BRIDGING THE GAP:
Transforming Knowledge into Action through Gaming and Simulation

Proceedings of the 35th Conference of the International Simulation and Gaming Association, Munich, 2004

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Combining various time scales though joint use of Agent Based Modelling and Role Playing Games: application to a river basin management game

O. BARRETEAU, G. ABRAMI & S. CHENNIT

1. Introduction

Dialogue support for territory planning or natural resources management is increasingly using Agent Based Simulations or Role Playing Games or both categories of tools jointly. However dialogue support takes place within settings involving notably duration constraints. Computerization of tools is a classical way of speeding up processes, but sometimes to the cost of their clarity and transparency. Among the large diversity of joint uses of Agent Based Modelling and Role Playing Games, we chose a way to tackle this issue of time. The key feature is the similarity of architecture between Agent Based Modelling and Role Playing Games. We present here an application to a specific case study concerning irrigation management in the south of France.

2. Joint Use of Agent Based Modelling and Role Playing Games

ABM and RPG have both been developed for group decision or dialogue issues in separate trends (Barreteau, 2003). RPG, including notably policy exercises, are historically the first ones. They have been used to understand these collective decision processes as well as to train stakeholders involved in them or to bring support within them. From an analysis viewpoint, they make misunderstandings emerge through splitting the decision process among several decision centres (Schelling, 1961). They constitute tools close to the experiments economists do. They are very good tools to empower stakeholders in the decision processes and to facilitate sharing of information (Tsuchiya, 1998). However they are rather heavy to design and repetitions of experiments with a control of parameters are at 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, they are always perceived by stakeholders as black boxes, which is raising issues of their legitimacy and acceptability.

Formally ABM and RPG have the same architecture: autonomous entities situated in an environment and interacting dynamically. This helped to overcome both limits: 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, Bousquet & Attonaty, 2001). This has lead to a large series of joint use of ABM and RPG in these last years (Boissau & Castella, 2003; D’Aquino, Le Page, Bousquet & Bah, 2003; Etienne, 2003; Etienne, Le Page & Cohen, 2003; Hare & Pahl-Wostl, 2003). Most of them use a companion modelling approach (Bousquet et al., 2002) which aims at involving more stakeholders in the modelling process itself. Several categories of joint uses might be identified, presented in table 1, according to relations between conceptual models on one hand and to organization of joint use on the other hand. The two main interests of using ABM rather than other kind of modelling also jointly used with RPG (Duijn, Immers, Waaldijk & Stoelhorst, 2003; Meadows & Meadows, 1993) are: the possibility of implementing the same conceptual model in various formats and the continuity among entities in RPG and ABM.

RPG and ABM, jointly or not, are used notably for renewable resources management issues. RPG are always associated to at least a simple model to represent the dynamic of the resource. In the field of irrigation management, several RPG have been developed to train people due to manage these complex issues (Burton, 1994; Smith, 1989; Steenhuis et al., 1989).

### 3. Issue of time representation for NRM issues

Using a RPG as the main medium in interactive settings for dialogue support necessitates fitting in two kinds of practical time constraints: total duration of a game session and number of repetitive tasks.

Collective participatory decision processes are rather new and involve people not used to spend time for that purpose and with other activities. Therefore the time they can allocate to an interactive session is limited. A three hours

<table>
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<th>Model and game used in parallel processing</th>
<th>Different underlying conceptual model</th>
<th>Same underlying conceptual model</th>
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<td>-Mutual support in use</td>
<td>-Association of virtual and real players</td>
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<td>-Variety of time scales</td>
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<td>Model and game used sequentially</td>
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<td>-Mutual support in design and assessment (co-design, validation, benchmarking)</td>
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Table 1: Categories of joint use of models and games.
length 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, cumulative or delay effects occur. Complex systems involved by NRM issues are usually implementing these effects, if not all of them.

Time concentration is one feature of RPG leading stakeholders involved to share information through their gathering in the same place at the same time, which is not happening in real systems. However this time concentration should not induce repetitive boring tasks for players. For dialogue support purposes, models are used to simulate dynamics of the actors’ relations to stakes in the negotiation. This may involve simulation of collective or individual decision processes and actions but at a different organizational level: a model designed to support a collective decision process involving a constitutional or macro time scale will simulate decision processes and actions as regards the operational or micro time scale. If these micro time scales actions are repeated too many times in a RPG this may lead to make the whole interactive setting boring loose the gaming atmosphere.

A mean to overcome these two time issues is to have a representation of time at a heterogeneous scale such as in the Njoobari Ilnoowo RPG (Barreteau et al., 2001): time step in the game looses thus much of any realistic meaning and calibration of the game is tricky and focusing the discussion on specific points. A second way to overcome these issues of time representation is to use computer tool for the finer and more repetitive time scale: either by playing one step out of n and computing others as in the MejeanJeu RPG (Etienne et al., 2003), or by separating time scales to be computed from those to be played. In this last option, the ABM is considered as the extension of players at short time scales. Longer time scales are simulated through the game, providing patterns of individual actions which are altogether simulated at shorter time scales. Each player is represented by one agent whose behavioural pattern is determined by the player’s choices. This makes a full use of the similarity of agent and player in ABM and RPG. Both RPG and ABM have the same static conceptual models but are differing on the dynamics represented. This provides the opportunity to deal with three categories of time scales:

Systematic actions which are simulated by computer tool,
Strategic choices which are simulated by the RPG,
Negotiation consequences which are the purposes of using the tools.

We explore below this second option in a specific case study dealing with irrigation in the South of France.
4. Pieplue: an hybrid tool associating a RPG and an ABM

4.1. The Drome River Valley Case Study

A SAGE (Local Water Management Plan) has been signed up for the Drôme River Valley (Major tributary of Rhone river in the South-East of France) at the end of 1997 by the Prefect (State representative) building upon an agreement among representatives of local elected bodies, water users representatives and state representatives. It tackles among others the issue of minimum flows to be observed in downstream part, where main use is irrigation, through an agreement among stakeholders on a minimum threshold for downstream flow of 2.4 m³/s all the year long. We have then been involved in the facilitation of the dialogue among the farming sector on how reaching collectively this objective through a collective mastering of irrigation upakes. A set of collective rules has already been agreed upon early 2003, but not yet tested due to the exceptional drought of year 2003 (water flow at the upstream part of the irrigated area has been naturally below the minimum level for most of the normal irrigation season). This set of collective rules is based upon the use of complementary resources coming from outside of the river basin and the definition of allocation rules among farmers. The RPG and ABM presented below aim at providing an interactive setting for future possible revisions of the agreement.

Farmers are the major consumers of water for irrigation, which is mainly that of corn fields: irrigation is the main reason for water pumping, with 80% of the irrigated fields (3000 ha) being on the downstream part of the river. Total pumping capacity for 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 these three associations. Remaining irrigated areas are irrigated through wells in the alluvial aquifer. The whole context is evolving with:

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 agricultural policy, which cause interests in specific crops demanding more or less on water to evolve.

4.2. Co-ordination of RPG and ABM

Dealing with dialogue support for collective decision processes for irrigation management issues raised the need to tackle a large sample of time scales: from the day when hydraulic balance and water level in the river is com-
puted or observed and the practical decisions for cropping and irrigating are made up, to years when irrigation investments are made. The interactive setting presented here, named PIEPLUE, is constituted by a couple of an ABM and a RPG. It has to be able to deal with:

a short time scale, typically the day, as the time for the farmer to choose the plot to irrigate,

a medium time scale corresponding to the evolution of priorities among crops, typically the month, for the farmers to update their irrigation patterns,

a long time scale, typically the year, for cropping pattern choices and collective discussion on rules to share water.

The short time scale is simulated by the ABM according to the choices made at the two other time scales. These medium and long time scales are simulated in the game, benefiting from the simulation results of the first one.

The RPG constitutes the basis of the interactive setting. As for many games using computer tools, the ABM is embedded in the RPG. All players take on roles of farmers. Two game facilitators are required, one for the gaming part and one to use the ABM. It builds upon a sequence of several stages summed up in figure 1. In the initialisation stage players are allocated 6 fields each characterized by a soil water capacity (superficial, medium or deep) as well as two water supply facilities characterized by a location (an individual well or an outlet on a collective irrigation network) and capacity. These allocations are provided randomly by the computer to each player individually. Each player receives also an objective to help in taking on their role. The basic setting involves two collective 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 not enough players are available. The collective irrigation networks are initiated with the choice of a president among players holding an outlet in it, and with the definition of water pricing for outlet holders.

During the start of cropping season time step, players choose their cropping pattern based on an affectation of a crop for each field among (wheat, maize, tomato, garlic).

Then they choose an irrigation pattern for each month time step. This step is repeated four times considering that irrigation season is lasting four months in that area (June, July, August and September). Players fill in for each of these time steps a form specifying a weekly irrigation pattern for their both water sources as shown on table 2. These forms are then entered as parameters for the ABM by a game facilitator on specific computer interfaces.
Players can base their choice on the irrigation pattern of previous month time step which is provided together with information on the evolution of private and public indicators during the previous month time step. They have also information on the way they are affected by collective rules in case of water shortage. Private information concerns systematically the evolution of state of crops according to soil-water availability as shown in figure 2. 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 source by day, irrigation amount by field and by day.
Figure 2: 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 projected directly from the computer. It concerns notably the series of downstream flow which appears on a computer interface as presented in figure 3 and is projected systematically. Other indicators are computed and might be projected on request from players: climatic data on previous month (rain and Potential Evapo-Transpiration), evolution of crisis level, upstream flow.

Figure 3: 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 in-between two time steps by the computer ABM. The ABM has the same architecture as the RPG: agents are farmers (with one instance of farmer for each player, water user 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);
objects are the fields, the crops, the outlets, the pumps (collective or individual) and the river.

The ABM is implementing the irrigation patterns provided by each player at the day time step. The resulting downstream water flow is then daily compared to the objective and the collective rules implemented, generating possibly crisis and decrease of water pumping. Expenses for each cropping activity as well as incomes from yield are also computed, updating 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. Current collective rules are then reminded and a discussion time is open to possibly modify these collective rules for a new cropping season.

5. Modularity in use of Pieplue

5.1. Two test sessions

Two test sessions have already been undertaken, one with scientists in the field of irrigation water management, and another one with employees of the Communauté de Communes du Val de Drôme, association of communes in charge of the implementation of the SAGE. The first one was aimed at calibrating the game and validating the relevance of the ABM simulations from an expert point of view. It led notably to propose new indicators and provide more information to players. It also led to provide the evolution of indicators along 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 analyse and better understand the reasons of current state of their field. A water shortage may for example be due to the implementation of collective rules reducing water uses or to too little supply of water through irrigation.

The second test session was held with the institution in charge of the SAGE implementation and thus of the facilitation of collective decision processes which are induced by the SAGE. The objective was that this institution has a good knowledge of PIEPLUE before any test with real farmers and that they take part in its design upon the basis of this first prototype. In this second test session players were a little bit 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 to help players understand these rules during the play of the first cropping season. Players could understand the relations between their choices and their results. However these explanations were time consuming and only one cropping season could be played, which did not allow testing the capacity of PIEPLUE to foster the generation of new collective rules.
Repetition of tasks has been well accepted in these PIEPLUE tests, since they were associated with direct simulation of consequences of various actions made by each player. These simulations, and notably private information provided to players did generate comparisons between neighbours in the interactive session. However whole duration is still too long and has to be improved, or time dedicated to explanations has to be reduced through a progressive learning of the game.

5.2. Diversity of uses of Pieplue

From the second test came up another feature provided by the similarity of architecture between the RPG and the ABM: although PIEPLUE has been designed for medium and long time steps to simulated by play and not computation, all the time steps and the categories of action implemented in the RPG can be simulated through computation. This possibility for a diversity of implementation of PIEPLUE between play and computation provides a mean to implement a progressive learning of the RPG: begin with a fully computer simulated cropping season and giving progressively the parameters which are at hand to players asking them to do better than the computer.

6. Conclusion and perspectives

The development of PIEPLUE is still on-going following a Companion Modelling approach (Bousquet et al., 2002), which implements a succession of versions confronted to the field at various levels. Here we go from experts external to the field closer and closer to actors more directly involved in the use of water resource. First versions have however entailed to tackle the issue of variety of time scales through a specific association of RPG and ABM. However the use as dialogue support could not yet be tested as it is planned to: through the comparison of propositions in the game with the possibility to implement them in real world.

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**Authors**

BARRETEAU, O.

ABRAMI, G.

CHENNIT, S.

Cemagref, UR Irrigation, BP 5095, 34196 Montpellier Cedex, France

Email: olivier.barreteau@montpellier.cemagref.fr