Design of an Artificial Decision Maker for a Human-based Social Simulation – Experience of the SimParc Project

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Abstract
This paper addresses an ongoing experience in the design of an artificial agent taking decisions in a social simulation (more precisely, a role playing game) populated by human agents and by artificial agents. At first, we will present our current research 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 to help various stakeholders (e.g., environmentalist NGOs, communities, tourism operators, public agencies) to collectively understand conflict dynamics for natural resources management and to explore negotiation management strategies for the management of parks, one of the key issues linked to biodiversity conservation. Our approach combines techniques such as: distributed role playing games (serious games), geographical information systems, support for negotiation between players, and insertion of various types of artificial agents (virtual players, decision making agents, assistant agents). In this paper, we will focus on the design of the decision making agent architecture for the park manager agent, the rationales for his decision and how he takes into account the preferences/votes from the players of the game and may justify/explain his decisions.

Keywords
Social simulation, serious games, participatory management, decision making, multi-agent, negotiation, argumentation, explanation

1. Introduction

In this paper, we discuss the issue for an artificial agent to take decisions in a social simulation. The type of social simulation that we refer to here is a social simulation populated by humans. More precisely, we consider a role playing game ("serious game") where humans play some role and discuss, negotiate and take decisions about a common domain, in our case environment management decisions.

We are now in the process of inserting artificial agents into the human-based social simulation [Briot et al. 2008]. One of the ideas is to possibly replace some of the human players by artificial players (artificial agents). The social simulation will therefore become hybrid, with human and artificial agents. A first motivation is to address the possible absence of sufficient number of human players for a game session [Adamatti et al. 2007]. But this will also allow more systematic experiments about specific configurations of players profiles, because of artificial players' objective, deterministic and reproducible behaviors.

More precisely, we are considering three types of artificial agents: artificial park manager, artificial players and assistant agents. In this paper we focus on the design of the artificial park manager 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.

In this paper, after introducing the SimParc project, its role playing game and its computer support, we describe the park manager 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") [Briot et al. 2007]. It is based on the observation of several case studies in Brazil. However, we chose not to reproduce exactly a real case, in order to leave the door open for broader game possibilities [Irving et al. 2007]. 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 [Barreteau et al. 2003]. Their pioneer method, called MAS/RPG, consists in coupling multi-agent simulation (MAS) of the environment resources with a role-playing game (RPG) [Barreteau 2003]. Hence, stakeholders may understand and explore the consequences of their decisions. 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 [Guyot and Honiden 2006], focused on a distributed support for role-playing and negotiation between 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 [Adamatti et al. 2007]. It also innovated in the possible replacement of human players by artificial players.

2.3 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, nongovernmental 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. 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 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 between 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 between the players, and on his personal profile (e.g., more conservationist or more open to social concerns) [Irving 2006]. He may also have to explain his decision, on players demand. Players and the park manager roles may be played by humans or by artificial agents.

2.4 Game Cycle

The game is structured along six steps, as illustrated in Figure 1. At the beginning (step 1), each participant is associated to a role. Then, an initial scenario is presented to each player, including the setting of the landscape units, the possible types of use and the general objective associated to 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. 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 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.

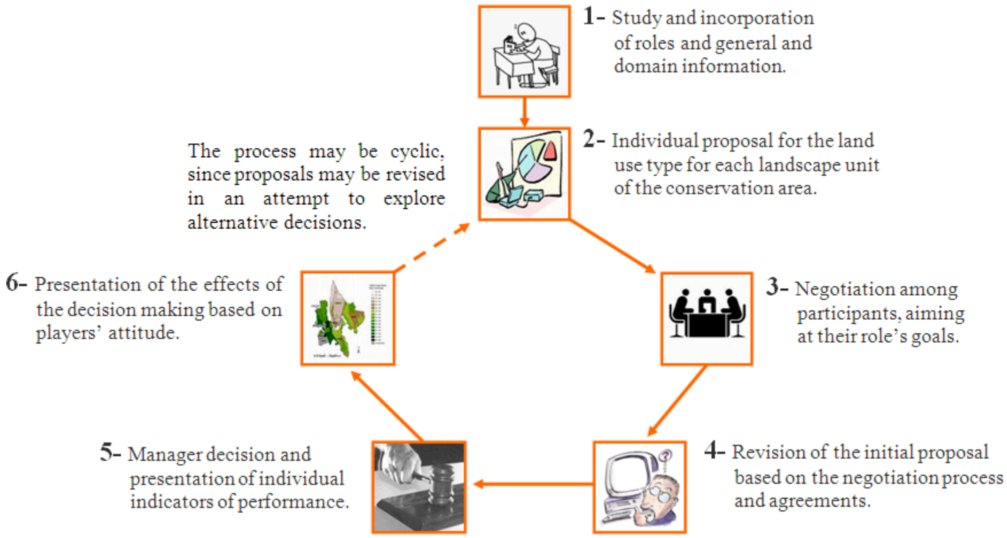

Figure 1. *The six steps of SimParc game.*

2.5 Towards Evaluating the Viability of Decisions

As described in previous section, the last step of the game "closes" the cycle by considering the possible effects of the decision. In the current game, players provide a simple feedback on the decision by selecting their level of acceptance of the decision. In a future project, we would like to introduce some technical evaluation of the quality and viability of the decision (e.g., considering the survival of an endangered species). Therefore, we plan to identify cases of usage conflicts (e.g., between tourism and conservation of an endemic species) and model the dynamics of the system (in an individual-based/multi-agent model or/and in an aggregated model). We would then like to explore the use of viability theory to evaluate the viability of the decision. Note that in our project current stage, we are concerned with credibility and not yet with realism because our objective is epistemic and not about producing an (hypothetical) optimal decision.

3. Computer Support for Role Playing Games

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 2 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 (see in Figure 3 an example of the corresponding user interface [Vasconcelos et al. 2008]), 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' logs, game configurations, game results and general management information are recorded and read from a PostgreSql database.

The game and the supporting prototype have been tested through two game sessions by expert players (including a professional park manager) in January 2009 (see Figure 4).

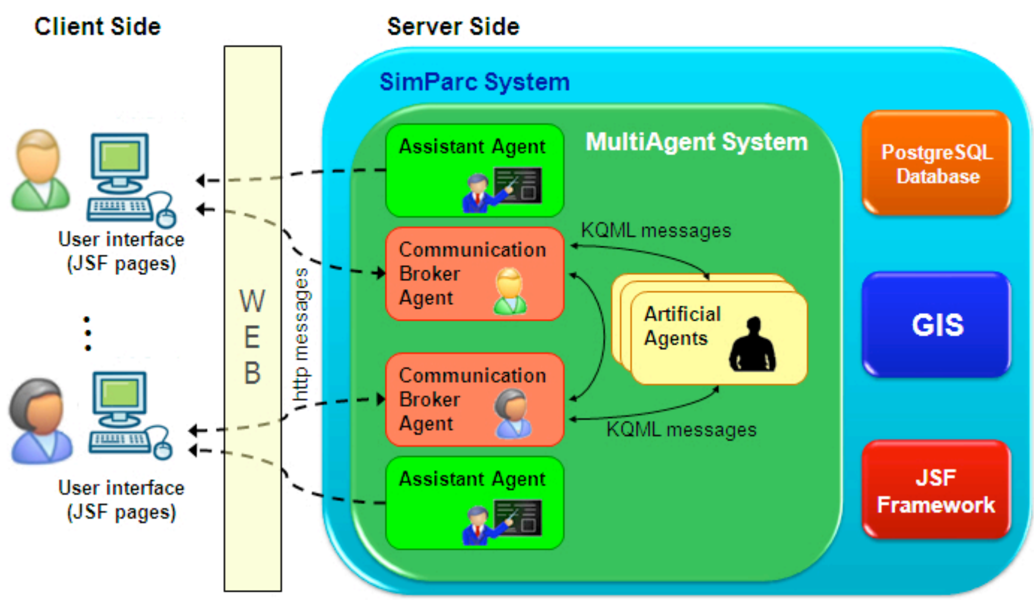

Figure 2. *SimParc version 2 general architecture*

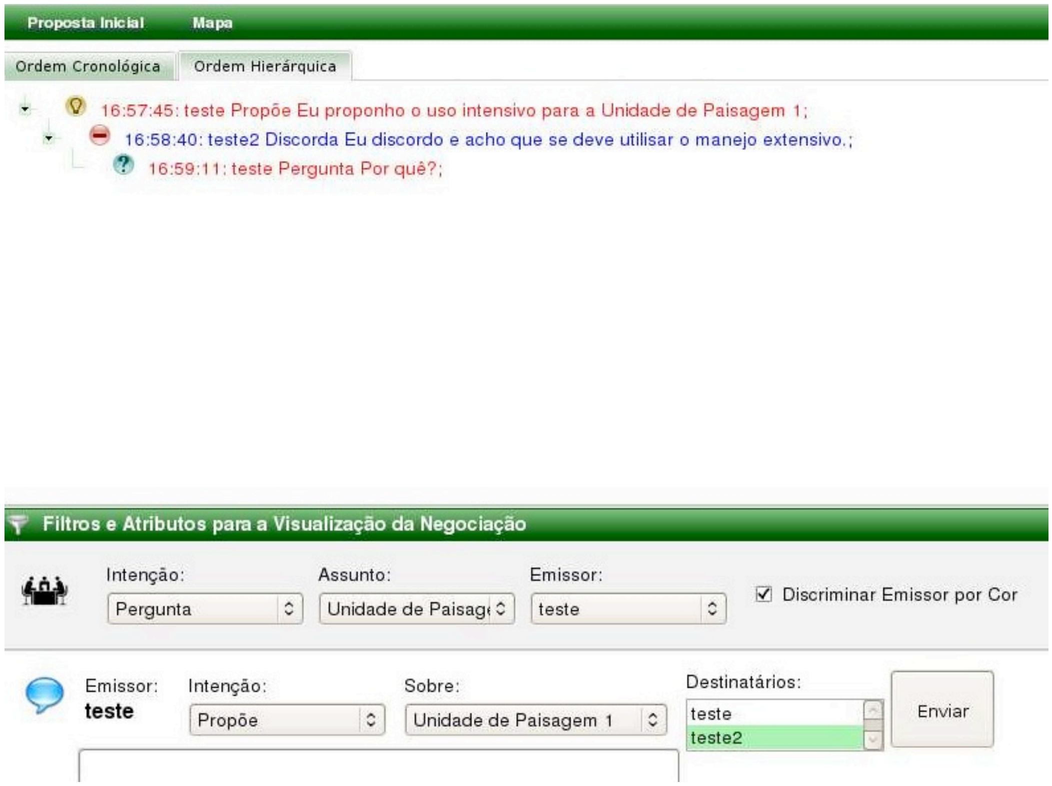

Figure 3. *Example of SimParc negotiation graphical user interface*

Figure 4. *SimParc session (January 2009)*

4. Inserting Artificial Agents in 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 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 next section.

Concerning artificial players, we refer to previous experience about virtual players in the ViP-JogoMan system [Adamatti et al., 2007]. The idea is to possibly 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 park manager existing architecture. We plan to use its argumentation capabilities to generate the negotiation process. In parallel, we also explore using automated analysis of recorded traces of interaction between human players in order to infer models of artificial players. In some previous work [Guyot and Honiden 2006], genetic programming had been used as a technique to infer interaction models, but we will also intend to use 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 selected some objectives, e.g., to identify other players' roles with similar or dissimilar goals, which may help the human player to find possible coalitions or conflicts. An initial prototype implementation of an assistant agent has been implemented.

Further details about SimParc artificial players and assistant agents may be found in [Briot et al. 2008] and in future publications. Some advanced interface has also been designed for human players dialogue and negotiation support and is detailed in [Vasconcelos et al. 2008]. Now we will detail the rationale and architecture of our automated park manager who makes the final decision.

5. Park Manager Artificial Agent

In this section, we propose an agent architecture to implement 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.

5.1 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; 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 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*. 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 generate its preference relation according with its preferential profile. We distinguish two preferential profiles:

i. *Preservationist,* aims to preserve ecosystems and the natural environment.

ii. *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 stakeholders are given may vary on 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 stakeholders' preference preorders with manager's one to establish one participatory final decision. 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 over allowed levels of conservation (according to its preferential profile).

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.

5.2 Architecture Overview

Let us now present an architecture overview of the park manager agent. As depicted in Figure 5, 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.

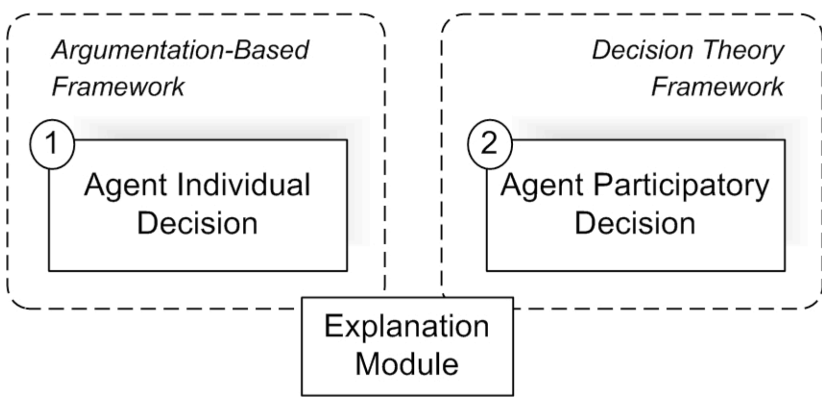

Figure 5. *Park Manager Agent 2-steps decision process*

The first decision step concerns agent's individual decision-making process: the agent deliberates about the types of conservation for each landscape unit. Broadly speaking, 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 of taking account of players' preferences. The result of the execution is the modified park manager decision, called agent *participatory* decision, according to stakeholder's preferences.

5.2.1 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 account of newly acquired knowledge. Dung's work [Dung 1995] proposes formal proof that argumentation systems can handle epistemic reasoning under open-world assumptions, usually modeled by non-monotonic 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* [Hulstijn and Torre 2003, Amgoud and Kaci 2004, Rahwan and Amgoud 2006]. 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 don't hold in our context. Agent's knowledge base isn't updated during execution, since it's 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 to the players, 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 [Rahwan and Amgoud 2006]. The key idea is to use 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. levels of conservation, 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 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 agent's 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→ *Avoid_Fires, 0.4*
Intangible → *Avoid_Fires, 0.8*

where *Primitive, Intangible* represent levels of conservation and values *0.4, 0.8* represent their utility in order to satisfy the corresponding desire.

5.2.2 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.

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 manager's point of view.

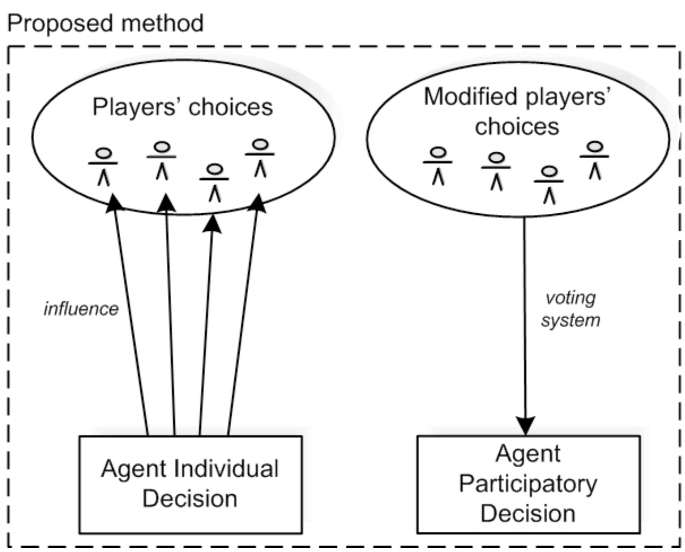

Figure 6. *Park Manager Agent Participatory Decision*

This concept is illustrated in Figure 6. The process is structured in two phases. Firstly, manager agent injects its own preferences into players' choices by means of an influence function describing agent's participatory attitude. Stronger influence translates into more autocratic managers. Secondly, 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 > is a preference relation (a > b means "a is preferred to b") and A={*Intangible, Primitive, Extensive*} the candidates' set. Players' choices are converted into numeric vectors specifying the candidates' rank (each column corresponds to a candidate) for each vote:

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

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

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

Let Manager individual decision be:

manager_individual: Extensive > Primitive > Intangible, $\mathbf{v}_M$ = (1, 2, 3)

Let the following be the influence function:

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

Modified player's vectors will be :

$$\mathbf{mv}_1 = \langle f(\mathbf{v}_1(1), \mathbf{v}_M(1)), \langle f(\mathbf{v}_1(2), \mathbf{v}_M(2)), \langle f(\mathbf{v}_1(3), \mathbf{v}_M(3)) \rangle = (1.5, 2, 0.5)$$

$$\mathbf{mv}_2 = (1, 2, 3)$$

$$\mathbf{mv}_3 = (1, 3, 2)$$

In order to find manager participatory decision, we apply the Choquet integral C_μ [Choquet 1953] choosing a symmetric capacity measure $\mu(S) = |S|^2 / |A|^2$, where A is the candidates set.

C_μ(*Intangible*) = 1.05, C_μ(*Primitive*) = 2.12, C_μ(*Extensive*) = 1.27

The result of the execution will then be:

manager_participatory: Primitive > Extensive > Intangible.

Further details about architecture formal background and implementation are reported in [Sordoni, 2008] and will be in future publications.

5.3 Examples of results

Presented manager agent architecture and its first implementation were tested over different scenarios. Tests of the park manager agent were conducted offline in laboratory and have been validated by team experts. We are currently completing the integration of the park manager agent into the prototype. We will then soon conduct new session tests with human players and park manager agent.

We report hereafter an example of explanation for manager's decision over a landscape unit. Let manager individual decision be the following:

Manager_individual: Intangible > Recuperation

Arguments for *Intangible* are:

Endangered_Species & Tropical_Forest → Maximal_Protection

Intangible → Maximal_Protection

Arguments for *Recuperation* are:

Fire & Agricolture_Activities → Recover_deteriorated_zone

Recuperation → Recover_deteriorated_zone

5.4 Implementation framework

The architecture presented in this paper has been implemented in Jason multi-agent platform [Bordini and Hubner, 2007]. 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 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. It can justify its behavior and generate a participatory decision. Our argumentation system is based on [Amgoud and Kaci 2004, Rahwan and Amgoud 2006]: 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 addressed in the literature. The game and the supporting prototype have already been tested through game sessions by expert players (including a professional park manager) in January 2009. The final integration of the complete SimParc prototype (with artificial agents) is under completion and we will soon start to test it. 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 of the players are considered. We are considering exploring how to introduce dynamicity in the decision model, taking into account the dynamics of negotiation among the players (the evolution of player's decisions during negotiation).

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