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Combining various time scales through joint use of Agent Based Model and Role Playing Game: the PIEPLUE river basin management game

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This paper presents a specific association of a Role Playing Game and an Agent Based Model aimed at dealing with a large range of time scales. Applications to the wide field of natural resources management lead one to consider the short time scale of resource use in practice at the same time as the longer ones related to resource dynamics or actors' investments for natural resource uses. In their daily practice, stakeholders are translating their long term strategies, a translation which is contextualized and combined with some co-occurring events. Motivating people to think about long term issues is required for sustainable use of natural resources. This long term thinking should then take into account its necessary adaptation on a short time scale, which may induce as feedback some revision of the long term strategy. This raises the necessity for tools able to tackle these various time scales and connect them in both ways. Similarity of architecture between computerized Agent Based Models and Role Playing Games makes them easy to associate in a hybrid tool, making it a good candidate for meeting this requirement. The proposition of this paper dealing with this issue of time scale diversity is to allocate the representation of short time scales to computerized ABM and the long ones to RPG, while keeping the same static structural conceptual model, shared as a common root by both. This synergy is tested and illustrated with an example for a case study of water sharing in the south of France. The tool developed, PIEPLUE, proposes an interactive setting dealing with time steps from day to year and was designed with a dialogue support purpose.

KEYWORDS: agent-based model • case study of water sharing • conceptual model • hybrid tool • investments • long-term issues • natural resource management • PIEPLUE • participatory modeling • resource dynamics • resource use • role-playing game • stakeholders • sustainable use of natural resources • time-scale diversity • variable time scales • water management

Dialogue support for territory planning or natural resources management is increasingly using simulations with Agent Based Models (ABM) or Role Playing Games (RPG) or both categories of tools jointly (Barreteau, Bousquet, & Attonaty, 2001; Bousquet et al., 2002; Etienne, Le Page, & Cohen, 2003; Mayer & Veeneman, 2002; Meadows, 2001; Pereira et al., 2003; Piveteau, 1995). These tools provide the means for simulations, which are supposed to offer thought support to participants for their real

systems, within a safe and creativity-enhancing environment (Duke & Geurts, 2004). Participants are expected to learn some lessons applicable to real systems, based upon what is happening during a simulation. Used by themselves, these tools are either too cumbersome to design or difficult to communicate (Barreteau, 2003). Computer based tools are also more efficient in simulating natural resource dynamics, especially when short time scales are concerned.

In this communication, we are proposing a fully integrated hybrid approach, based on a joint use of an RPG and a (computerized) ABM, to take advantage of their complementarities. This proposition, built upon several experiences of joint uses of ABM and RPG, is characterized by an allocation of short time scales to computerized ABM and longer ones to RPG, with a shared conceptual model for both leading to the hybridization. The proposition is illustrated in a specific case study concerning irrigation management in the south of France, which shows the feasibility of this approach.

Joint use of Agent Based Modeling and Role Playing Games

ABM and RPG have both been developed with group decision or dialogue concerns in separate trends (Barreteau, 2003). RPG, including notably policy exercises, are historically the first ones. They have been used to understand or support these collective decision processes as well as to train stakeholders involved in them. From an analysis viewpoint, they make misunderstandings among stakeholders become explicit, by splitting the decision process among several decision centers (Schelling, 1961). They constitute tools rather close to the experiments economists perform, but within more open and interactive settings. They are very good tools to empower stakeholders in the decision processes and to facilitate sharing of information (Barreteau, 2003; Tsuchiya, 1998). However they are rather labor-intensive to design and repetitions of experiments with a control of parameters are at the least difficult (Piveteau, 1995).

More recently ABM have been used to simulate complex systems, with the idea of using them not only to represent collective decision processes, but also to support them. This second standpoint aims at broadening the field of information available to the participants (Benbasat & Lim, 2000): providing stakeholders with the potential consequences of various choices involved in an on-going group decision process reportedly mobilizes them more actively in the process (Driessen, Glasbergen, & Verdaas, 2001). Here the objective of the ABM is to represent the stakes at the center of the collective decision process so as to lead stakeholders to better formulate the problems or to give them a tool to share viewpoints. However as they are usually embedded within a computer tool, ABM might be perceived by stakeholders as black boxes, which raises the issue of their legitimacy and acceptability.

Use of computer tools to support the implementation of an RPG is now common. This support relies on the complementarities between both: computer based simulation to

represent the dynamics of a resource and RPG to represent the dynamics of actors' interactions. The FISHBANKS game in the early seventies was already implementing such joint use of computer and gaming simulation. In other settings, simulations provide conditions of the world intended to make players in the game think about them. A traffic simulator, for example, was developed to provide insights to decision makers when designing new road development schemes (Duijn, Immers, Waaldijk, & Stoelhorst, 2003).

Agent Based Models are more specifically considered here as computer tools. Formally ABM and RPG have the same architecture: autonomous entities situated in an environment and interacting dynamically, with more or less developed cognitive capacities. This can help to overcome limits of both tools when taken individually:

- RPG might be used as a translation of an ABM more explicit to stakeholders,
- ABM can be used to repeat and simulate game sessions (Barreteau et al., 2001).

This has led to a large series of joint uses of ABM and RPG in recent years (Boissau & Castella, 2003; D'aquino, Le Page, Bousquet, & Bah, 2003; Etienne, 2003; Etienne et al., 2003; Hare & Pahl-Wostl, 2003). Most of them use a companion modeling approach [1] (Bousquet et al., 2002; Bousquet, Barreteau, Le Page, Mullon, & Weber, 1999) which is aimed at involving more stakeholders in the modeling process itself.

Several categories of joint uses might be identified, according to the relationships between conceptual models on one hand and to the organization of joint use on the other hand. The synergy among both tools may provide either mutual support in use or in design and assessment of each of them. Mutual support in use is reached when both tools are used in parallel, are specialized and exchange pieces of information between them. Mutual support in design and assessment is reached when both tools share the same conceptual model and are used sequentially (Barreteau, 2003). The two main advantages of using ABM rather than any other kind of modeling used jointly with RPG are the possibility of implementing the same conceptual model in various formats, and the potential for continuity among entities in RPG and ABM.

RPG and ABM, employed jointly or not, are used for renewable resources management issues because of their ability for representing dynamics of complex systems, with a special focus on interactions. In these cases RPG are always associated with at least a simple model to represent the dynamics of the resource, be it a physical model (Lankford & Sokile, 2003), paper or computer models. In the field of irrigation management, several RPG have been developed to train people appointed to manage these complex issues (Burton, 1994; Smith, 1989; Steenhuis, Oaks, Johnson, Sikkens, & E.J., 1989).

Issue of time representation for NRM issues

Using an RPG as the main medium in interactive settings for dialogue support necessitates fitting two kinds of practical time constraints: total duration of a game session and number of repetitive tasks. The NRM field of application brings a third constraint: the diversity of relevant time scales for any management issue.

Time scales at stake with NRM issues

There are basically at least four time scales to be considered:

- *operation time scale* deals with the practices of resource use, which are typically at the day time scale or even shorter;
- *strategy time scale* deals with the design of strategies guiding these practices, which are usually seasonally based. These strategies constitute the basis for the determination of choices at the operation time scale level;
- *constitution time scale* deals with investments or collective rule design, which have a longer characteristic time of a few years. This is the time of the constitutional choices which frame the design of strategies at the strategy time scale level;
- *resource time scale* deals with resource dynamics, which is not hierarchically linked to others but, for some resources like forestry, might even reach several dozens of years.

Maximum duration of interactive exercises

Collective participatory decision processes are rather new and involve people not used to spending time for that purpose. These people have other activities, which most often have priority over the participation in collective decision processes. Therefore the time they can allocate to an interactive session is limited. Three hours is a typical maximum duration for the case studies we are working with. This constraint might raise difficulties when issues to be dealt with involve actions and decisions at various time scales, with cumulative, delay or threshold effects occurring. Complex systems involved in NRM issues usually address some if not all of these effects.

This maximum duration is a side effect of one of the key features making RPG good tools to support dialogue among stakeholders: time concentration leads them to share information through their gathering in the same place at the same time, which hardly ever happens in real systems. For example the NJOOBARI ILNOOWO game (Barreteau et al., 2001) reduces real life from hectares to two rooms and a few cropping seasons to a few hours. Players are thus able to understand that all of them as farmers share the same constraints in real irrigated systems, which they have no opportunity to discuss within these real irrigated systems. By implementing such time concentration, game designers should be wary not to induce repetitive boring tasks for players. For dialogue support purposes, models are used to simulate the dynamics of the actors' interactions with the stakes in the negotiation. As far as water sharing is concerned for example, models used as dialogue support tools will simulate the interactions of users

with water, such as their pumping or cropping activities. This may involve simulation of collective or individual decision processes and actions at a different time scale than the one concerned in the dialogue process: a model designed to support a collective decision process involving a constitutional time scale will simulate decision processes and actions as regards the strategic or operational time scales. If these operational time scale actions are repeated too many times in an RPG, this may lead to making the whole interactive setting boring, losing the gaming atmosphere, and not focusing on the objective of natural resources management rule design level.

Giving up realism of time representation

A means of overcoming this issue in the gaming atmosphere as well as keeping it within duration constraints is to abandon a representation of time with any realistic relation to real time steps such as in the Njoobari Ilnoowo game. In this game, one time step does not represent a specific period of time. It is defined as the time on which players base their decision whether or not to go to their field and, if they go, whether they will open or close the irrigation inlet of their field. It is calibrated so that: (i) a cropping season is subdivided into the least number of time steps, and (ii) farmers need to irrigate their field at least twice, and competition over water might take place among farmers with various personal constraints. There are thus eight time steps to represent a cropping season, usually lasting a hundred days or some 10 irrigation rotations at the canal level when such rotation is organized. None of these time characteristics of irrigation systems' activity are represented by the game time step.

Such choice of representation of time makes the calibration of the game tricky and dependent upon the focus expected for the discussion. The positive aspect of this option is that, since the model is being implemented only through the game, its assumptions are openly presented. The negative aspect of this option is that only one time scale is represented, the time scale of the main process supposed to be relevant for the stake under discussion. In the example above, stake is the sustainability of irrigated system and cropping seasons are supposed to be the key process, without any possibility of modifying it.

Towards hybrid tools

A second way to overcome these issues of time representation is to go through the use of a computer tool, for a more detailed and repetitive but more representative choice of time steps. This comes in the continuation of using a computer tool to simulate natural resource dynamics according to actions of players: computer simulation provides inputs in a game for something that is not playable, due to computation intensity, duration or redundancy. Such integration of a computer tool within a game setting had already been developed with that purpose in the seventies with games such as FISHBANKS. Here we are going further in the integration with computer tools simulating actions of players, in order to increase the quantity or diversity of actions which might be simulated.

We consider creating a hybrid tool, as soon as it is made of computer agents and players either interacting in the same setting or representing the very same actor. This means continuity between the virtual world of the computer simulation and the virtual world of the game. Either the world simulated or the agents themselves is shared.

Interactions between real and virtual players are implemented, for example, in ATOLLGAME (Dray, Perez, Le Page, d'Aquino, & White, 2006), making it possible to overcome the concern about size limitation of a game in terms of number of players with direct interactions, since some players are replicated either through replication of real players' choices or through simulation based on behavioral assumptions. This does not address the time issue however.

This issue can be addressed through sharing of agents between computed and played worlds. It can be done either by playing one step out of 5 and computing others as in the MejanJeu (Etienne et al., 2003) (increasing number of actions), or by separating time scales to be computed from those to be played as in the experiment reported in this paper (increasing diversity of behavioral patterns). In both options, players have their computer avatar, as a continuity of themselves inside the machine, even though in the first one it remains mainly implicit.

The MEJANJEU game is an example of the first option. The basic time step of action considered for the dynamics of pine tree invasion on the Causse Méjan is the year, and the horizon of the simulation so that all phenomena to be discussed appear is several tens of years. Year has however been chosen as the basic time step of the model, with players acting one simulated year out of five, and their computer avatar acting with the same behavioral pattern for the four following years. This option helps in exploring a longer time scale and thus possible cumulative effects. It focuses on micro-processes which are supposed to pave the way for the apparition of the issue at stake. There is no structuring of the relation between both time scales. Thus, this option does not pave the way to implementing a diversity of time scales, which is important when some time scales are controlled by decisions at other time scales or when feedbacks of actions might span time scales.

In the second option, which is proposed in this paper and implemented in the example described in section 3, the ABM is considered as the extension of players at shorter time scales. Longer time scales are simulated through the game, providing patterns of individual actions which are simulated all together at shorter time scales. Each player is represented by one agent whose behavioral pattern is determined by the player's choices. This makes full use of the similarity of agent and player in ABM and RPG. Both RPG and ABM have the same static conceptual models but differ in the dynamics represented. This option of hybridization goes one step further: making explicit the behavioral choices of players instead of staying at the level of action.

This second option provides the opportunity to deal with three categories of time scales, crossing the perspective of the both real world and the simulation world :

- Systematic actions at operational time scale are simulated by computer tool,
- Choices at strategic time scale are simulated by the RPG,
- The RPG implications and the topic of the discussions it should generate concern the constitutional time scale.

Below we explore this second option of separating the representation of time scales between a computer tool and a gaming tool, through a specific case study dealing with irrigation in the south of France. In the following sections, we will specify any computer implementation of a conceptual ABM as a computerized ABM (CABM), in order to distinguish them from role playing games which might be other implementations of conceptual ABMs.

Pieplue: a hybrid tool associating an RPG and a CABM

The Drôme River Valley Case Study

A SAGE ('Schéma d'Aménagement et de Gestion des Eaux' = local water management plan) was signed for the Drôme River Valley (a major tributary of the Rhone River in southeastern France) at the end of 1997 by the Prefect (State representative), building upon an agreement between representatives of local elected bodies, water users' representatives, and state representatives. These representatives make up a CLE ('Commission Locale de l'Eau' = local water committee), in charge of implementing this plan. The SAGE addresses, among others, the issue of minimum flows to be observed in downstream areas. The main quantitative use of water in the basin is irrigation, which is even more dominant in the downstream part. The SAGE, building upon a dialogue process among all stakeholders' representatives, features a minimum threshold for downstream flow of 2.4 m3/s all year long.

Farmers are the major consumers of water for irrigation, mainly for maize or tomato fields: irrigation is the main reason for water pumping, with 80% of the irrigated fields (3000 ha) on the downstream part of the river. The total pumping capacity for the downstream part is 2 m3/s. Farmers are partially organized within three irrigation systems managed by users' associations: three-quarters of the irrigated area falls within one of these three irrigation systems, and 85% of farmers belong to at least one of the three associations. The remaining irrigated areas are served by wells in the alluvial aquifer. The whole context is evolving with:

- the occurrence of droughts, causing individual expectations for critically dry years to evolve,
- political stakes, such as local elections, which cause new scenarios to appear and others to become taboo,
- national and European pricing/ agricultural subsidizing policy, which cause specific crops demanding more or less on water to become more or less attractive.

We have been involved in facilitating dialogue in the farming sector regarding how to reach the SAGE objective through a collective mastering of irrigation uptakes. A spreadsheet model of water balance had been used for that purpose. A set of collective rules was agreed upon in early 2003 (Barreteau, Garin, Dumontier, Abrami, & Cernesson, 2003). It is based on the allocation of water among farmers through an organized limitation of uptakes in case of excessively low water at the downstream of the river,

together with the use of complementary resources coming from outside of the river basin. They have not been implemented yet for two reasons: the exceptional drought of 2003 (the water flow at the upstream part of the irrigated area was naturally below the minimum level for most of the normal irrigation season), the completion of the works necessary to make the complementary resource available only at the end of 2005.

Another concern with this spreadsheet model used to facilitate the emergence of the first agreement was its focusing the discussions on the water flows, which were available either for various farmers, or for the river. No issue of cropping pattern can come up through it, and thus no discussions of uses of water were invited around the table.

The RPG and CABM presented below aim to provide jointly an interactive setting for possible revisions of the agreement among farmers in the future. These potential revisions will have to comply with the overarching constraint of the minimum flow defined in the SAGE. From the farming sector point of view, the relevant time scales are (i) the constitutional choices of rules to share water among irrigating farmers, and (ii) the strategy definition of water uses by farmers. An objective of this new tool is to make the collective discussion of cropping pattern choices possible.

Co-ordination of RPG and CABM

Dealing with dialogue support for collective decision-making processes on irrigation management issues raised the need to tackle a wide range of time scales:

- day when water level in the river is observed and practical decisions for cropping and irrigating are made,
- week for an intra-farm irrigation pattern: fields are irrigated one after the other according to a regular rotation, which involves moving some irrigation facilities It might include some additional day(s) possibly used to irrigate a field which seems to be stressed,
- month for adaptation of the irrigation pattern throughout the season according to the evolution of crop needs,
- year for collective rules and cropping patterns to evolve,
- years when irrigation investments are made or contracts are signed for specific crops such as seed maize.

The interactive setting presented here, named PIEPLUE, is a highly integrated CABM and RPG, through the continuity from agents to players. PIEPLUE is able to deal with the time scales above (1) to (4):

- a short-term, operational, time scale, to take care of time scales (1) and (2). This is the time for the farmer to choose the plot to irrigate, which means implementing his weekly intra-farm irrigation pattern,
- a medium-term, strategic, time scale corresponding to time scale (3) above, i.e. the evolution of priorities among crops, for the farmers to update their irrigation patterns,

- a long-term, constitutional, time scale, corresponding to time scale (4) above, for cropping pattern choices and collective discussion on rules to share water.

The short term time scale is simulated by the CABM according to the choices made at the other two time scales. At the medium time scale, players choose their irrigation pattern, which is implemented at the short time scale. The medium and long-term time scales are simulated through the RPG and benefit from the simulation results of the first one.

The RPG constitutes the basis for the interactive setting. As for many games using computer tools, the CABM is embedded in the RPG. All players take on roles of farmers and are randomly assigned an objective for managing their farm from the set {maximum income; water access security; minimum debts; low workload}. This set had been elicited from interviews of farmers of the valley (Zanker, 1999). Two game facilitators are required, one for the gaming part and one to use the CABM. It builds upon a sequence of several stages:

1. an initialization stage, with the assignment of roles and farm characteristics to players ,
2. a cropping season starting stage with a choice of cropping patterns by players,
3. a month time step, with a choice of irrigation patterns by players (four times),
4. a cropping season end stage with the allocation of cropping season results and a discussion of the collective rules.

In the initialization stage, players are each allocated six fields that are characterized by a soil water capacity (superficial, medium or deep) and two water supply facilities that are characterized by a location (an individual well or an outlet on a collective irrigation network) and a capacity. These allocations are assigned randomly by the computer to each player individually. The computer keeps these allocations as an initialization of the structure of the CABM: it sets the players' avatars with the same characteristics as the players. Player also receives objectives to help in assuming their roles. The basic setting involves two collective irrigation networks, one with a pumping station at the upstream part of the irrigated area and the other at the downstream part. It might be reduced to only one if too few players are available. The collective irrigation networks are initiated with the choice of a president among players holding an outlet in it. This president is in charge of the definition of water pricing for outlet holders.

During the cropping season starting stage, players choose their cropping pattern based on a choice of a crop for each field from the following set {wheat, maize, tomato, garlic}, which are the most common crops in the area. Choices of each player are taken as inputs for the CABM. Maize and tomato are those receiving the most irrigation water at low water season, while wheat and garlic do so earlier in the season. Players are supposed to know the characteristics of each crop, which is nevertheless explained to them, together with the market assumption of the model: costs of production by hectare and selling values by tons. These are supposed to be fixed for the whole simulation and to be independent of players' cropping choices.

They then choose an irrigation pattern for each month time step. This step is repeated four times as an irrigation season lasts four months in the area (June, July, August and September). For each time step, players fill in a form specifying a weekly irrigation pattern for their two water sources as shown in table 1. These forms are then entered as parameters for the CABM by a game facilitator on specific computer interfaces. With these inputs, each month is simulated independently at the day time step with the CABM.

	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6
Monday						
Tuesday						
Wednesday						
Thursday						
Friday						
Saturday						
Sunday						

TABLE 1: table to be filled in by each player at each month time step for each water source

To base their choice, players receive private and public information about the evolution of the environment (the river and their farm) along the previous monthly time step, which they might try to link with their own practices. They also have permanent information on the way they are affected by collective rules in the case of water shortages: the game is initialized with the current rules in the Drôme River Valley, implementing days when irrigation is forbidden for private wells, the ratio of decreasing water uptakes for collective networks.

Private information systematically concerns the evolution of the condition of the crops according to soil-water availability as shown in figure 3. It is printed out and given privately to players for their own fields. Other private information is available and provided to players on request: water consumption for each of their water sources by day, irrigation amount by field and by day.

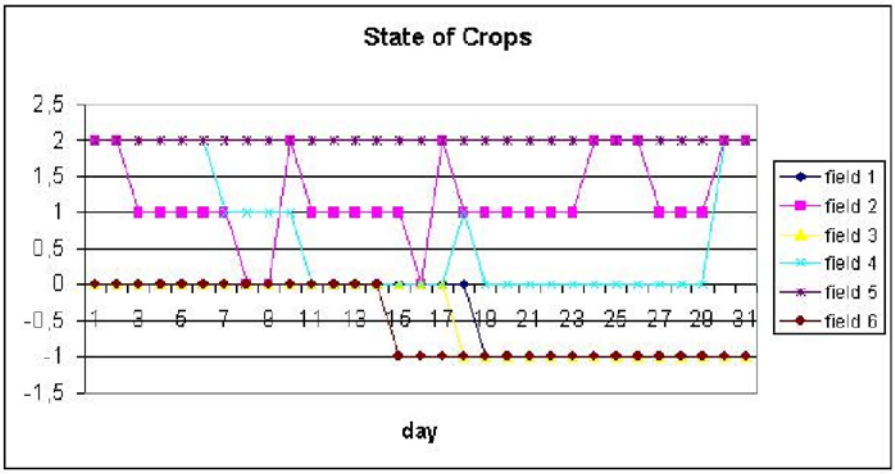

FIGURE 1: evolution of state of crops during a month for all fields of a player (2 stands for "good", 1 stands for "thirsty", 0 stands for "very thirsty", - 1 stands for the absence of crop usually due to harvest already passed).

Public information is displayed directly from the computer. It concerns notably the series of downstream flows which appears on a computer interface as presented in Figure 4 and is projected systematically. Other indicators are computed and might be projected on request of players: climatic data on the previous month (rain and Potential Evapo-Transpiration), the evolution of crisis levels, upstream flow.

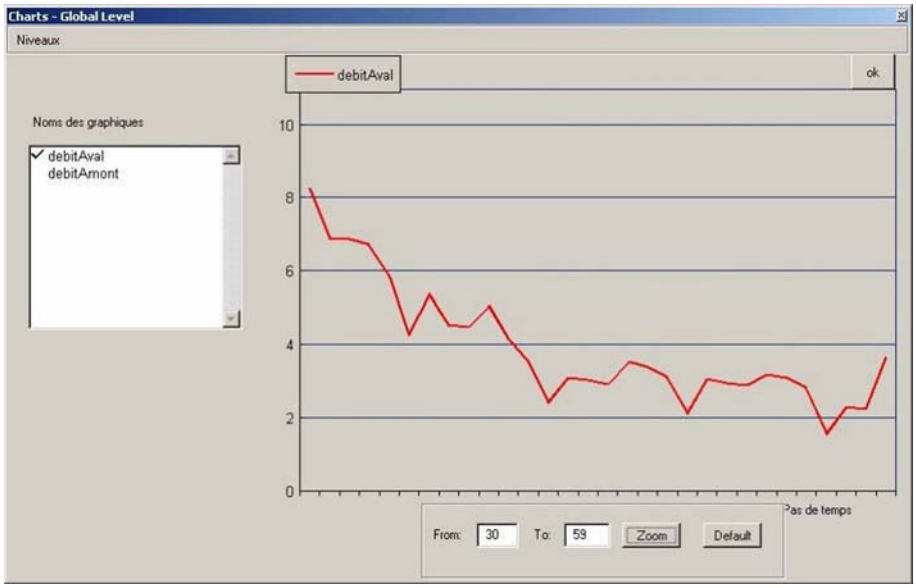

FIGURE 2: evolution of downstream flow during a month time step. Y-axis is downstream flow in m^3/s, X-axis is time in days.

All these indicators are computed between two time steps by the CABM. The CABM has the same structure as the RPG:

- agents are farmers (with one instance of farmer for each player), water users' associations (one for each collective irrigated network), and one local water commission (implementing the collective rules and played in

the RPG by the RPG facilitator). Each virtual agent is the avatar of one player. Players chosen to be president of a collective network have two avatars: one farmer agent for their activity of farmer and one water users' association agent for their activity of president;

- objects are the fields, the crops, the outlets, the pumps (collective or individual) and the river.

The CABM implements the irrigation patterns provided by each player at the day time step. The resulting downstream water flow is then compared daily to the objective and the collective rules are implemented, generating possibly crises and decreases of water pumping. The expenses for each cropping activity as well as incomes from yields also are computed, updating the cash level of each player.

At the end of the cropping season, each player is privately provided with his own results: yield for each crop and current cash level, which are computed by the CABM as synthesis of the four monthly simulations. Current collective rules are then reviewed and a discussion time is opened to possibly modify these collective rules for a new cropping season.

Discussion: from technical features to uses of PIEPLUE

PIEPLUE features a specific association, or hybridization, of an RPG and a CABM within a single tool. We discuss below the specificity of this association, and then its capacity to take care of a variety of time scales in the frame of a 3 hour long role playing game generating discussions. Based upon a test within the river basin of the Drome River Valley, we propose some further adaptations of this kind of tool towards a tool that promotes some progressive learning.

Association of CABM and RPG in PIEPLUE

This association is grounded in (i) the sharing of a conceptual model and (ii) a concomitant use, while most existing joint uses of RPG and CABM are either (i) with an aim of mutual support in their design and assessment or (ii) with an aim of mutual support in use (Barreteau, 2003). Sharing of a conceptual model means that both CABM and RPG are implementations of a given conceptual model, at least structurally. They are supposed to represent the same situation and might be described by the same formal diagrams for their structure. It is a way to implement mutual support in design, through progressive adaptation of the model to the evolution of its context. Use of RPG and CABM is then sequential. In the case of PIEPLUE, the objective of the association is rather a mutual support in use, which is implemented through a concomitant use of an RPG and a computer tool, basically providing the dynamics of the environment. In this

experiment we added a sharing of conceptual model between the CABM and the RPG. Computer tools used in that context are usually dedicated to simulating the dynamics of the resource. They may also be used to repeat players' actions sequentially or at the same time step, in order to overcome concerns with size limits of RPGs. The CABM in PIEPLUE also simulates the behavioral patterns as chosen by players. It adds the possibility of overcoming time scale limits because it allows the CABM to simulate decisions taken in the RPG, through the direct continuation of players in agents and of game's entities in CABM's objects.

The implementation of a shared conceptual model relies upon the specialization of classes as RPG or CABM classes, and on a specific protocol for communication among these classes. Figure 5 below provides an overview of PIEPLUE as a UML class diagram. The white classes at the centre of the figure are those from the core of the shared conceptual model. These classes are used to describe the dynamics of the basin at stake in the role playing game. The classes in dark grey are those specific to the gaming part of PIEPLUE. They are the framework for describing the roles of player. The classes in light grey are those specific to the computer implementation. The class at the upper left is the key interface between both the world of the game and that of the computer. There is a real sharing of a common conceptual model since all players and all computer agents are inherited from the same classes. This common conceptual model acts as a shared root of the RPG and the CABM, making PIEPLUE more than an association of two separate complementary tools, but rather one inseparable hybrid tool.

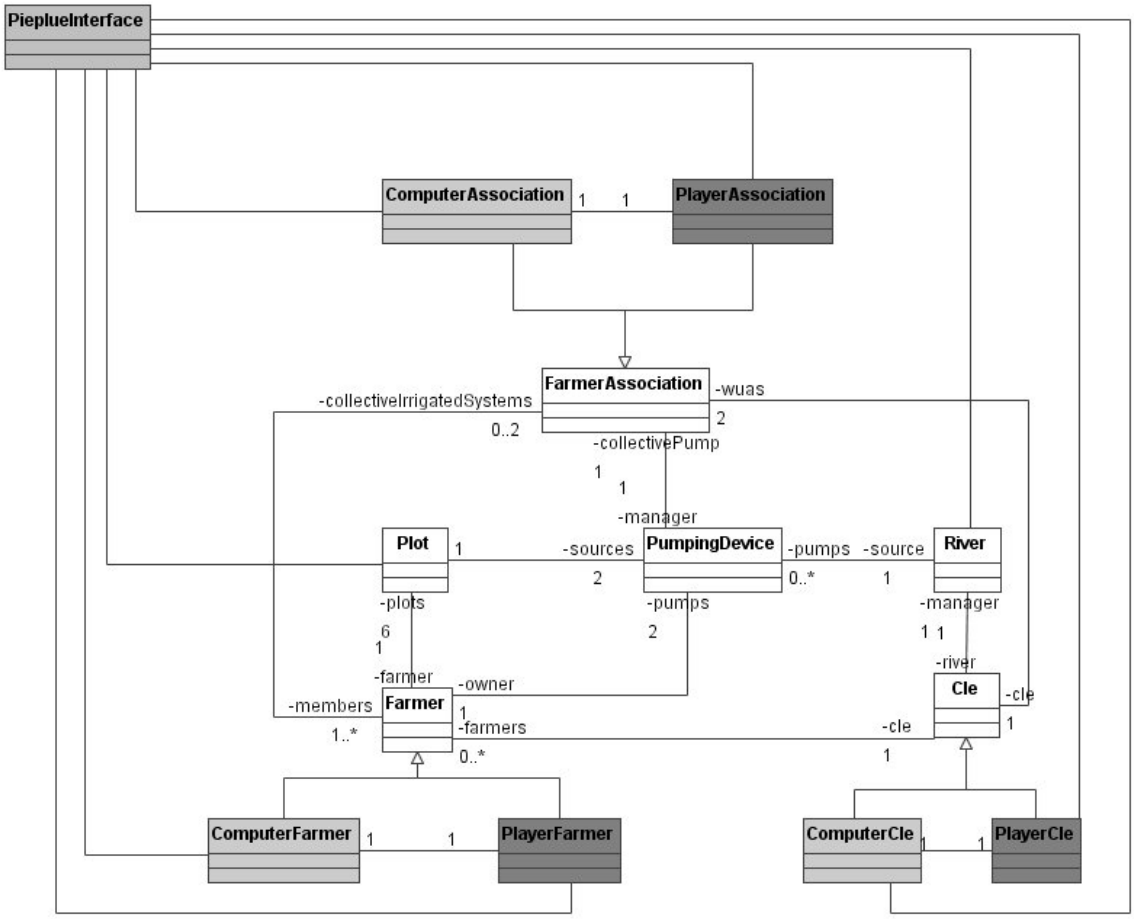

Figure 3: UML class diagram of an overview of PIEPLUE. Entities from the shared conceptual model are in white, entities specific to the CABM are in light grey, entities specific to the RPG are in dark grey.

These classes have then to interact to send choices of action in one direction and feedback on the current state of the farm and the whole system in the other direction. The limit of action domains among these classes, ComputerXxx and PlayerXxx, is the month time step. It is the limit between the world of the computer and the world of the game: all that happens at a time scale longer than the month is addressed by the RPG, while all that is at a time scale shorter than a month is handled by the CABM. Month as a decision time step is handled by the RPG: the basic time of action of players is the month, along with the choice or the adaptation of typical irrigation patterns. Month as an observation time step is handled by the CABM, which provides monthly data series on water level in the river or water stress in the fields. The sequence of activities and interactions among various classes of agents of PIEPLUE are shown at this time step on the UML activity diagram in figure 6.

The key role of the class PieplueInterface is very strong, since all the interactions go through this interface: collection of information on the current state of the system in one direction, collection of players' action choices in the other direction. This interface

also holds the filters for private and public information, through either printing it or projecting it.

In this application, we have chosen to implement this PieplueInterface class with a human being, who becomes one of the game's facilitators. This role of facilitation slows down the process somewhat (time for entering the players' choices and printing the feedback) and is rather sensitive to human error in entering the players' choices. This choice, rather than a network solution with players directly entering their choices to their computer avatar has been made for:

- technical simplicity reasons,
- ease of setting and running a session in any context,
- unequal experience with this kind of interaction using a computer among the potential players' population.

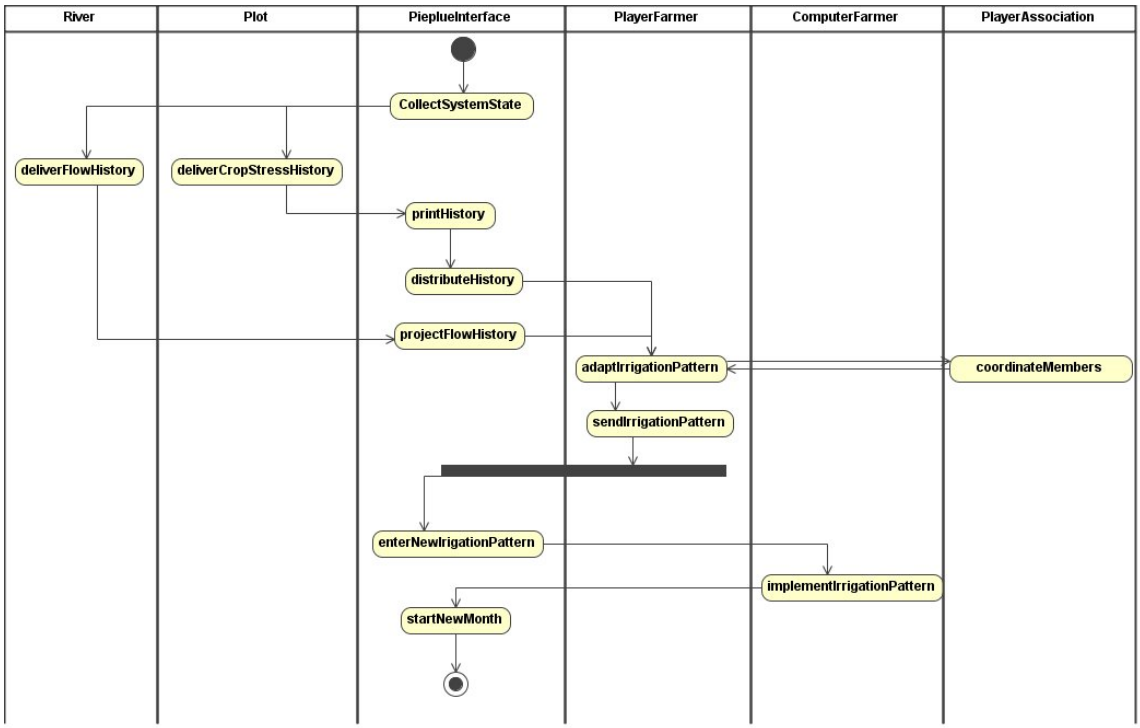

FIGURE 4: UML activity diagram of a month time step, specifying interactions among players and their computer avatars.

Uses of PIEPLUE: feasibility of the concept of a hybrid tool

Two test sessions have been undertaken, one with scientists in the field of irrigation water management, and another with employees of the Communauté de Communes du Val de Drôme (CCVD), an association of municipalities in charge of the implementation of the SAGE. The first one was aimed at calibrating the game and validating the relevance of the CABM simulations from an expert point of view. It led

notably to making new indicators available and providing more information to players, such as the climate and flow delivered to each network (Chennit, 2005). It also led to providing the evolution of indicators throughout the whole month instead of the mere current state at the beginning of the month. The objective of all these modifications is to give more keys to players to possibly analyze and better understand the reasons of the current state of their field. A water shortage may for example be due to the implementation of collective rules reducing water uses or to an inadequate supply of water through irrigation.

The second test session was held with the organization in charge of the SAGE implementation and thus of the facilitation of collective decision processes which are induced by the SAGE. A first objective was to make a test with people with a good knowledge of farmers in the area before performing any test with real farmers. The second objective was to provide CCVD with a good knowledge of PIEPLUE, since they are our main partner in the field. In this second test session, players were somewhat lost by the amount of rules to be learned at the beginning. These difficulties of understanding were notably due to the participation in the game of employees of the CCVD not familiar with irrigation issues, to reach a minimum number of players.

The supply of the series of indicators was useful in helping players understand these rules during the play of the first cropping season. Players could understand the relations between their choices and their results: occurrence of water shortage for some crops receiving irrigation outside of a period of water shortage in the river led the players to discuss with the members of the irrigation network they are part of.

Repetition of tasks has been well accepted by players taking part in these PIEPLUE tests, since it was in a limited number (four) and the repeated tasks were associated with direct simulation of consequences of the various actions made by each player. These simulations, and notably private information provided to players, did generate comparisons between neighbors around the game table in the interactive session.

The hybrid tool PIEPLUE thus fit the objective of a discussion support tool, with a variety of time scales. The use of a computer tool within has not been considered as a brake for communication on its basis, since the outcomes of simulations were discussed by players among themselves in order to understand the consequences of their practice. However, the explanations, which were to be provided throughout the game session, were time consuming, especially for players not familiar with farming, and only one cropping season could be played. This did not allow testing the capacity of PIEPLUE to foster the generation of new collective rules, but could at least show the feasibility of a hybridization of an RPG and a CABM.

Potential adaptations of PIEPLUE: a progressive learning by players

The whole duration of a PIEPLUE session is still long since only one cropping season could be simulated in a 3 hours session. This has to be improved. Time dedicated to explanations might be reduced through a progressive learning of the game. Such a progressive use of PIEPLUE came out of the second test, as another feature provided by the existence of a shared conceptual model between the RPG and the CABM. Although

PIEPLUE has been designed for medium and long time steps to be simulated by play and not computation, all the time steps and the categories of action implemented in the RPG can be simulated through computation. According to the objective of simulated farmers' knowledge of water needs for the various crops, some typical behavioral patterns have to be programmed in order to make players understand what different types of actions they have to do, make them react to those programmed, and propose their own behavioral patterns in the context of the game.

This possibility for a diversity of implementation of PIEPLUE between play and computation provides a means of implementing a progressive learning of the RPG. Each player still has a computer avatar. However, in a first season, this avatar is not controlled at all by the player but executed instead, assuming typical behavioral patterns. Players are informed of the actions of their avatars and progressively take the lead and control over it, implementing their roles by themselves. Such a progressive learning starts with a fully computer simulated cropping season, including cropping and irrigation behavioral patterns of farmers, and progressively provides the parameters available to players, asking them to do "better" than the computer. This is a second potential benefit of such deep integration of two simulation engines within a single tool: adaptation of the game to going progressively from computer simulated players to control by human players, is very slight.

Conclusion and perspectives

Building on the common architecture of CABMs and RPGs, we have succeeded in designing a hybrid tool that makes the representation of a wide range of time scales possible, suitable for a river basin management issue. We also use the complementarity of interactive features of both kinds of tools: generation of discussions through the interactive and gaming atmosphere while tackling scenarios through the computer simulation part. With the continuity of computer and player agents, we go further than other uses of computer tools in role playing games, which couple at the level of data flows. We have implemented here a deep integration of RPG and CABM: the players fully control their computer agents, with which they share a common root at the level of the conceptual model.

This should help to overcome the time scale constraints of RPG while retaining most of its interactive and discussion-generating characteristics, even though the test described could not be really conclusive, due to contextual reasons. This test provides its own explanation about its slow pace and lack of knowledge of farming activity on the part of players, as well as the way to go towards progressive learning: the framework is ready to initiate a session through computer simulation only with players taking progressive control over their computer avatars as they learn about the system. The feasibility of the concept, however, is supported by the development of the tool and its first test: dialogue on a constitutional or strategic decision level, when supported by such a tool, can take into account the constraints and effects of the micro-components of these collective decision processes.

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Notes

1. This approach has been written down in a charter, consultable at the following website: http://cormas.cirad.fr/en/reseaux/ComMod/index.htm

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