brazilian researchers in the various fields involved (computer science, modeling, simulation, regional planning, environment). It is mainly funded by the ARCUS program ("Actions en Régions de Coopération Universitaire et Scientifique") of the French Ministry of Foreign Affairs, Région Île-de-France, and Brazil.

Outline of the Paper

Section II will introduce and discuss the various challenges of our project. Section III will introduce the companion modelling approach. Section IV will discuss the merits of participatory simulation. Section V will describe our plan for study and experiments for the Tijuca National Park. Section VI will conclude this paper.

II. Environmental and Political Challenges

The question of the integration of the social actors in the management of biodiversity is still largely under discussion in fundamental and applied research fields. It constitutes also a key element of the application of the Convention on Biological Diversity. It concerns Brazil but also France, in particular on the stakes of the development of national parks at the border (parks of Tumucumaque [3] and Cabo Orange in the state of Amapa, and the future park close to the south of Guyana [4]). Our objective is, starting from case studies, to elaborate a strategy for management of protected areas, which integrates local actors and defines spaces of dialogue about the public policies. Therefore, the following questions are some inspiration for research [5]:

- Who are the social actors?
- What are their negotiation strategies?
- What are the conflicts and how can we contribute to their resolution?
- What are the political, economic, social and ecological stakes of the conservation of protected areas?
- What are the social dynamics?
- On what representations and practices are they based?
- How to design a model of management able to consider the existing conflicts and the solutions suggested?
- How to envision management of protected areas through middle and long term projections of scenarios?

These questions will imply to establish an assessment of the situation of social dynamics related to these protected areas, and to reflect on the interest of the models of management at use in Brazil and in other countries.

For this study, we decided to study the use of advanced accompaniment methodologies combining role playing games and simulation [6]. These approaches, although recent, already proved their potential on a certain number of projects of management of renewable resources. From an applicative point of view, their application to the management of protected spaces will be a first attempt, with returns awaited on methodology. Moreover, from a computer science perspective, we expect the project to be an opportunity to assess some proposed innovations such as the use of assistant agents, the use of learning mechanisms for analyzing experiments, and dynamic adaptation of the game parameters and rules, as described in Section IV.

III. ComMod MAS/RPG Coupling

Since the end of the 1990s, a group of researchers has been developing a participatory approach to support negotiation about collective practices in the context of natural resource management. Gathered within the ComMod movement (standing for "Companion Modelling" [1]), they mostly belong to French agriculture- or development-centered research institutes, such as CIRAD, CEMAGREF, INRA and IRD. Their method, called the MAS/RPG approach [7], consists in coupling agent-based simulations (MAS, Multi-Agent Systems) and role-playing games (RPG) with the concerned actors (stakeholders).

The origin of the ComMod movement lies in an analysis of agent-based simulations. Because they are built from models of individual behaviors, they are well-suited to simulate phenomena from a combination of diverging or conflicting points of view and representations. This aggregation and the possibility to present the impact of individual behaviors on the environment are exploited by these researchers to support negotiation [8]. The topic of the negotiation can include the rarefaction of water resources [9], the process of deforestation or reforestation [10], or the risk of disappearance of an endangered species [11].

The MAS/RPG approach was also strongly affected by the agent-based simulation platform developed by the CIRAD called Cormas [12]. Compared to other agent-based simulation tools, Cormas is specialized in common pool resource management and it has many advantages for this purpose. For example, agent-based simulations are coupled with a cellular automaton simulator. The cells of the automaton represent the geographical units where agents can be located, and the simulator can be initialized with GIS data. Cormas also implements the notion of "point of view". Points of view are methods to represent the state of the simulation, including agents and the cellular automaton. For instance, from the same simulation of the Mejan plateau, Cormas can display the repartition of the different species of pine trees, e.g., *Pinus sylvestris* and *Pinus nigra*, which are of interest to the foresters, or the land value based on the landscape quality, which is more interesting for the conservationist [13].

Role-playing games are particularly well-suited to foster dialog between actors. Indeed, experiments conducted by members of the ComMod movement assessed the improvement brought by the joint use of role-playing games and agent-based simulations displaying the dynamics of the resource and its exploitation. The method was first used to allow farmers to collectively design irrigation strategies [14]. Besides, this approach can help actors gain a broader understanding of a problem, notably by conducting role-playing games where roles are exchanged.

In these participatory experiments, the dynamics of the resource to be protected, constituting the environment, is represented by a cellular automaton which is derived from the cellular automaton coupled with the agent-based simulation of the same problem (see Fig. 1). The organizers of the role playing game often input the decisions of actors to allow Cormas to compute the evolution of the environment (see Fig. 2).

The MAS/RPG method is iterative and based on successive improvements of the agent-based simulation and the role-playing game. For example, the initial simulation based on a global model of the environment and hypotheses on the behavior of actors is often presented to stakeholders; their remarks are used to improve the model by including their local knowledge. The role-playing game is then designed from the agent-based simulation. Usually, initial versions are used with students (for example students from the ENGREF, the French Institute of Forestry, Agricultural and Environmental

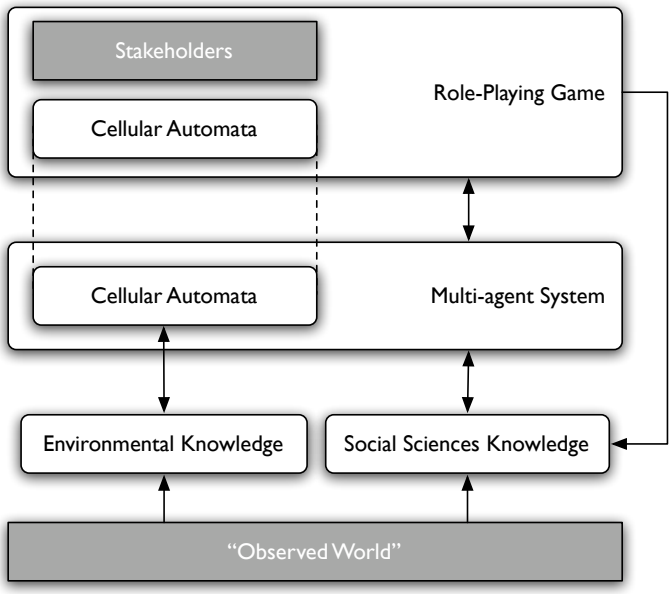

Fig. 1. Abstract representation of the ComMod MAS/RPG process

Engineering) to teach them the impact of individual behaviors on the environment, and later versions are used for decision-making support [10].

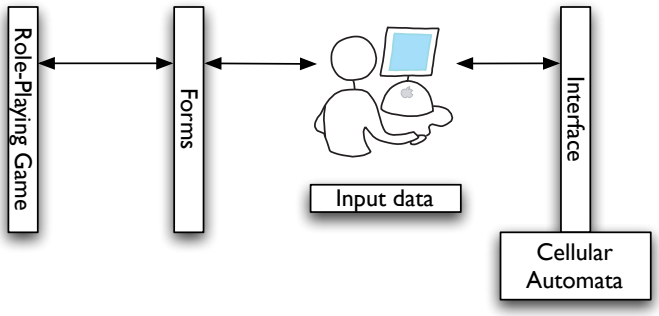

Fig. 2. The role of the organizers in the MAS/RPG approach (inspired from [9])

In summary, the MAS/RPG approach is a participatory method applied to natural renewable resource management and designed to teach the impact of individual behaviors on the environment, to help stakeholders understand the point of view of the other actors, to support negotiation and to favor collective decision-making.

IV. Participatory Simulation

A main drawback of the traditional joint-use of agent-based simulations and role-playing games is that organizers must be physically present during the role-playing game. They manually input the decisions and actions taken by participant to allow the computer to determine the new state of the environment and they present this result to the actors (see Fig. 2). This process is complex and prone to possible errors of transcription. Several authors have developed computer interfaces used by all participants [10], but they are all using a single computer and organizers must record the discussion between participants.

We developed an alternative to the MAS/RPG approach called "agent-based participatory simulations". This approach consists in further integrating computers into the role playing-game, and can be considered as a merge of the role-playing game and the agent-based simulation. Where organizers manually entered the decisions of players, participants directly access the simulation like agents, using a graphical user interface. All communications between participants take place on the network, as in distributed games. All interactions are agent-based and are recorded. Fig. 3 summarizes the complete methodological process.

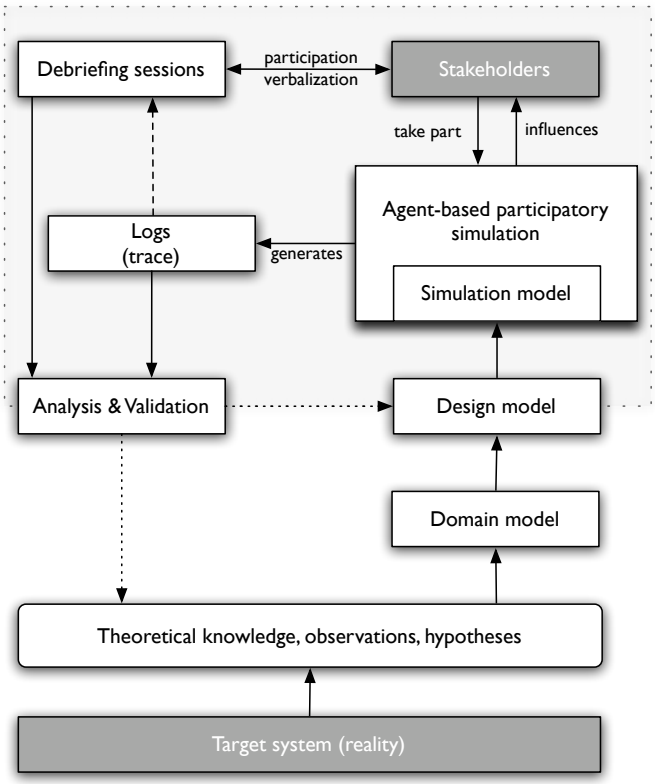

Fig. 3. Participatory Simulation Process

We developed a software prototype, called Simulación [15], to conduct such simulations. Simulación is an agent-based framework written in Java that allowed us to easily design applications for agent-based participatory simulations based on various models. It has been used for experiments on coalitions on the coffee market (SimCafé), for two sets of experiments based on game theory (SimBar and SimBar III) and for experiments based on renewable resource management (SimCommod).

The framework provides many facilities, from the networking logic for communication between agents, to the localization of applications in various languages (experiments

have been conducted in English, French, Japanese, Portuguese, Spanish and Thai). Applications based on Simulación are Java processes made of a graphical user interface and one or more underlying agents. The underlying agents behave like autonomous agents from an external point of view but are in fact controlled by human participants. Simulación is based on the Model-View-Controller design pattern, and components (usually Swing-based) act like views and controllers while the agent acts like a model. Most messages that the agent receives trigger a visual or auditive change in the interface and, conversely, most user input events, such as clicks or text input, are translated to messages which are sent, through the agent, to other agents on the network.

The "agent-based participatory simulations" approach has many advantages over the traditional MAS/RPG approach [16]. The most obvious advantages belong to four categories:

- Because participants interact through a computer mediated interface, simulations can involve stakeholders who are geographically distant [17].
- Because all interactions are computer mediated, they can be recorded and this record can be automatically processed and used to help participants and organizers better understand the dynamics of the game.
- Because of the game and the agent-based simulation are merged, this approach decreases the existing gap between the agent-based model and the behavior of participants.
- Because participants access the simulation like software agents, participants can be replaced by artificial agents when they are away and cannot take part in the simulation [18].

In MAS/RPG, experiments rely on an agent-based model purposely calibrated to trigger reactions from participants. For example, in ButorStar simulations, a disagreement between participants yields the worst possible irrigation plan [11]. In Sylvopast, if the shepherd is eliminated from the game, the forest is set on fire [10]. This way of triggering reactions from participants by creating problematic or annoying situations is reminiscent of techniques used by social scientists such as ethnomethodological breaching, which consists in breaching the social order to study the way it is usually maintained [19]. However, participants can feel guilty for the evolution of the simulation or feel manipulated.

Also, an important issue when designing a role-playing game is the relative valuations of actions, actors, and resources. Usually this calibration is done by the designer with a specific objective (e.g., to favor cooperation) for the game and, at least initially, it is not transparent to the game participants. We would like to experiment with ways to interactively open-up these design decisions, as well as the rules of a game, in order for participants to progressively envision these parameters and to participate in their setting. The Self-Cormas experiments [20], where the game participants were themselves participating in the construction of the game, could be an interesting source of inspiration for us.

Last, in agent-based participatory simulations, since all interactions between participants are mediated, the computer interface introduces a layer that can be specifically engineered to both deconstruct the relations between participants and empower them with the evolution of the simulation. It is possible to introduce eliciting assistant agents with learning capabilities that make suggestions based on the mistakes of the participants (see Fig. 4). Such assistant agents have been known to help at motivating the participants. Additionally, the division of actions in primitive actions and interactions allowes participants to build their own interaction protocols and avoid pre-defined behaviors. Indeed, past agent-based participatory experiments showed that they often behave in surprising ways [21] and that the method encouraged them to create solutions to difficult problems.

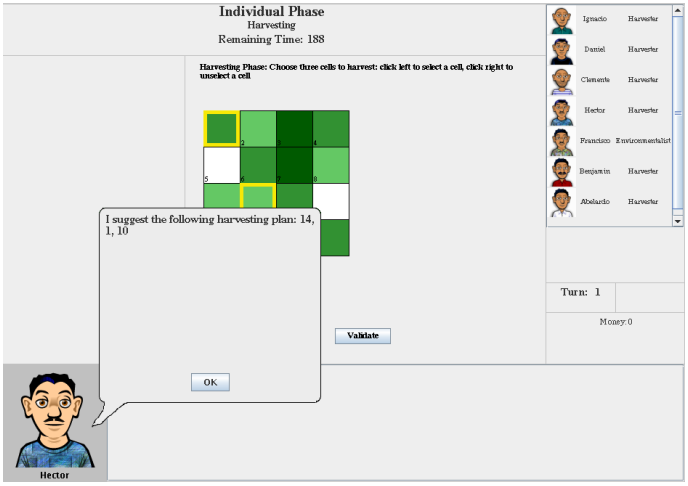

Fig. 4. An assistant agent in SimCommod

V. Application to the Tijuca National Park

Our objective is to study the use of agent-based participatory simulations for participatory management of protected areas. Our first site of study is the urban Tijuca National Park, in Brazil. Created in 1961, and integral part of the Reserve of Biosphere of the Atlantic Forest, the Tijuca National Park is a protected area internationally recognized for its ecological, cultural and historical importance. It is inserted in an urban network of a large metropolis (Rio de Janeiro) and has a surface of approximately 4000 hectares, at the center of some important residential districts of the city (see Fig. 5).

The Tijuca National Park undergoes a real pressure, notably by underprivileged populations (favelas). This makes conflict resolution one of the key questions for the management of the park [22]. Because of its organization and of its urban proximity, we chose it as a pilot site for study and experiments.

According to the Brazilian legislation, as a national park, the Tijuca National Park is a protected area devoted at integral preservation. Resources of the park (e.g., water, forest, and space) can only be used for research purposes, environmental education, and tourism. The management of the Park also considers a peripheral zone, called "*zona de amortecimento*"

Fig. 5. Map of the Tijuca National Park (Source: Instituto Pereira Passos - Eduardo Lage Santos)

in Portuguese, within a certain distance from the park, with a more flexible use of resources defined through a specific management plan. This peripheral buffer zone is actually the main zone for potential (and actual) conflicts (e.g., use of water or forest resources by local communities for different purposes). It is also important to stress that, besides the questions of conflicts, the participatory management of the Park can also include potential uses and economical alternatives for the population living in the peripheral zone. Some examples are eco-tourism and trading of traditional craft-work based on local products.

The management strategy is coordinated by the administration of the park, through the management plan and the management council. That latter has been installed recently and includes representatives of the various actors located or acting at the surroundings of the park. More precisely, the management council includes 24 members. One half are representatives of governmental institutions, e.g., the agency of the Ministry of Environment (IBAMA), the water state agency, and local police. The other half are representatives of non-governmental organizations (NGOs) and of the private sector, concerned with, e.g., ecology, tourism, religion, or a specific community.

The situation of the Tijuca National Park echoes cases studied by researchers of the ComMod movement: what is at stake is the protection of an ecologically endangered area. It requires the elaboration of satisfactory agreements for the various stakeholders. Our objective is to study how agent-based participatory simulations can help stakeholders to elaborate collective solutions for the participatory management of protected areas.

We took part as observers in the beginning of the process of installation and enpowering of the management council, as organized and accompanied by a contracted NGO, named IBASE [23]. A first set of issues for the park (e.g., quality of water, biodiversity, security) were identified in a participatory manner. Then, a first role playing game (without any computer) was also organized by IBASE. We are now currently identifying the various actors, their roles, various resources, their dynamics, the actions by actors and their effects, their interdependences and known conflicts, in order to draw the domain model (see Fig. 3). Based on this analysis, we will select a subset of this model and build a first model of participatory simulation (the design model). Then, we will implement a first prototype, based on Simulación, and conduct preliminary experiments as a first bootstrapping step.

Other sites for studies are also considered, in the long run. A second potential site is the National Park Montanhas de Tumucumaque. It is located at the border of Brazil, French Guiana and Surinam. With more than 3 millions of hectares, it is the largest park of Brazil and in the world. It is integrated in a complex mosaic of protected surfaces and Indigenous Grounds. Located at the extreme north of the country, it is relatively isolated from dynamic urban and the decision-making centers of the country. Spaces of negotiation are thus open to propose studies on the topics of biodiversity conservation and social integration.

More generally speaking, there are currently 55 National Parks in Brazil, aimed at a compromise between nature protection and social inclusion. They represent great challenges for construction of democratic governance [24].

VI. Conclusion

In this paper, we introduced our SimParc research project on the use of agent-based participatory simulations to help the management of protected areas for biodiversity conservation and social inclusion. We discussed the challenges and situation of the Tijuca National Park which is our current site of study. Our approach is filiated with “Companion modelling”, as developed by the ComMod group, which combines role-playing games and agent-based simulation. Meanwhile, we propose to use an evolution of this approach, named “agent-based participatory simulations”, and pointed out its potential merits.

Past research showed that agent-based participatory simulations can be used to support negotiation for collective management [15]. For example, the complete records can be used to give an overview to stakeholders, as an agent-based simulation, of the solution they created. Moreover, traditional approaches to support negotiation for collective management of natural resources require to discuss with experts and stakeholders beforehand, in order to define the model and the rules of the simulation based on a priori knowledge of the resource and existing collective management processes.

While several aspects of the model are necessarily fixed and can be considered as constraints of the model, such as the natural dynamics, others could be an object of negotiation between stakeholders. Using agent-based participatory simulations, we think it is possible to allow social actors to negotiate the rules and the roles of the model during the experiment, and use the simulation to let them define and introduce participatory management practices.

In summary, we hope that this description of our ongoing project could witness both on the important challenges of constructing democratic governance of protected areas, and on the potential of agent-based participatory simulations as an innovative companion approach.

Acknowledgments

The authors would like to thank our colleagues: Alexis Drogoul, for his role in the participatory simulation approach; all the ComMod group, for their great pioneering work; and Ivan Bursztyn, Vincent Corruble, Gustavo Melo, Altair Sancho and Vinicius Sebba Patto, for their participation to this initial phase of the project. We also thank Sonia Peixoto, the head of the Tijuca National Park, for her support and encouragement, and Nahyda Franco, the key IBASE person in charge of the establishment of the management council, for the opportunity to share this experience. This project is primarily funded by the ARCUS program between French Ministry of Foreign Affairs, Région Île de France and Brazil. One of the author is also partly funded by a fellowship from the Japanese Society for the Promotion of Science. The artwork of Simulación-based applications were designed by Michael Vacík. We also would like to thank the reviewers for their constructive comments.

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