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# Use of Viability Analysis-based Assistants to Help Decision and Negotiation between Stakeholders in a Social Simulation of an Environment Management Council

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**Abstract:** The integrated management of the biodiversity of our planet, sustainable development and social inclusion is one of the largest current challenges for the human kind. This management cannot be addressed only by technocratic means, as it would face the issue of acceptability and also miss potential solutions coming from the local practices and local stakeholders. Therefore, we need to explore and support participatory methodologies for combining as well as possible biodiversity conservation and social inclusion.

Among these methodologies, companion modeling (ComMod, Barreteau et al. 2003) stands as one of the leading reference. This approach combines: 1) a social simulation of the decision processes between stakeholders, via some role-playing game (RPG); and 2) a multi-agent-based modeling and simulation (MAS) of the underlying renewable natural processes (biological, ethological, physical...), in order to provide the players of the game with some feedback on their decisions, individual and collective.

In spite of all its merits and of being our main source of inspiration, this combined MAS/RPG methodology suffers from some limitations. At first, it presupposes a prior consensus of all players on a choice of a simulated model. Second, the covering by the simulation is incomplete and has some bounded temporal horizon, a consequence of its stochastic nature.

We propose an alternative (and/or a complement) to MAS/RPG through a set of various assistants agents for helping players at individual decision and negotiation between them. Examples are: an agent proposing and capable of defending (through an argumentation process) decisions; an assistant agent for decision analysis (proximities of choices, dominance relation...); a mediation agent to propose compromises and their argumentation; and an assistant agent for assisting players in individual decision and also negotiation, based on a viability analysis (analyzing the consistency of one player objectives with its decisions and the dynamics of the eco-socio-system).

In this paper, we will detail this viability-based assistant agent, compare it to the MAS/RPG approach, illustrate it by an example scenario, detail its design and way of use, and summarize some preliminary evaluation of use. We will conclude in analyzing future prospects.

**Keywords:** participatory, management, companion modeling, protected areas, environment, biodiversity, stakeholders, social actors, decision, negotiation, role-playing game, simulation, agent, multi-agent, assistant, viability analysis.

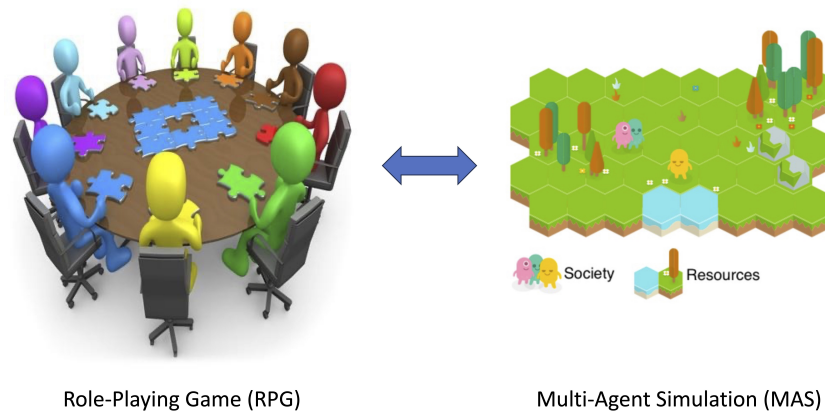


Figure 1: MAS/RPG ComMod model

## ● Introduction

- 1.1 The integrated management of the biodiversity of our planet, sustainable development and social inclusion is one of the largest current challenges for the human kind. This management cannot be addressed only by technocratic means, as it would face the issue of acceptability and also miss potential solutions coming from the local practices and local stakeholders. Therefore, we need to explore and support participatory methodologies for combining as well as possible biodiversity conservation and social inclusion.
- 1.2 Among these methodologies, companion modeling (ComMod, Barreteau et al. 2003) stands as one of the leading reference. This approach combines: 1) a social simulation of the decision processes between stakeholders, via some role-playing game (RPG); and 2) a multi-agent-based modeling and simulation (MAS) of the underlying renewable natural processes (biological, ethological, physical...), in order to provide the players of the game with some feedback on their decisions, individual and collective.
- 1.3 In this paper, we will introduce our proposal and experience in the line of the ComMod and MAS/RPG methodology, but with somewhat different and also complementary directions. We will motivate it, detail it as well as our experimental results and conclude in analyzing future directions.

## ● Related Work

### ComMod and MAS/RPG

- 2.1 ComMod (Companion Modeling) approach (Barreteau et al. 2003), which had been initiated within the GREEN (Renewable Resources and Environment Management) research unit at CIRAD in Montpellier, and quickly became a network of inter-institutional researchers (ComMod 2024) has been our primary source of inspiration.
- 2.2 We believe that ComMod attempts at reconciling two traditionally opposed decision-making approaches:
  - the *technocratic* approach, based on a technical-based decision, but without participation of the social actors concerned. The risk is the lack of acceptability of decisions, but also the inability to integrate possible information or potential strategies developed by social actors;
  - the *participatory* approach, based on the participation of the social actors concerned. The risk is not to provide sufficient technical basis for decisions. In theory, we could encounter a paradoxal situation of some consensual decision but ultimately a bad one (for the majority or all of the social actors). Another risk is the difficulty in deciding between opinions and solutions, if they remain incommensurable (risk of relativism), other than through manipulation (raising one's voice, moral arguments, intimidation, etc.).
- 2.3 ComMod is based on the MAS/RPG coupling of (see Figure 1):
  - a *role-playing game (RPG)*, where human players play the roles of the different stakeholders, in order to model the participatory process of decision and negotiation between stakeholders;

- and a *multi-agent simulation (MAS)*, which models the dynamics of the renewable natural resources (e.g., water, forest, fish, etc.) of the eco-socio system shared by the stakeholders (the social actors at risk), in order to model the evolution of the resources based on the interactions between the individual and collective decisions of the stakeholders and the dynamics of the renewable resources.

**2.4** The game sessions consist of an alternation of individual decisions by the players (for example, taking a quantity of resources such as water, fish, etc.) and collective decisions (for example, the construction of a dike) and a cycle of simulation of the evolution of renewable resources, the result of which allows players to be informed about the impact of their decisions as well as their interdependencies, and thus helps them to better understand the issues (and strategies) of participatory management (Barreteau 2003).

## Limitations

**2.5** In spite of all its merits and of being our main source of inspiration, we have identified some fundamental limitations of the MAS/RPG methodology:

- It presupposes a prior *consensus* of all players on a choice of a simulated model. In ComMod, consensus and validation by players of a simulation model may be a long process, with various modeling and validation steps (Barreteau et al. 2003). Moreover, the necessity to converge to a single model means the exclusion of a possible (actually, likely) diversity of models brought by various stakeholders viewpoints, from their local experience and knowledge. Thus, some useful information for the modeling and the future decision and negotiation process may be lost;
- The covering by the simulation is *incomplete*. As it is a stochastic multi-agent simulation, some configurations and effects may not be covered, even by a well-designed experimental plan. Also, the simulation has some bounded temporal horizon;
- The simulation acts as the technical validation of the policies decided by the stakeholders. But it is *unique*, whereas various types of technical validations as well as assistance could be useful, e.g., decision analysis (e.g., relations of dominance or equity between stakeholders), and argumentation analysis (e.g., to identify possible undercutting arguments, etc.), in order to analyze and support collective decision and negotiation;
- In addition, this single technical validation is *global*, whereas individual assistants may personalize the assistance based on the player preferences, objectives and history. An example is to be able to quantify the distance, and the effort to be made, by a given player to reach its objectives, or to reach a consensus with another player.

## ● Example Scenario of an Extractivist Marine Reserve

**3.1** Let us consider as an illustrative example the case of a *marine extractivist reserve*<sup>1</sup>, with a modeling of the evolution of its resources (fish, turtles, tourism, etc.) according to the decisions and actions of social actors (traditional fishermen, tourists, etc.).

**3.2** Note that we consider here a scenario for a *fictional* reserve protected area, in order to prevent players from identifying too much with a specific real case, because, here and as for ComMod (Barreteau et al. 2003), our objective is not to help directly resolve specific problems linked to a particular protected area, but to work at the *epistemic* level, towards the improvement by the social actors of the process itself (resolution of conflicts of use).

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<sup>1</sup>The concept of extractivist reserves was born in the Brazilian Amazon in the 1980s, as the combination of reasonable extraction of rubber latex by the local population, while guaranteeing sustainable protection of the forest. Other types of local sustainable extraction (for example, palm nut, fish, etc.) are possible depending on the nature of reserves of this type, including the marine extractivist reserve of Arraial do Cabo in the State of Rio de Janeiro (ICMBio 1997), which served as inspiration for this scenario, see Figure 2.

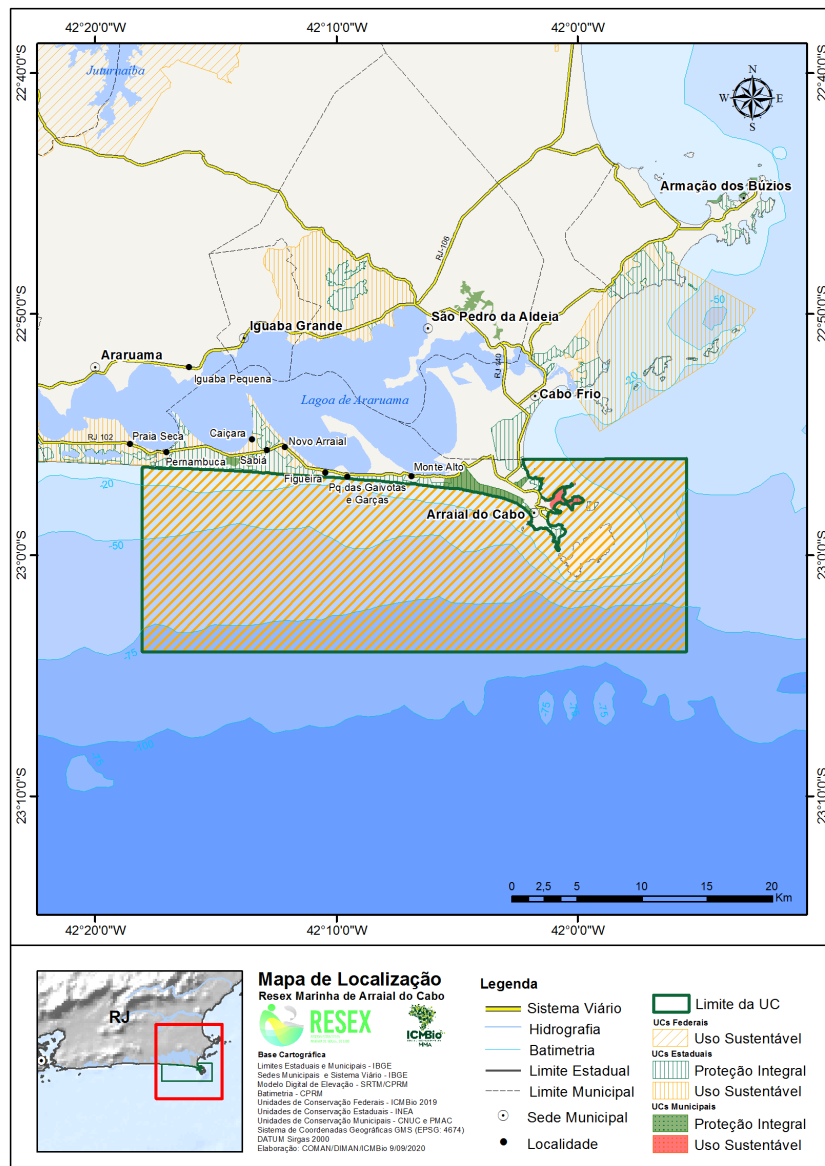


Figure 2: Map of the marine extractivist reserve of Arraial do Cabo. Source: (ICMBio 1997, Plano de manejo, page 9)

## Model

**3.3** To model the dynamics of the evolution of resources (turtles, fishermen's capital, tourists) of the marine reserve, according to their own laws of renewal and interaction as well as the actions of social actors, we have chosen, as an alternative path to ComMod multi-agent simulation approach, an *equational* (aggregated) model of the dynamics of the eco-socio system. It is specified as a set of *variables* and a set of *parameters*:

- *Variables* (whose values change over time):
  - the number of animals of an endangered species (sea turtles),
  - the number of tourists visiting the reserve,
  - the capital of the cooperative of fishermen practicing traditional fishing in the reserve;
- *Parameters*, e.g.<sup>2</sup>:
  - the growth rate of turtles,

<sup>2</sup>The complete list of parameters is introduced below.

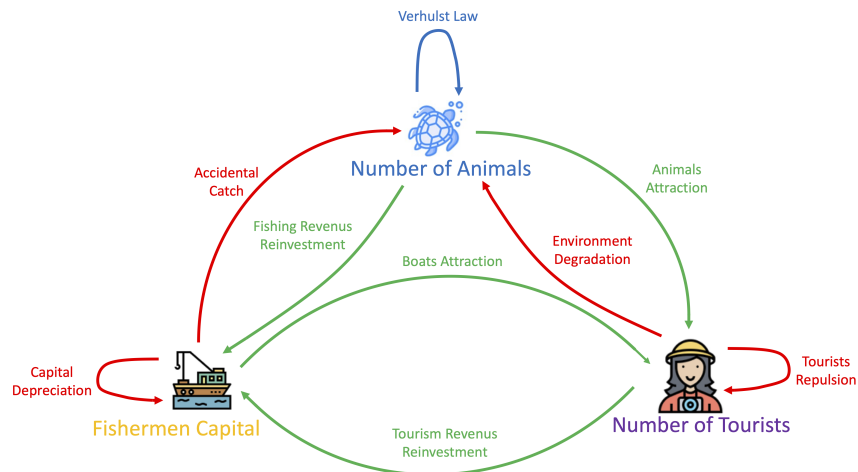


Figure 3: Abstract model – Arrows show the interactions between variables, in red they are negative, in green positive and in blue either.

- the value paid by tourists to fishermen (for using their boats to bring tourists to see turtles);
- *Controls*, which are parameters whose social actors can dynamically change their values (through a function called *control function*):
  - the proportion of turtle living areas made accessible to tourists,
  - the bycatch rate (accidental catch of turtles by fishermen), it can be modified by varying the mesh size of the net.

3.4 An *abstract model* of the eco-socio system, summarizing the interactions between variables, is shown in Figure 3.

## Roles

3.5 In the proposed scenario, the three<sup>3</sup> *roles* of the social actors involved, that will be played by participants of the role-playing game, are:

- representative of some NGO<sup>4</sup> for the protection of marine turtles threatened with extinction,
- representative of the traditional fishermen cooperative,
- tourism operator.

3.6 As suggested by the viability analysis assistant (as shown in Figure 4), each player will inform, according to his preferences (and his role): his *objectives*, both on the *variables* (named *viability constraints*) and also on the *controls* (means of action). The *green* interval means: *desired*, *orange*: *tolerated* and *red*: *excluded*. In this version of the assistant, the constraints are defined by minimum and maximum values of intervals.

3.7 For example:

- The main objective of the turtle protection NGO representative is to ensure the turtle population stays always above some threshold (minimum) that he considers critical for the biological viability of the species;
- The tourism operator's objective is to ensure a minimal number of tourists, in order to maintain the viability of his economic model. But he may also set a maximum threshold in order to avoid the risks linked to uncontrolled mass tourism (inadequacy of infrastructure availability and deterioration of the environment, and thus of its capacity of attraction).

<sup>3</sup>Note that there is not necessarily an isomorphism between the set of roles and the set of variables (the case in this scenario). We may for instance consider an additional role as an ethnologist, analyzing the sustainable practice of fishermen and their relation to natural resources.

<sup>4</sup>Non-governmental organization.

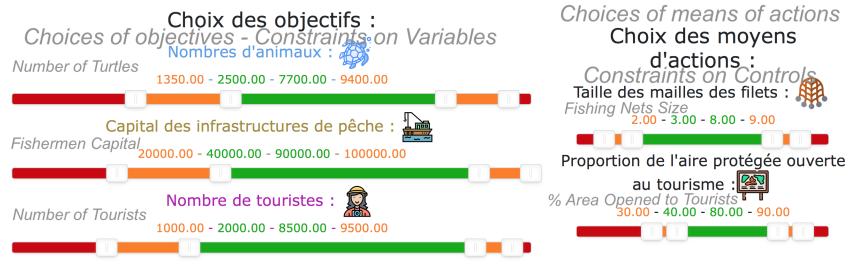


Figure 4: Players objectives (constraints on variables and controls). The green area defines the constraint set. (Assistant Interface – *Translations added*)

## Formal Model

4.1 For this proof of concept scenario, we assume that the structure of the *formal model* is a consensus set of equations. The players can disagree only on the parameters of the model. It is specified by the following equations:

4.2

$$\frac{dA}{dt} = gA \left(1 - \frac{A}{K_A}\right) - \zeta l T A - i_p A C \quad (1)$$

$$\frac{dC}{dt} = -\delta C + p m_p i_p A C + m_t i_t T \quad (2)$$

$$\frac{dT}{dt} = T \left(-\alpha T + \frac{a \zeta A}{A + \phi} + \mu_E C\right) \quad (3)$$

4.3 with  $K_A = 1 + M [1 + \eta T / (1 + \epsilon)]^{-1}$ .

### A(nimals)

4.4  $\frac{dA}{dt} = gA \left(1 - \frac{A}{K_A}\right) - \zeta l T A - i_p A C$

4.5 with  $K_A = 1 + M [1 + \eta T / (1 + \epsilon)]^{-1}$

4.6 Animals follow a Verhulst law (Schtickzelle 1981), where  $g(1 - \frac{A(t)}{K_A})$  is the number of turtles (for instance) that would be present without direct tourist interference. The carrying capacity  $K_A$  depends on the absolute carrying capacity  $M$  as well as on the damage related to tourist pollution  $\eta T$  and the effort to restore the environment  $\epsilon$ .

4.7 This number includes the number of turtles killed by direct interaction with tourists  $\zeta l T(t) A(t)$  and those accidentally caught by fishing boats. We assume that fishing leads to accidental mortality proportional to fishing activity (Peckham et al. 2007).

### Related Parameters

- $g$  corresponds to the growth rate of turtles, it is equal to the birth rate minus the mortality rate;
- $l$  corresponds to the mortality rate of turtles related to direct interaction with tourists;
- $M$  corresponds to the maximum capacity of the animals;
- $\eta$  corresponds to the number by which a tourist divides the capacity of the environment;
- $\epsilon$  corresponds to the effort to restore the environment;
- $\zeta$  represents the proportion of the life habitats of the turtles opened to access by the tourists. It is a *control parameter*;
- $i_p$  corresponds to the proportion of turtles accidentally killed by fishing. It can be modified by varying the mesh size of the net. It is a *control parameter*.

## C(apital)

4.8  $\frac{dC}{dt} = -\delta C + pm_p i_p A C + m_t i_t T$

4.9 Capital here is the money invested in fishing infrastructures. Its value decreases over time by a factor of  $\delta$ .

4.10 Two sources contribute to the capital:

- income from fishing  $pm_p i_p A(t)C(t)$ ; and
- income from tourism:  $m_t i_t T(t)$ .

This second source of income comes from fishermen using also their boats for the tourists to visit the reserve and see the turtles<sup>5</sup>.

### Related Parameters

- $\delta$  corresponds to the depreciation of fishermen (fishing) infrastructures;
- $p$  corresponds to the proportion of turtles killed by fishing;
- $m_p$  is the price of the number of fish caught for a turtle caught;
- $m_t$  corresponds to the money paid by tourists to fishermen;
- $i_t$  is the proportion of tourism-related income that is invested in fishermen infrastructures.

## T(ourists)

4.11  $\frac{dT}{dt} = T(-\alpha T + \frac{a\zeta A}{A+\phi} + \mu_E C)$

4.12 For the evolution of the number of tourists, we have been inspired by Wei et al. (2013). Tourists are attracted by animals  $\frac{a\zeta A(t)}{A(t)+\phi}$ . They are more attracted if they are more likely to see an animal but to a certain degree (this is specified by the parameter  $\phi$ ).

4.13 Tourists are also attracted by the fishermen's infrastructures (boats) in the same way. Moreover, tourists repel each other, this is expressed by the parameter  $\alpha$ .

### Related Parameters

- $\alpha$  is the congestion parameter, it expresses the fact that tourists prefer a low number of tourists;
- $a$  is the attractiveness of the site related to the animals;
- $\mu_E$  is the attractiveness of the site related to the fishing infrastructures;
- $\phi$  is the half-maximum saturation constraint. It corresponds to the number of turtles for which tourist satisfaction is at half the maximum;

## Control Parameters

4.14  $\zeta$  and  $i_p$  are *control parameters* (already presented above in Section 4.7). They are not constant and may vary with time in a certain range, fixed by the participants of the negotiation.

- $\zeta$  represents the proportion of the park that is open to tourism;
- $i_p$  corresponds to the proportion of turtles accidentally killed by fishing.

It can be modified by varying the minimum mesh size of fishing nets, a regulation policy on fishing activity.

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<sup>5</sup>In the actual case of the Arraial do Cabo marine reserve, tourists also come to see dolphins, a sea cave, islands, beaches, etc. Source of income for the fishermen is actually twofold: 1) an individual sum for boat renting and trip; 2) a collective entry value to the marina (departure of boats), paid to the fishermen cooperative.



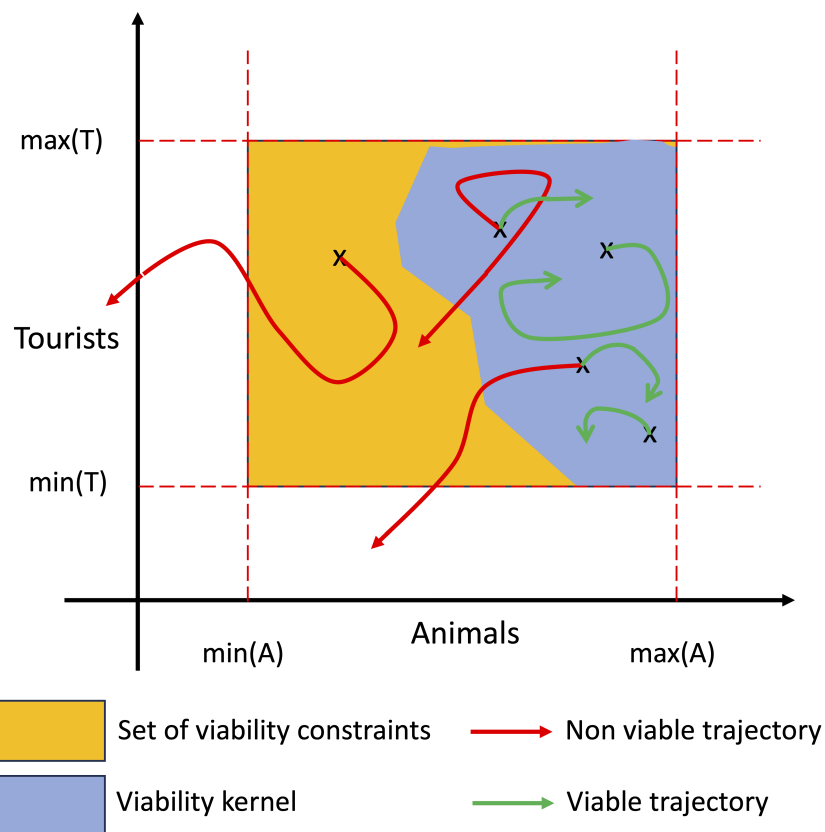


Figure 5: Viability kernel

## ● Viability Analysis

- 5.1** One of the interesting concepts of *viability theory*, by Aubin (1991), is the concept of *viability kernel*. It is defined as the set of *states* of the system for which there exists (*at least*) one control function which maintains the variables of the system within the limits of viability constraints, i.e. permanently in a state desirable for a given player. An example of viability kernel is illustrated in Figure 5, for a model reduced to 2 variables (for reasons of readability) and with one control parameter representing the proportion of turtle living areas made accessible to tourists.
- 5.2** Algorithms allow the calculation of an approximation of the viability kernel<sup>6</sup> and thus to evaluate the consistency of the objectives of a stakeholder, i.e. the compatibility of the viability constraints (constraints on variables) aimed by the player with his means of action (control function). If the viability kernel is empty, this means that the objectives are not viable, i.e. that there will be a loss (even transient) of ecological, economic, and/or social viability, depending on the nature of the variables concerned.
- 5.3** Our motivations for using viability theory, used successfully for various cases of natural resource management, see, e.g., (Martin 2004), are as follows:
- It does not presuppose a *hierarchy of criteria*, unlike the case of a direct optimization approach;
  - It works with an *infinite horizon*, and thus allows intergenerational equity, unlike a simulation which has a limited horizon;
  - It guarantees *completeness*, unlike a stochastic simulation, for which certain configurations and effects may not be covered, even through a good design of (sequence of) experiments;

<sup>6</sup>The first and main algorithm is presented in Saint-Pierre (1994), with proof of convergence. See Alvarez et al. (2016) for a short review, Krawczyk & Pharo (2019) for the Vikaasa Matlab library, and Désilles (2020) for the optimized ViabLab library, used in particular by Durand et al. (2017). Note that Vikaasa and ViabLab also compute viable trajectories (with viable controls to keep the trajectory in the viability kernel). ViabLab computes viable trajectories following some simple strategy (constant control unless change is necessary).

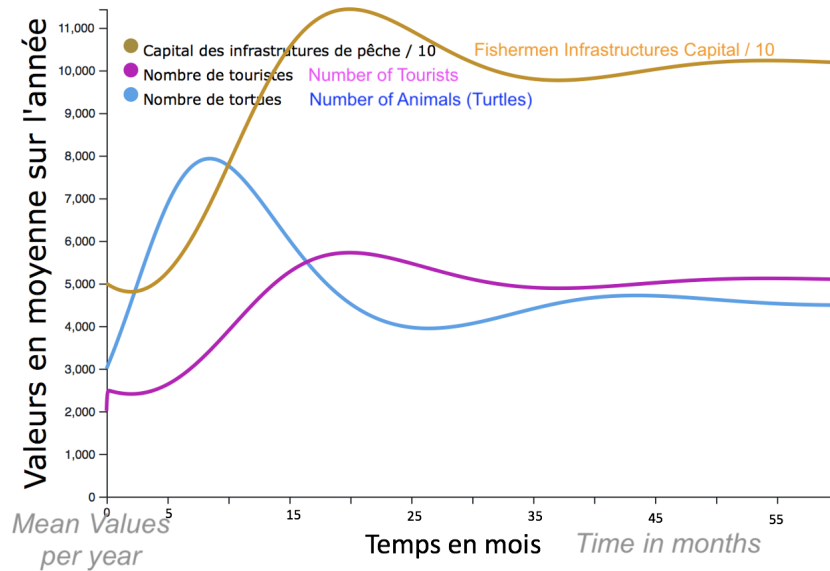


Figure 6: Analysis of a specific model (Assistant Interface – *Translations added*)

- It does not presuppose a *prior consensus* of social actors on a *choice of model*, thanks to recent results in terms of *guaranteed viability* for a multi-model case (see Section 7.6);
- It allows a straightforward and usable definition of the important notion of *resilience*<sup>7</sup>.

## ● Viability-Analysis Assistant

6.1 We have designed and built a *viability analysis assistant* model (Zaleski et al. 2019), with two modes of use.

### Model Analysis and Configuration

6.2 At first, the viability analysis assistant can help the player at analyzing the dynamics of the model and at configuring it, i.e., selecting the values of the parameters of the model<sup>8</sup> and analyzing the related dynamics, as shown in Figure 6.

### Individual Decision Support

6.3 The first type of assistance is to help the player analyze whether his objectives are viable, i.e. viability constraints are compatible with his means, the controls on the model and its dynamics. The assistant then suggests launching a validity kernel computation.

### Non-Empty Kernel

6.4 If the kernel is non-empty, this means that the objectives of the player are fulfilled: the viability constraints can always be enforced. The player can then move onto the next step, although he can conduct additional analyzes using the assistant, for instance:

<sup>7</sup>In ecology, *resilience* is usually defined as the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and subsequently recovering. Within the viability framework, the resilience to a perturbation (defined as a jump from state  $x$  to a possible set of states  $Y$ ) is defined from the point of view of the inverse of the cost of restoration to  $t$ , that is the cost along a trajectory returning to the viability kernel: when a trajectory reaches the viability kernel with infinite cost (e.g. does not reach it in finite time), its resilience has a value of zero. More formally, the resilience at state  $x$  to a jump to  $Y$  is defined as the maximum for  $y \in Y$  of the minimum of the cost of restauration over all trajectories starting at  $y$  (Martin 2004).

<sup>8</sup>We will see in Section 7.6 that each player can have a specific model.

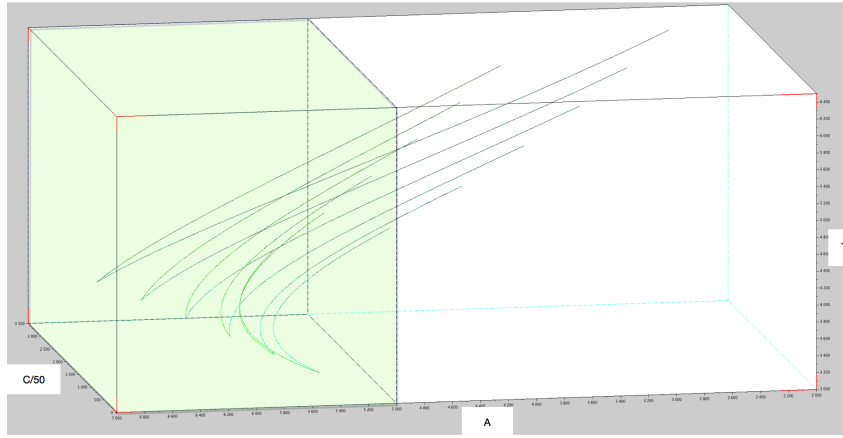


Figure 7: Analysis of trajectories (all non viable) for an empty kernel (Assistant Interface)

- To illustrate the relations between the kernel and the dynamic, the assistant may show to the user some dynamic trajectories that are viable;
- The assistant may check the *sensitivity* of the kernel to some modifications (of objectives and/or of control), as a way to anticipate possible future room for negotiation;
- The assistant may check the *proximity* to the kernel boundary. Because, once the state of the system arrives near the kernel's boundary, it is more difficult to control if the viability problem leads to a satisfying kernel.

In order to verify that, it is possible to *erode* the kernel, by removing states near the boundary and calculate the new kernel corresponding to the eroded kernel as a new constraint set (Alvarez et al. 2016). If the new kernel's shape is close to the previous one, it means that the controls specified are versatile enough for the dynamics' trajectory to avoid the boundary. On the other hand, if the eroded kernel is way smaller than the original one, the system is likely to go near the original kernel.

### Empty Kernel

- 6.5** If the kernel is empty, this means that the player's objectives are not compatible with the dynamics.
- 6.6** The assistant then can help the player at analyzing the situation, i.e., how trajectories exit from the constraints, see an example in Figure 7, and at suggesting him to *relax* some of its objectives (constraints on variables and/or controls) in order to obtain a non-empty kernel (using exploration strategies and/or anticipated kernel calculations).
- 6.7** In order to manage a search space within a reasonable time (for the player), the assistant asks the player what are its most important (priority) objectives. A dichotomic search with privileged directions is then computed, in order to approximate the Pareto front corresponding to a minimization of the relaxation. The space exploration by dichotomy uses a property specific to hyper-rectangle constraint sets (and the monotony of the viable property with respect to inclusion: problems with larger constraints sets than a viable problem are viable). The difference between the desired and tolerated threshold values can be used as a normalization factor between directions. For details, please see (Zaleski 2020, pages 87–89).

### Negotiation Support

- 6.8** The second type of assistance is to help several players (two or more) *negotiate* with each other to make their wishes compatible. The assistants interact with each other and first ask the players to check if their respective viability kernels are compatible, i.e. their respective viability kernels have a non-empty intersection (see an example in Figure 8). In this case, they calculate the viability kernel for the corresponding *intersection of viability constraints*.
- 6.9** In the case where this intersection is non-empty, a *consensual solution* may be possible (see Section 7.9). Otherwise, the assistants first offer suggestions on which players should relax their constraints first, and as in the

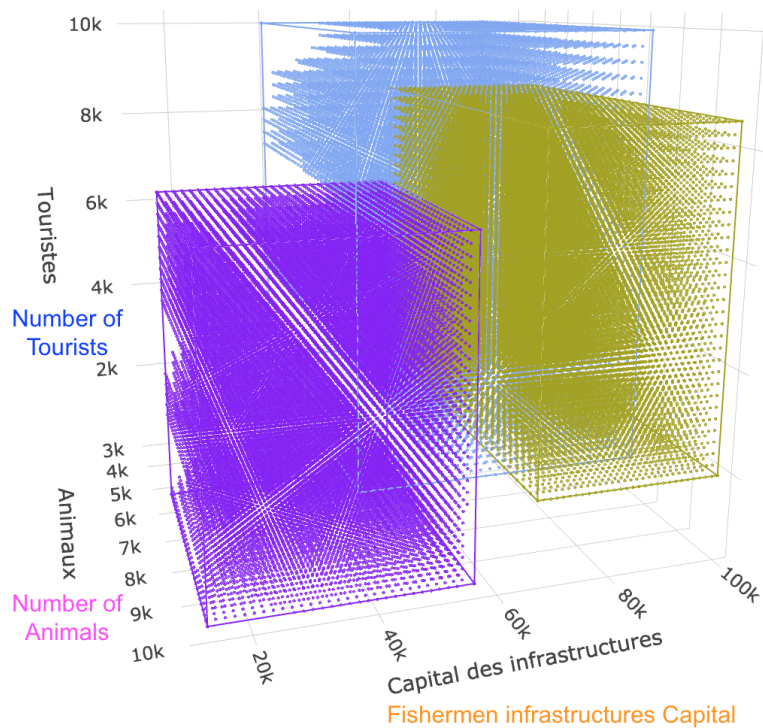


Figure 8: Comparison and intersection of viability kernels (Assistant Interface – *Translations added*)

individual case described in 6.4, it uses priorities among objectives as specified by the player. In addition, the assistants' strategies take into account *fairness* in the level of *efforts* made by the players. Efforts depends on the size of the tolerated area. We considered two types of fairness: individual fairness, for which the same level of effort is demanded to each player; group fairness, for which players with interest in minimal and maximal bounds are separated in two groups. The same sum of level of effort is demanded to each group at each step. For details, please see (Zaleski 2020, pages 190–112).

## ● Discussion

### Evaluation of the Assistant

- 7.1 We have tested this scenario with the game server prototype and the viability analysis assistant model with participants (all with at least graduated level, for the majority in engineering or life sciences) for a series of game sessions. In practice, we have developed an evaluation and cross-comparison protocol with or without viability analysis assistants<sup>9</sup>, with questionnaires completed by the participants, to be able to estimate their contribution to the understanding and success of negotiations.
- 7.2 Quantitative statistical analyzes (Wilcoxon-Mann-Whitney and Fisher tests) show a significantly better evaluation when using the viability analysis assistants. The qualitative analysis is also generally positive: players are generally satisfied with their experience and have the feeling of having understood the challenges of managing protected areas.

<sup>9</sup>In practice, we have a simplified version of the assistant without any viability analysis capability. To minimize bias (as players would have to evaluate the same scenario with two successive versions of the assistant), we propose two different scenarios: the marine reserve scenario and also an agro-tourism scenario (with three variables: quality of environment; number of tourists; and the capital of the agriculture cooperative). See details in (Zaleski 2020).

- 7.3 Finally, the results at the end of negotiations with assistants are considered more equitable, which is very encouraging.
- 7.4 On the other hand, two current disadvantages are mentioned: 1) the lack of interaction of the player in relation to the quantity of information that he receives, even if the exchanges between participants punctuate the progression; and 2) the mathematical complexity of the model. Improvements planned in terms of ergonomics should be able to minimize these disadvantages. For more details, please see (Zaleski 2020).

## Modeling

- 7.5 An obvious limitation of our approach is that we need some formal aggregated model. This may be more demanding than multi-agent models. In practice, we construct the model based on some inspiration and modification of existing models, for instance, the number of animals follow a Verhulst law (Schtickzelle 1981) and the tourism model of Wei et al. (2013) for the evolution of the number of tourists. We set up some parameters and their values on actual data from the Arraial do Cabo reserve or some data and/or models from the literature. Remember that, here, we focus on the decision and negotiation process and not on an actual specific situation. Thus, the model needs to be plausible but does not have to be completely realistic.

## Multi-Model

- 7.6 As opposed to the MAS/RPG methodology, we do not have to presuppose a prior consensus between stakeholders on a choice of model. Indeed, the ComMod approach (Étienne 2014) has shown that modeling the evolution of the system at stake is difficult and hardly consensual, since scientific or technical viewpoints can be considered by stakeholders as viewpoints among others.
- 7.7 The idea of our approach is to consider the variability of models as perturbations of each individual model. We then consider the *guaranteed viability kernel*, subset of the set of desirable states where it is possible to maintain the state of the commons even when its evolution is represented by several conflicting models, see details in (Alvarez et al. 2023).
- 7.8 The only assumption is that all models share a same subset of variables that are considered for the viability analysis. In other words, this is not limited to the case of a single model with different values of the parameters.
- 7.9 The assistant only verifies that the intersection of the different players' viability kernel is not empty. This is a necessary condition to a consensus solution. But it is not sufficient. The single guaranteed viability kernel associated with the many players' viability problems is an efficient answer to this problem. See an example of a guaranteed kernel in Figure 9, and more details in Alvarez et al. (2023) and Zaleski (2020).

## Scalability

- 7.10 An aggregated model of the dynamics of the resources of the protected area does not intend to be complete nor realistic (remember that this is a fictional scenario with an epistemic objective). In practice, the model is usually restricted to the issues and conflicts (set of variables and actions/controls) that the participatory process will focus on at some moment.
- 7.11 Some issue is that the computation of the viability kernel is intensive and depends on the number of variables. However, it remains useable: in the scenario illustrated here with 3 variables, computing a viability kernel takes about 15 seconds, which is acceptable for a human interaction with the assistant agent.<sup>10</sup> Note that recent results allow using a modular decomposition of the system modeled (a gain in terms of modeling and understanding) which provides a very significantly reduced computation time (de Lapparent et al. 2024).

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<sup>10</sup>General approximation algorithms with proof of convergence based on Saint-Pierre (1994) discretize the state space on a regular grid. Computation time is exponential with the dimension of the state space.

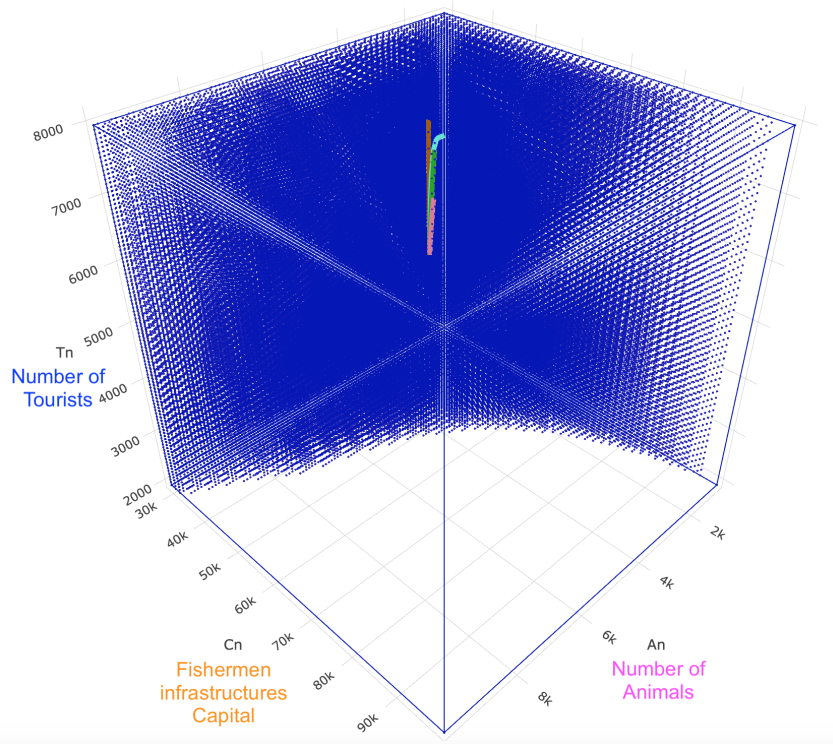


Figure 9: Approximation of the guaranteed viability kernel (in blue): a common control keeps the evolution viable for four role-players at initial time and state, although the four trajectories (in different colors) are different for each model

## ● Other Assistants and Agents and Future Prospects

### 8.1 We have built and tested other assistants and agents<sup>11</sup>:

- an *artificial manager agent* proposing and capable of defending (through an argumentation process<sup>12</sup>) its decisions, based on an internal *argumentation* reasoning process to make a decision and a *social choice* algorithm to combine with the players votes (Sordoni et al. 2010);
- an *assistant agent for decision analysis* (proximities of choices, relationships dominance...), based on decision theory;
- a *mediation agent* to propose compromises and their argumentation, based on social choice theory and argumentation (in order to be able to both argue his suggestions and to detect and undercut false or cyclic arguments from players) (Gargouri 2017).

**8.2** The idea is indeed to offer a variety of assistant agents, offering complementary points of view and objectives (viability analysis, decision, negotiation, etc., see Figure 10), each of which can offer personalized help to each player<sup>13</sup>, while coordinating between them, for stages such as negotiation.

**8.3** *Artificial agents* are also proposed, either as substitutes to human players, as in (Sordoni et al. 2010) or also, e.g., by colleagues in (Adamatti et al. 2009), the main motivations being: 1) to be able to play a game, even without enough human players; 2) to control a game, though the control of the behaviors of the artificial players.

<sup>11</sup>Note that they have been developed and tested with another game scenario (and game server). Actually, our overall project, named SimParc (SimParc 2024), stands for “Simulation of participatory management of parks and other protected areas”, had as its first scenario a scenario inspired by Brazilian national parks, with a collective process of decision about the levels of conservation to be decided for each part of the park (Briot et al. 2017).

<sup>12</sup>Argumentation is a reasoning framework based on logic (non monotonic logic), where arguments are logical formula which may be refuted or undercut by other arguments, see seminal paper (Dung 1995).

<sup>13</sup>Unlike centralized technical assistance (for all players), as is for example the case for a multi-agent simulation completing the role-playing game in the ComMod methodology (ComMod 2024).



Figure 10: RPG + Assistant Agents

## Conclusion

- 9.1 We hope, through this text, to have been able to present our alternative and complementary proposal, relative to the ComMod MAS/RPG methodology for helping at participatory management of eco-socio-systems, as well as its experience and its results.
- 9.2 The different test sessions with different types of users, experts or not, showed the benefits of our methodology and of the associated artificial assistants and agents to help players at deciding and negotiating. We wish to explore its use for training protected area managers.
- 9.3 Furthermore, although the project is centered on the participatory management of protected spaces, we can see that the objective is in fact broader, conflicts over the use of shared renewable resources, like the problem of the Tragedy of the commons (Hardin 1968).
- 9.4 We hope that our experience can thus serve as inspiration for other projects in terms of IT support for the management of shared resources and the resolution of usage conflicts.

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