Design of a Decision Maker Agent for a Distributed Role Playing Game – Experience of the SimParc Project

Jean-Pierre Briot[1], Alessandro Sordoni[1], Eurico Vasconcelos[2], Marta de Azevedo Irving[3], Gustavo Melo[3], Vinícius Sebba-Patto[1], and Isabelle Alvarez[1]

[1] Laboratoire d'Informatique de Paris 6 (LIP6), Université Pierre et Marie Curie – CNRS, Paris, France
[2] Computer Science Department, Pontifícia Universidade Católica (PUC-Rio), Rio de Janeiro, RJ, Brazil
[3] EICOS Program, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, RJ, Brazil

Abstract. This paper addresses an ongoing experience in the design of an artificial agent taking decisions in a role playing game populated by human agents and by artificial agents. At first, we will present the context, an ongoing research project aimed at computer-based support for participatory management of protected areas (and more specifically national parks) in order to promote biodiversity conservation and social inclusion. Our applicative objective is, through a distributed role-playing game, to help various stakeholders (e.g., environmentalist, tourism operator) to collectively understand conflict dynamics for natural resources management and to explore negotiation management strategies for the management of parks. Our approach includes support for negotiation among players and insertion of various types of artificial agents (decision making agent, virtual players, assistant agents). In this paper, we will focus on the architecture of the decision making agent playing the role of the park manager, the rationales for its decision, and how it takes into account the preferences/votes from the stakeholders.

1 Introduction

In this paper, we are discussing our experience of inserting artificial agents in a role-playing game populated with humans. The role playing game we consider may be considered as a serious game, as our objective is educational and epistemic. In this game, humans play some role and discuss, negotiate and take decisions about a common domain, in our case environment management decisions.

We are currently designing and inserting different types of artificial agents into this human-based role-playing game. More precisely, we are considering three types of artificial agents:

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– artificial players – A first motivation is to address the possible absence of sufficient number of human players for a game session [1]. But this will also allow more systematic experiments about specific configurations of players profiles, because of artificial players' objective, deterministic and reproducible behaviors.
– artificial decision maker – The park manager acts as an arbitrator in the game, making a final decision for types of conservation for each landscape unit and it also explains its decision to all players. As for artificial players, using an artificial manager in place of a human manager will allow reproductible experiments with controllable levels of participation and of manager profile (see Section 6.1).
– assistant agents – These agents are designed to assist a player by performing tasks, such as orientation within games steps and actions expected, and also support for negotiation, e.g., by identifying and suggesting potential coalitions.

In this paper we focus on the design of the artificial decision maker agent. Its objective is to take decision based on its own analysis of the situation and on the proposals by the players. The agent is also able to explain its decision based on its chain of argumentation.

The structure of this paper is as following: after introducing the SimParc project, its role playing game and its computer support, and the insertion of artificial agents, we describe the decision maker agent objectives, architecture and implementation.

2 The SimParc Project

2.1 Project Motivation

A significant challenge involved in biodiversity management is the management of protected areas (e.g., national parks), which usually undergo various pressures on resources, use and access, which results in many conflicts. This makes the issue of conflict resolution a key issue for the participatory management of protected areas. Methodologies intending to facilitate this process are being addressed via bottom-up approaches that emphasize the role of local actors. Examples of social actors involved in these conflicts are: park managers, local communities at the border area, tourism operators, public agencies and NGOs. Examples of inherent conflicts connected with biodiversity protection in the area are: irregular occupation, inadequate tourism exploration, water pollution, environmental degradation and illegal use of natural resources.

Our SimParc project focuses on participatory parks management. (The origin of the name SimParc stands in French for "Simulation Participative de Parcs") [2]. It is based on the observation of several case studies in Brazil. However, we chose not to reproduce exactly a real case, but a fictive park, in order to leave the door open for broader game possibilities [3]. Our project aim is to help various stakeholders at collectively understand conflicts and negotiate strategies for handling them.

2.2 Approach

Our initial inspiration is the companion modeling (ComMod) approach about participatory methods to support negotiation and decision-making for participatory management of renewable resources [4]. They pioneer method, called MAS/RPG, consists in coupling multi-agent simulation (MAS) of the environment resources and role-playing games (RPG) by the stakeholders [4]. The RPG acts like a "social laboratory", because players of the game can try many possibilities, without real consequences.

Recent works proposed further integration of role-playing into simulation, and the insertion of artificial agents, as players or as assistants. Participatory simulation and its incarnation, the Simulación framework [5], focused on a distributed support for role-playing and negotiation among human players. All interactions are recorded for further analysis (thus opening the way to automated acquisition of behavioral models) and assistant agents are provided to assist and suggest strategies to the players. The Games and Multi-Agent-based Simulation (GMABS) methodology focused on the integration of the game cycle with the simulation cycle [1]. It also innovated in the possible replacement of human players by artificial players. One of our objectives is to try to combine their respective merits and to further explore possibilities of computer support.

3 The SimParc Role-Playing Game

3.1 Game Objectives

Current SimParc game has an epistemic objective: to help each participant discover and understand the various factors, conflicts and the importance of dialogue for a more effective management of parks. Note that this game is not (or at least not yet) aimed at decision support (i.e., we do not expect the resulting decisions to be directly applied to a specific park).

The game is based on a negotiation process that takes place within the park council. This council, of a consultative nature, includes representatives of various stakeholders (e.g., community, tourism operator, environmentalist, non governmental association, water public agency...). The actual game focuses on a discussion within the council about the "zoning" of the park, i.e. the decision about a desired level of conservation (and therefore, use) for every sub-area (also named "landscape unit") of the park (remember that this is a fictive park, see Section 2.1). We consider nine pre-defined potential levels (that we will consider as types) of conservation/use, from more restricted to more flexible use of natural resources, as defined by the (Brazilian) law. Examples are: Intangible, the most conservative use, Primitive and Recuperation.

The map of the park (a GIS with different layers of information) is shown at Figure 1. It includes icons for various types of "elements of concern" for the different stakeholders (e.g., various animals to be protected, tourism spots, types of illegal occupation, etc.).

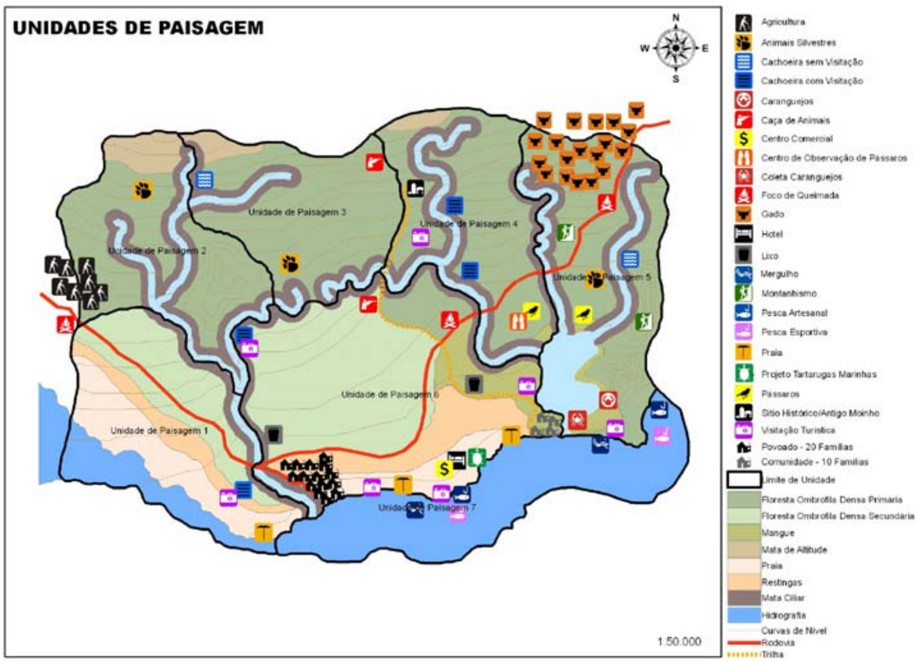

Fig. 1. The map of the SimParc park

The game considers a certain number of players' roles, each one representing a certain stakeholder. Depending on its profile and the elements of concerns in each of the landscape units (e.g., tourism spot, people, endangered species...), each player will try to influence the decision about the type of conservation for each landscape unit. It is clear that conflicts of interest will quickly emerge, leading to various strategies of negotiation (e.g., coalition formation, trading mutual support for respective objectives, etc).

A special role in the game is the park manager. He is a participant of the game, but as an arbiter and decision maker, and not as a direct player. He observes the negotiation taking place among players and takes the final decision about the types of conservation for each landscape unit. His decision is based on the legal framework, on the negotiation process among the players and on his personal profile (e.g., more conservationist or more open to social concerns) [3]. He may also have to explain his decision, if the players so demand. We plan that the players and the park manager may be played by humans or by artificial agents.

3.2 Game Cycle

The game is structured along six steps, as illustrated at Figure 2. At the beginning (step 1), each participant is associated with a role. Then, an initial scenario is presented to each player, including the setting of the landscape units, the

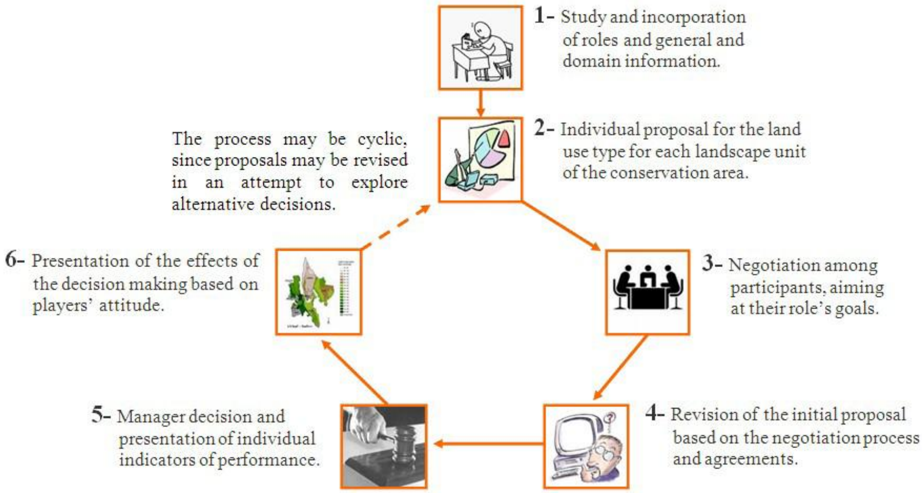

Fig. 2. The six steps of the SimParc game cycle

possible types of use and the general objective associated with his role. Then (step 2), each player decides a first proposal of types of use for each landscape unit, based on his/her understanding of the objective of his/her role and on the initial setting. Once all players have done so, each player's proposal is made public.

In step 3, players start to interact and to negotiate on their proposals. This step is, in our opinion, the most important one, where players collectively build their knowledge by means of an argumentation process. In step 4, they revise their proposals and commit themselves to a final proposal for each landscape unit. In step 5, the park manager makes the final decision, considering the negotiation process, the final proposals and also his personal profile (e.g., more conservationist or more sensitive to social issues). Each player can then consult various indicators of his/her performance (e.g., closeness to his initial objective, degree of consensus, etc.). He can also ask for an explanation about the park manager decision rationales.

The last step (step 6) "closes" the epistemic cycle by considering the possible effects of the decision. In the current game, the players provide a simple feedback on the decision by indicating their level of acceptance of the decision.[1]

A new negotiation cycle may then start, thus creating a kind of learning cycle. The main objectives are indeed for participants: to understand the various factors

[1] A future plan is to introduce some evaluation of the quality of the decision. Possible alternatives are: computable indicators (e.g., about the economical or social feasibility), a more formal model (based on viability theory, which allows to compute the viability and resilience of the result of the zoning decision), or a multi-agent simulation of the evolution of resources. Note that a real/validated model is not necessary as the park is fictive and the objective is credibility, not realism.

and perspectives involved and how they are interrelated; to negotiate; to try to reach a group consensus; and to understand cause-effect relations based on the decisions.

4 The SimParc Game Support Architecture

4.1 Design and Implementation of the Architecture

Our current prototype benefited from our previous experiences (game sessions and a first prototype) and has been based on a detailed design process. Based on the system requirements, we adopted Web-based technologies (more precisely J2E and JSF) that support the distributed and interactive character of the game as well as an easy deployment.

Figure 3 shows the general architecture and communication structure of SimParc prototype version 2. In this second prototype, distributed users (the players and the park manager) interact with the system mediated internally by communication broker agents (CBA). The function of a CBA is to abstract the fact that each role may be played by a human or by an artificial agent. A CBA also translates user messages in http format into multi-agent KQML format and vice versa. For each human player, there is also an assistant agent offering assistance during the game session. During the negotiation phase, players (human or artificial) negotiate among themselves to try to reach an agreement about the type of use for each landscape unit (sub-area) of the park.

A Geographical Information System (GIS) offers to users different layers of information (such as flora, fauna and land characteristics) about the park geographical area. All the information exchanged during negotiation phase, namely users'

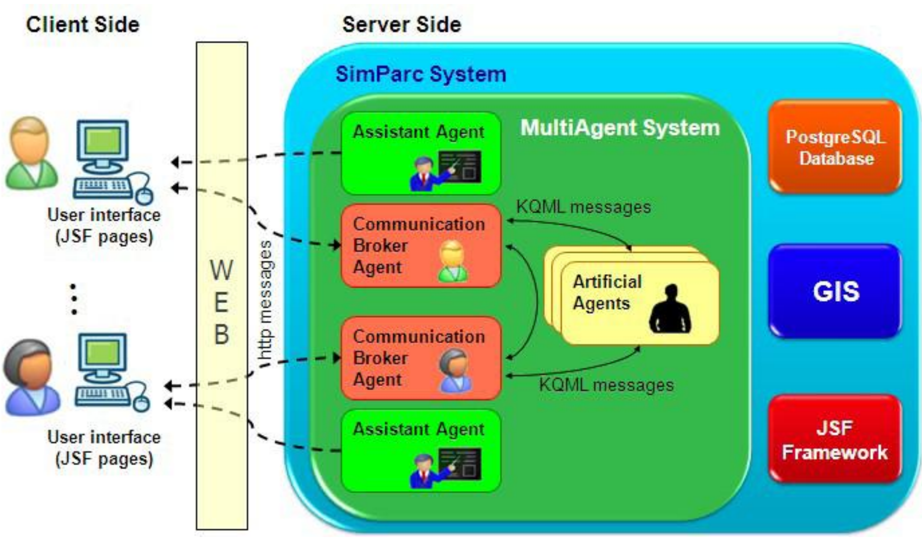

Fig. 3. SimParc version 2 general architecture

logs, game configurations, game results and general management information are recorded and read from a PostgreSQL database.

4.2 Interface Support

The interface for negotiation is shown at Figure 4. It includes advanced support for negotiation (rhetorical markers and dialogue filtering/structuring mechanisms, see details in [6]), access to different kinds of information about other players, land, law and the help of a personal assistant. The interface for players decision about the types of use is shown at Figure 5. In this interface, the players can analyze the area based in its different layers (e.g., land, hydrography, vegetation. . .).

4.3 Preliminary Evaluation

The current computer prototype has been tested through two game sessions by domain expert players in January 2009. The 9 roles of the game and the park manager were played by humans, Among them, 8 were experts in park management (researchers and professionals, one being a professional park manager in Brazil). The two remaining players were not knowledgeable in park management, one being experienced in games (serious games and video games) and the other one a complete beginner in all aspects.

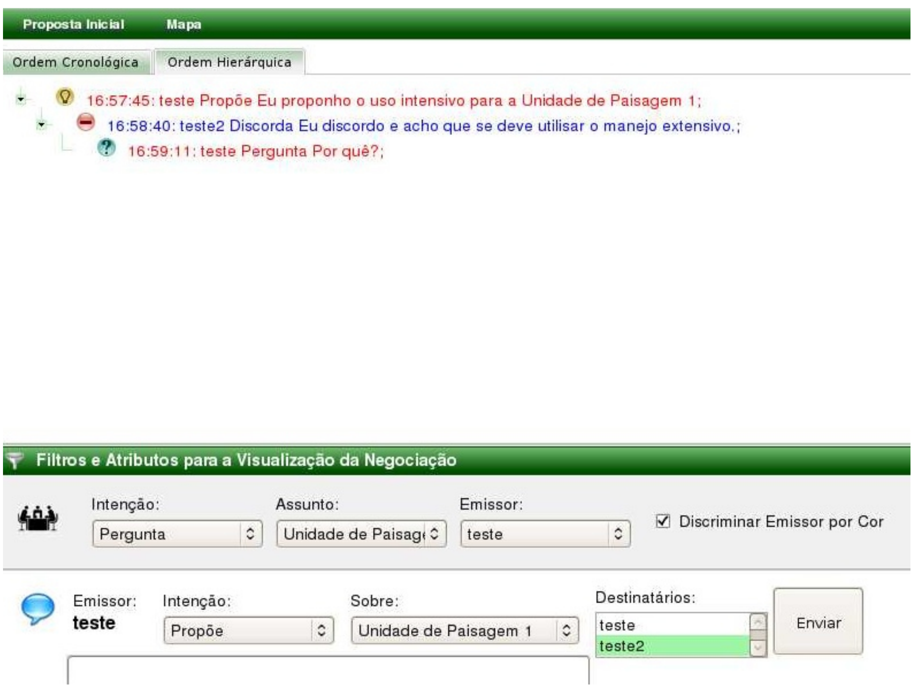

Fig. 4. Current prototype's negotiation graphical user interface

Fig. 5. Current prototype's decision graphical user interface

We analyzed data on the game sessions (written questionnaires, recorded debriefing, etc.) and a more detailed analysis is presented in [7]. Overall, the game was well evaluated by the human players. As one of the player also took part in a previous game session in September 2007, with no computer support yet, we could also have some preliminary clues at the benefits of a computer support as well as the relative loss in modality of interactions between players. That player acknowledged the progress in structuring and analysis of the negotiation, thanks to the computer support. An interesting finding after the sessions was also that all players learned and took benefit of the game. The experts explored and refined strategies for negotiation and management, whereas the beginner player took benefit of the game as a more general educational experience about environmental management. In other words, the game appeared to be tolerant to the actual level of expertise of players, an aspect which had not been planned ahead. Last, the fact that the prototype is accessible through Internet via a standard Web browser, and that it does not require preliminary installation of a software on all players computers, was acknowledged as a potential for greater mobility and larger dissemination of this game. In summary, we believe these preliminary results are very encouraging and we will soon conduct new game sessions with domain experts.

5 Inserting Artificial Agents into the SimParc Game

We are currently inserting artificial agents into the prototype. We consider three types of artificial agents: the park manager, the artificial players and the assistants.

The park manager acts as an arbitrator in the game, making a final decision for types of conservation for each landscape unit and explains its decision to all players. He may be played by a human or by an artificial agent. We have implemented a prototype implementation of an artificial park manager, based on 2 steps: (1) internal/individual decision by the park manager, based on some argumentation model; (2) merging of the decision by the manager with the votes by the players, based on decision theory (social choice). Traces of argumentation may be used for explaining the rationale of the decision. The artificial park manager architecture is detailed in Section 6.

For the artificial players, we build up on previous experience on virtual players in a computer-supported role playing game, ViP-JogoMan [1]. The idea is to potentially replace some of the human players by artificial players (artificial agents). The two main motivations are: (1) the possible absence of sufficient number of human players for a game session and (2) the need for testing in a systematic way specific configurations of players' profiles. The artificial players will be developed along the artificial park manager existing architecture, with the addition of negotiation and interaction modules. We plan to use its argumentation capabilities to generate and control the negotiation process. In a next stage, we would like to explore the automated analysis of recorded traces of interaction between human players, in order to infer models of artificial players. In some previous work [5], genetic programming had been used as a technique to infer interaction models, but we also plan to explore alternative induction and machine learning techniques, e.g., inductive logic programming.

The last type of artificial agent is an intelligent assistant agent. This agent is designed to assist a player by performing two main tasks: (1) to help participants in playing the game, e.g.: the assistant agent tells the player when he should make decisions; what are the phases of the game; what should be done in each phase; etc.; (2) to help participants during the negotiations. For this second task, we would like to avoid intrusive support, which may interfere in his decision making cognitive process. We have identified some actions, e.g., to identify other players' roles with similar or dissimilar goals, which may help the human player to identify possible coalitions or conflicts. The general main idea for an assistance for negotiation is thus to combine and classify important information to help participants to make analysis and do it faster than they would do alone, while keeping their focus on the game proposal. An initial prototype implementation of an assistant agent has been implemented [7].

6 The Park Manager Artificial Agent

In this section, we describe an agent architecture to implement the park manager cognitive decision rationale. As we summarized before, our decision model is based on two mechanisms. These mechanisms could be viewed as modules of decision subprocesses. We believe that complex decision making is achievable by sequential organization of these modules. Before proceeding to the description of our agent architecture, we present some more detailed motivation for it.

6.1 Objectives

Participatory management aims to emphasize the role of local actors in managing protected areas. However, the park manager is the ultimate arbiter of all policy on devolved matters. He acts like an expert who decides on validity of collective concerted management policies. Moreover, he is not a completely fair and objective arbiter: he still brings his personal opinions and preferences in the debate. Therefore, we aim to develop an artificial agent modeling the following behaviors.

Personal preferential profile: The park manager decision-making process is supposed to be influenced by its sensibility to natural park stakes and conflicts. In decision theory terms, we can affirm that the park manager's preferential profile could be intended as a preference relation over conservation policies. One of the key issues is to understand that we cannot define a strict bijection between preferential profile and preference relation. The agent's preference relation is partially dependent on natural park resources and realities. Moreover, this relation is not likely to be an order or a preorder. Hence, our agent must be able to define dynamically its preference relation according with its preferential profile. We distinguish two preferential profiles:

- Preservationist: aims to preserve ecosystems and the natural environment.
- Socio-conservationist: generally accepts the notion of sustainable yield - that man can harvest some forest or animal products from a natural environment on a regular basis without compromising the long-health of the ecosystem.

Taking into account stakeholders' decisions: A participatory decision-making leader seeks to involve stakeholders in the process, rather than taking autocratic decisions. However, the question of how much influence the stakeholders are given may vary on the manager's preferences and beliefs. Hence, our objective is to model the whole spectrum of participation, from autocratic decisions to fully democratic ones. To do so, we want the park manager agent to generate a preference preorder over conservation policies. This is because it should be able to calculate the distance between any two conservation policies. This way, we can merge the stakeholders' preference preorders with the manager's one to establish one participatory final decision. The autocratic/democratic manager attitude will be modeled by an additional parameter during the merge process.

Expert decision: The park manager's final decision must consider legal constraints related to environmental management; otherwise, non-viable decisions would be presented to the players, thus invalidating game's learning objectives. These constraints are directly injected in the cognitive process of the agent. Hence, the agent will determine a dynamic preference preorder, according to its preferential profile, over allowed conservation levels.

Explaining final decision: In order to favor the learning cycle, the park manager agent must be able to explain its final decision to the players. We can consider that the players could eventually argue about its decision; the agent should then defend its purposes using some kind of argumentative reasoning. Even if such cases will be explored in future work, it is our concern to conceive a cognitive architecture which provides a good basis for managing these situations.

6.2 Architecture Overview

Let us now present an architecture overview of the park manager agent. As depicted at Figure 6, the agent's architecture is structured in two phases. We believe that sequential decision-making mechanisms can model complex cognitive behaviors along with enhanced explanation capabilities.

The first decision step concerns the agent's individual decision-making process: the agent deliberates about the types of conservation for each landscape unit. Broadly speaking, the park manager agent builds its preference preorder over allowed levels of conservation. An argumentation-based framework is implemented to support the decision making. The next step of our approach consists in taking into account the players' preferences. The result of the execution is the modified park manager decision, called the agent participatory decision, according to the stakeholder's preferences.

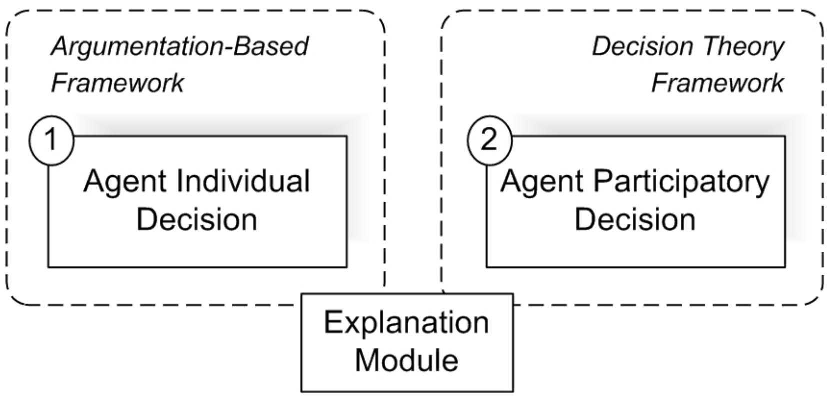

Fig. 6. Park manager agent 2-steps decision process

6.3 Agent Individual Decision

Recently, argumentation has been gaining increasing attention in the multi-agent community. Autonomous and social agents need to deliberate under complex preference policies, related to the environment in which they evolve. Generally, social interactions bring new information to the agents. Hence, preference policies need to be dynamic in order to take into account newly acquired knowledge. Dung's work [8] proposes formal proof that argumentation systems can handle epistemic reasoning under open-world assumptions, usually modeled by nonmonotonic logics. Argumentation thus becomes an established approach for reasoning with inconsistent knowledge, based on the construction and the interaction between arguments. Recently, some research has considered argumentation systems capabilities to model practical reasoning, aimed at reasoning about what to do [9,10,11]. It is worth noticing that argumentation can be used to select arguments that support available desires and intentions. Consistent knowledge can generate conflicting desires. An agent should evaluate pros and cons before pursuing any desire. Indeed, argumentative deliberation provides a mean for choosing or discarding a desire as an intention.

We could argue that open-world assumptions do not hold in our context. The agent's knowledge base is not updated during execution, since it is not directly exposed to social interactions. Knowledge base and inference rules consistency-checking methods are, therefore, not necessary. However, one key aspect here is to conceive an agent capable of explaining its policy making choices; our concern is to create favorable conditions for an effective and, thus closed, learning cycle. We believe that argumentation "tracking" represents an effective choice for accurate explanations. Conflicts between arguments are reported, following agent's reasoning cycle, thus enhancing user comprehension.

From this starting position, we have developed an artificial agent on the basis of Rahwan and Amgoud's work [10]. The key idea is to use an argumentation system to select the desires the agent is going to pursue: natural park stakes and dynamics are considered in order to define objectives for which to aim. Hence, decision-making process applies to actions, i.e. conservation levels, which best satisfy selected objectives. In order to deal with arguments and knowledge representation, we use first-order logic. Various inference rules were formulated with the objective of providing various types of reasoning capability. For example, a simple inference rule for generating desires from beliefs, i.e. natural park stakes, is:

$$Fire \rightarrow Avoid\_Fires,\ 4$$

where *Fire* (fire danger in the park) is a belief in agents knowledge base and *Avoid_Fires* is the desire that is generated from the belief. The value 4 represents the intensity of the generated desire.

Examples of rules for selecting actions, i.e. level of conservation, from desires are:

$$Primitive \rightarrow Avoid\_Fires,\ 0.4$$

$$Intangible \rightarrow Avoid\_Fires,\ 0.8$$

where *Primitive* and *Intangible* represent the levels of conservation and 0.4 and 0.8 represent their utilities in order to satisfy the desire *Avoid_Fires*.

6.4 Agent Participatory Decision

Despite participatory ideals, a whole spectrum of park managers, from autocratic to fully democratic ones, can be measured, depending on how more participatory and democratic decision-making is operationalized. We propose a method, fitted into the social-choice framework, in which participatory attitude is a model parameter.

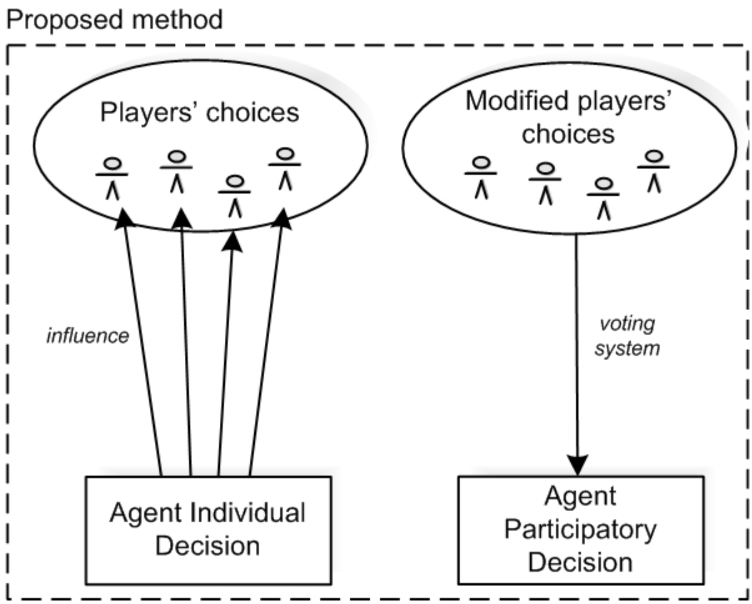

Fig. 7. Park manager agent participatory decision

In a real case scenario, a decision-maker would examine each stakeholder's preferences in order to reach the compromise that best reflects its participatory attitude. Our idea is to represent this behavior by weighting each player's vote according to the manager's point of view.

This concept is illustrated at Figure 7. The process is structured in two phases. Firstly, the manager agent injects its own preferences into the players' choices by means of an influence function describing the agent's participatory attitude. Stronger influence translates into more autocratic managers. Secondly, the modified players' choices are synthesized, using an aggregation function, i.e. Condorcet voting method. The result of the execution will be the agent participatory decision.

Example: Let the following be players' choices, where $\succ$ is a preference relation (a $\succ$ b means "a is preferred to b"):

$$player_1 = Intangible \succ Primitive \succ Extensive, \mathbf{v}_1 = (3, 2, 1)$$

$$player_2 = Extensive \succ Primitive \succ Intangible, \mathbf{v}_2 = (1, 2, 3)$$

$$player_3 = Primitive \succ Extensive \succ Intangible, \mathbf{v}_3 = (1, 3, 2)$$

Let Manager individual decision be:

$$manager_{ind} = Extensive \succ Primitive \succ Intangible, \mathbf{v}_M = (1, 2, 3)$$

The players' choices are converted into numeric vectors specifying the candidates' rank for each vote. Let the following be the influence function:

$$\odot(x, y) = \begin{cases} x & \text{if } x = y \\ x * 1/|x - y| & \text{otherwise} \end{cases}$$

The modified players' vectors will be:

$$\begin{aligned} \mathbf{mv}_1 &= \langle \odot(\mathbf{v}_1(1), \mathbf{v}_M(1)), \odot(\mathbf{v}_1(2), \mathbf{v}_M(2)), \odot(\mathbf{v}_1(3), \mathbf{v}_M(3)) \rangle \\ &= (1.5, 2, 0.5) \\ \mathbf{mv}_2 &= (1, 2, 3) \\ \mathbf{mv}_3 &= (1, 3, 2) \end{aligned}$$

In order to find the manager participatory decision, we apply the Choquet integral $\mathcal{C}_\mu$ [12] choosing a symmetric capacity measure $\mu(S) = |S|^2/|\mathcal{A}|^2$, where $\mathcal{A}$ is the candidates set.

$$\mathcal{C}_\mu(Intangible) = 1.05,\ \mathcal{C}_\mu(Primitive) = 2.12,\ \mathcal{C}_\mu(Extensive) = 1.27$$

The result of the execution will then be:

$$manager_{part} = Primitive \succ Extensive \succ Intangible$$

Further details about the architecture formal background and implementation are reported in [13].

6.5 Implementation Framework

The architecture presented in this paper has been implemented in the Jason multi-agent programming language platform [14]. Besides interpreting the original AgentSpeak(L) language, thus disposing of logic programming capabilities, Jason also features extensibility by user-defined internal actions, written in Java. Hence, it has been possible to easily implement aggregation methods.

6.6 Examples of Results

The presented manager agent architecture and its first implementation have been tested over different scenarios. Simulations conducted in laboratory have been validated by team experts. However, more results from further tests are expected. We report hereafter an example of explanation for the managers decision over a landscape unit. Let the manager individual decision be the following:

$$manager_{ind} = Intangible \succ Recuperation$$

Arguments for *Intangible* are:

$$Endangered\_species\ \&\ Tropical\_forest \rightarrow Maximal\_protection$$

$$Intangible \rightarrow Maximal\_protection$$

Arguments for *Recuperation* are:

$$Fire\ \&\ Agricultural\_activities \rightarrow Recover\_deteriorated\_zone$$

$$Recuperation \rightarrow Recover\_deteriorated\_zone$$

7 Conclusion

In this paper, we have presented the SimParc project, a role-playing serious game aimed at computer-based support for participatory management of protected areas. The lack of human resources implied in RPG gaming process acts as a constraint to the fulfillment of pedagogical and epistemic objectives. In order to guarantee an effective learning cycle, park manager role must be played by a domain expert. Required expertise obviously narrows game's autonomy and limits its context of application. Our solution to this problem is to insert artificial agents into the game. In this paper, we focused on the architecture to implement park manager cognitive decision rationale. The decision-making agent can justify its behavior and generate a participatory decision. Our argumentation system is based on [9,10]: conflicts between arguments can be reported thus enhancing user comprehension. Moreover, we presented a decision theory framework responsible for generating a participatory decision. To the best of our knowledge and belief, this issue has not yet been adressed in the literature. Although more evaluation is needed, we believe the initial game session tests are encouraging. The final integration of the park manager agent within the new version of the prototype is under way. We plan new game sessions with experts in January 2010. Besides the project specific objectives, we also plan to study the possible generality of our prototype for other types of human-based social simulations. In the current architecture of the artificial park manager, only static information about the park and about the votes by players are considered. We are considering exploring how to introduce dynamicity in the decision model, taking into account the dynamics of negotiation among players (the evolution of decisions by players during negotiation).

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