One more step towards participatory modeling. Involving local stakeholders in designing scientific model for participative foresight studies

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Abstract. This paper focuses on how to design and execute interactively agent's behavior by dynamically interpreting activity diagrams. To reach this objective, we have implemented an agent-based model (ABM) of livestock producers faced to drought phenomenon in Uruguay. The first step consists in implementing a standard ABM with pasture growth, herd dynamics and simple agents imitating roughly the farmers' strategies. The second step is more participative since it consists in assessing the model with the real cattle farmers. As it appears in a majority of modeling processes, this evaluation phase requires feedback on the model design. In order to make this assessment more lively and efficient, we have conceived a tool for drawing diagrams and interpret them immediately. Thanks to that new opportunity, the actors have quickly understood the functioning of the model and were able to criticize it and modify it. Thus, this innovative modeling tool enables to involve stakeholders in co-designing ABM for participatory foresight studies. We hope it helps in finding new efficient practices for farm management adapted to climate changes.

Keywords: Participative modeling, Collaborative modeling, Interactive modeling, Group modeling Agent-Based Model, Multi-Agent System, Activity diagram interpretation, Modeling tool, Executable UML.

1 Introduction

Prospective analysis has been developed to explore possible futures [1]. Initially dedicated to assist strategic management of enterprises (example: Shell's Planning Department, [2]), prospective analyses are also applied to land use issues and agricultural development in last few years. Prospective approach involves many tools such as operation research or management sciences. From them, simulation models are increasingly used by building various land use scenarios and simulating their mid to long-term consequences on agricultural and natural stakes.

Since few years, several modeling approaches have emerged in the purpose of involving the stakeholders in model design and assessment. In the case of simulation models, some experiments seek to collectively build scenarios where actors play a key role for defining the desired scenarios and the indicators of sustainability. As stated by the Companion Modeling approach (ComMod, see [3]), model design is a way to support and confront viewpoints [4], while simulation allows articulating their projection in time. The objective of such participatory approach is to help people in finding collective decisions and to improve the adaptive capabilities of the actors.

Within the Serious games scope, some innovative works seek to generate exploratory scenarios through interactive simulations ([5], [6] see [7] for a description of a continuous gradient of hybrid agents, from autonomous agent to avatar fully control led by human). As they are centered on the individual, agent-based simulations (ABM) enable the user to be in place of the agent which follows the evolution and, for example, to “think like a wolf, a sheep or a fly” [8].

But few modeling approaches integrate stakeholders at both the conception stage (identification of the problem, design and parameter setting) and the assessment stage (scenario building and collective exploration). If participative simulation is more and more carried out, the earlier phase of designing the conceptual model is more challenging and few works have been conduct toward the process of participatory modeling [9].

This paper describes a new experiment involving more deeply the stakeholders in the collective design of a scientific model. This experiment is thus a new step towards participatory modeling.

2 Requirements for involving stakeholders

Simulation models are useful to explore, explain and assess the complex interactions between ecosystems and human activities. Usually, they are mostly used to enhance the scientific understanding or to recommend corrective policy action [10]. In such cases, stakeholders are only contacted during the primary data gathering phase and are frequently bypassed in the transfer of knowledge between researchers and policy makers [11]. On the contrary, we argue that sustainable development cannot be imposed only through top-down regulations.

Since few years, several modeling approaches have emerged in the purpose of involving the stakeholders in the model design and evaluation. In the field of complex system science, this approach is known as the "post-normal" scientific posture [12]. In a situation where “facts are uncertain, values in dispute, stakes high and decisions urgent”, the decision should not depend only from expert knowledge and model results. Although there is still a strong belief in the performance and efficiency of computers models, “what comes out at the end of a program is not necessarily a scientific prediction; and it may not even be a particularly good policy forecast”. Decisions regarding renewable resources depend on evaluations of future states of the natural environment, resources and human society, all of which are unknown and unknowable. Beyond the lack of knowledge, it may be also argued that the experts have their own form of bias.

It is now recognized that the beliefs and feelings of local people must be respected and even taken into account. The ComMod Approach [3], [13] affirms that participatory process of a decision is even more important than the decision itself. It also implies that scientific expertise is just one element in the political process. Scientific contributions can help to delimit the range of possible outcomes but, lonely, they can not find out faithful solutions. When complex socio-environment problems are concerned, seeking for new alternatives requires the involvement of the stakeholders.

Thus, we defend the idea of an exposed modeling that must assume its choices without imposing its points of view. It is urgent to give up the naive vision which consists in thinking that a model is objective. On the contrary, a model is inevitably a subjective representation. It is thus necessary to clarify the modeler choices and to present them in the most readable way so that they can be understood, shared or criticized.

Therefore, ComMod does not restrict the stakeholders solely to the decision makers. It also involves more anonymous actors who take part nevertheless in the process of development. In the field of renewable resources which implies the responsibility of each one, the decision seldom depends on one person. It requires on the contrary that all those who influence the global dynamics by their behavior, participate actively in the decision. Indeed, better involvements in the stakes as well as the appropriation of a decision improve the process of the decision and lead to a better implication of the actors. Then, the ComMod purpose is not to propose some expert's solutions, but rather to enrich the decision-making process, as much on its technical aspects as on its social aspects (dialogue, strengthener of the actor’s capacity in the decision).

3 Presentation of the case study: adaptation of producers to the drought phenomenon due to climate change

The *Sequía* project aims at understanding the drought phenomena in Uruguay and at developing a participatory methodology to improve the adaptation capacity of livestock farmers [14].

Agriculture plays a central role in Uruguay's economy, mainly due to the large livestock sector. The producers are essentially extensive cattle ranchers on natural grasslands. With a cattle herd of 12 million head, Uruguay is the country with the highest number of cattle per capita (3.8) and produces about 600 thousand tons of beef a year. In 2010, 65 per cent of total beef production is exported. Based on extensive systems with outdoors grazing in natural pastures, Uruguay produces first quality beef and targets high value markets.

The *Sequía* project has been motivated due to severe droughts that affected the north Uruguayan region in the last century. Basaltic shallow soils of this region make them more sensitive to drought. The severity and frequency of the droughts has jeopardized the sustainability of ranches. In the late 1990s, livestock breeders experienced severe droughts and millions of animals died or had to be slaughtered prematurely. This led to weaken the beef production sector causing numerous bankruptcies.

Even though some few farmers were less affected to these extreme situations, it was unclear about how exactly they worked and which strategy was better in the long-run. This also evidenced the need for new methodological tools to work with, which would also facilitate the communication of these strategies among farmers and members of extension and support services for rural and agricultural development.

The main product of the project was to design and implement an ABM to simulate the evolution of farmers under different drought strategies. The ABM purpose was to build prospective scenarios under the assumption that future conditions (climate, prices) will be similar to previous ones during the 2000-2009 decade. The model design consisted in defining the most relevant elements and concepts that should be taken into account to describe the consequences of drought on herd growth. For that purpose, several modeling workshops were conducted with the interdisciplinary research project team, including producers.

4 Overview of the basic model

The first model is a standard ABM for which no interaction with simulation was planned. In that version, agents represent strong simplification of farmer's behaviors. For simplicity reason, two kinds of producers were considered respect to their corresponding drought strategies: "CC" Producer who focuses on cattle health or corporal condition score and "Pasto" Producer who makes drought-related decisions by looking at grass availability and climate.

Whatever his strategy, a producer owns a 500 ha farm composed of one single pasture (no matter spatial dimension). The grass grows according to the logistic equation which parameters change according to season and climate conditions. Two herds are grassing on the farm: sheep that are not affected by drought and for which the dynamics is very simple, and cattle vulnerable to height of grass and which lifecycle is more finely modeled (Figure 1 shows possible cattle state and its transitions).

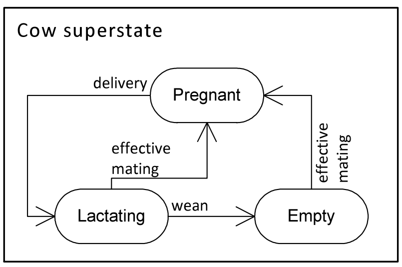


Fig. 1. UML State-transition diagram of cow superstate representing a fragment of cattle lifecycle.

The following UML class diagram (Fig. 2) represents a reduced view of the model structure.

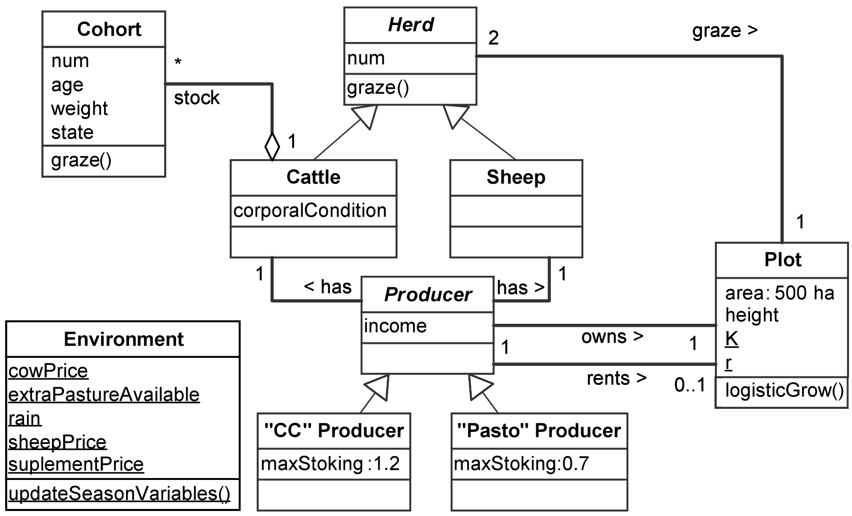


Fig. 2. UML Class diagram of a simplified view of the model.

As the farmers have distinct seasonal activities, the time-step for the simulations matches one season. But a one day sub-step is needed to represent more precisely the interactions between grass growth and grazing. The task scheduling order (i.e. order in which the behaviors of agents and resources are called upon at every time step) is shown on Fig. 3. The model is deterministic but some input parameters (climate data and international prices) have been added as "forcing variables". These time series gathered during the 2000-2009 decade influence the simulations.

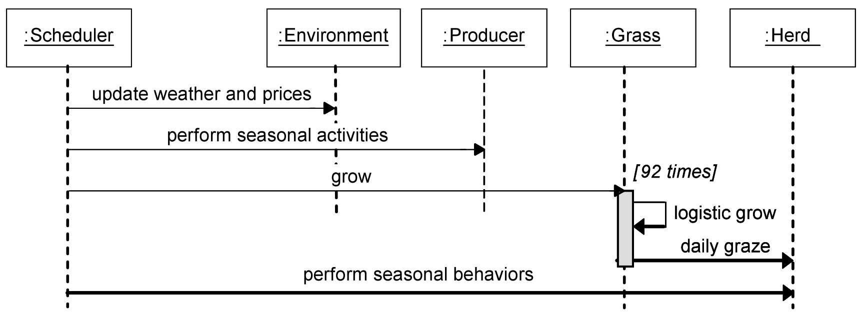


Fig. 3. UML Sequence diagram representing task scheduling of a seasonal step.

Eight farmers' behaviors where designed (one per season and per strategy). They consist mainly in managing the farm and the herds. Even if, for a given season, the strategies are roughly similar, differences exist on the decision points for each one: while the "CC" producer surveys the corporal condition of his cattle for his managing choices, the "Pasto" producer chooses its activities according to the grass height and by trying to stay under a low stocking threshold. The following figure describes an example of "Pasto" Producer's behavior in winter.

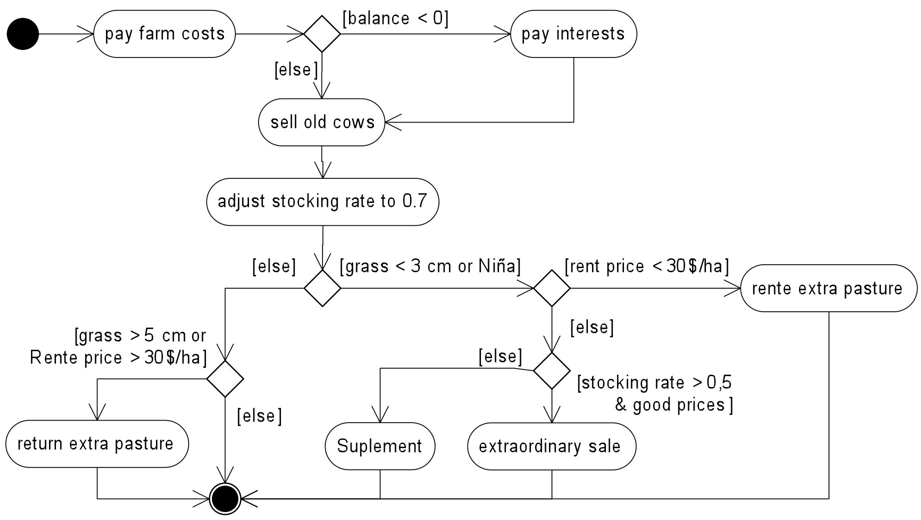


Fig. 4. UML Activity diagram showing the winter strategy for a "Pasto" Producer.

Several output parameters where defined, like producer's income and cattle mortality allowing to see the system evolution.

The model has been implemented on Cormas, a framework dedicated to ABM for renewable resources [15][16]. Three successive versions were implemented: first, a "grass only model" with the objective of validating the grass growth depending on climate; the second "wild model" introduced cattle and aimed at the grass-animal interaction; and finally the "management model" was done which included producers and their different behaviors (drought strategies).

The first results show that during drought's phases, "Pasto" Producers can generally better face these stressful periods than "CC" producers; they succeed in reducing the mortality peaks and they face less economic problems. But, outside these periods, they are less economically efficient. For more detailed descriptions and simulation results, see http://cormas.cirad.fr/fr/applica/sequia.htm.

5 Executable activity diagrams to further involve local stakeholders into participatory modeling

5.1 A need to collectively change the model

The first version of the model has been collectively designed with several members of the project including researchers and technicians. In order to share a common vision of the model, we made an exclusive and intensive use of UML. Implementation on Cormas has been done at the end of this long process.

Several participatory workshops were organized with livestock farmers from Basalt region of Uruguay, strongly affected by drought. The objectives were to present the project purpose and to clarify the management difficulties due to climate changes. As ABM may be seen as black box, it was also essential to present and to explain the contents of the model [17], [18]. From there, the stakeholders can assess the accuracy of the representation. But they can also criticize certain parts and participate in redrawing the model. Due to criticisms on the agents' behavior considered overly caricatured, changes have been made collectively.

5.2 Executable activity diagram editor

To assess immediately the consequences of changes, a new tool has been created that enables to design simple activity diagrams and to execute them without any need for translation into code. Indeed, this diagram editor allows creating new activity diagrams (or re-opening formers) that are interpreted "on the fly" by Cormas. Users can modify the simulator while it is running, without stopping or restarting the simulation. After been saved, a diagram is not compiled into programming language[1] but is interpreted by the simulation without need for developer skills.

For simplicity and user friendly reasons, the elements available on the diagram editor are restricted to initial and final nodes, simple activity nodes (without parameter, neither ability to handle output of an activity), transitions and decision points (Fig. 5). It doesn't include more sophisticated features such as swimlane, iteration and concurrency notations that are nowadays specified by the current version

[1] On the contrary of "Executable UML" [19] whose procedure consists in translating an Executable UML model into code by executable UML model compilers

of the UML 2.0 standard [20]. As stated initially, the purpose of this executable editor is to be understandable and usable by non-computer engineers

The decision points don’t respect exactly the UML notation but are rather like the old flow chart diagrams for which the question is written into the diamond and only two transitions come out indicating the fulfillment (true) or the negative answer (false).

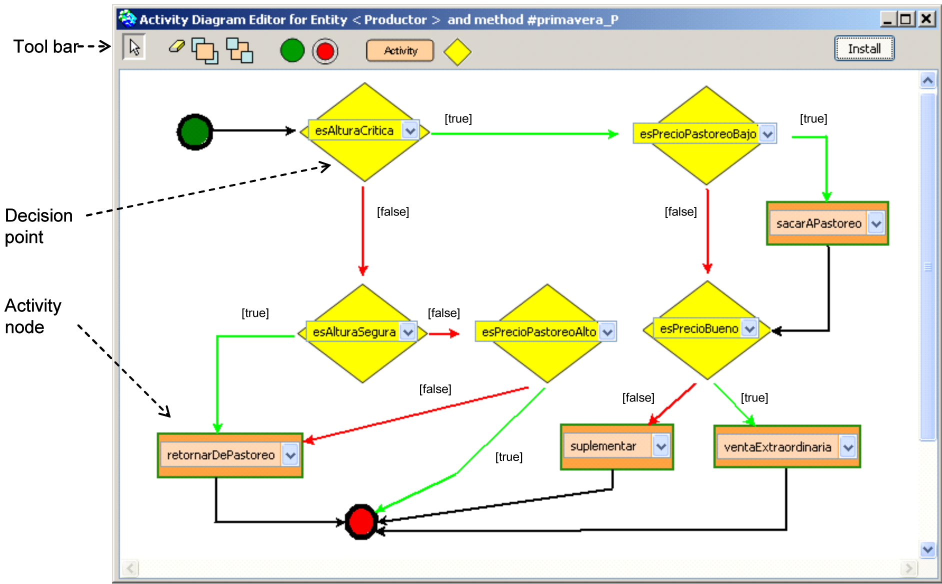
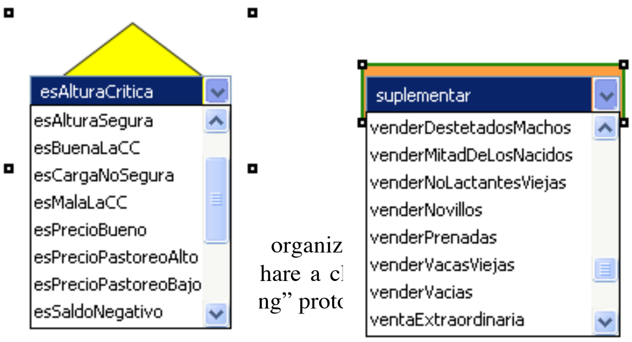


Fig. 5. The executable Activity diagram editor showing the spring strategy for a collectively designed Producer.

By selecting an activity node or a decision point on the tool bar, the user can add a new element on the diagram. Then, he can choose the operation to be performed by this element. Each element proposes a drop down menu displaying a list of methods belonging to the Producer class. To set up this list, Cormas inspects all the simple methods defined into the target class and its super-classes[2] (Fig. 6).



[2] For instance, … organiz … (also called “protocol” for … hare a c… f a decision point are colle … ng” protc…

Fig. 6. Example of drop down menus for decision point (left) and activity node (right).

Saving a new diagram generates a new method name that can be called in turn (future drop down menus will display this new name). A double click on an activity or a decision point opens either a code editor targeting the selected operation, or another diagram editor displaying the previously saved activities.

Thus, from basic operations already defined by the modeler, anyone is able to generate new behavior without any programming skills.

6 Discussion

6.1 Diagram limitations

The executable activity diagram editor does not prevent from computer programming. The current objective of this tool is not to generate an entire simulator by avoiding the coding phase. It rather aims at facilitating the collective changes of a model by organizing plug-and-play activity nodes. These activities contain pieces of code (software bricks or components) that were previously coded by developers.

Because it is intended for non-specialists, the editor has been designed to be as simple as possible in order not to repulse users. This is the reason why it does not contain all UML 2.0 notations. In return, this simplicity enables anyone to participate more actively in the modeling process with more efficiency thanks to immediate assessment of his modeling changes or his proposals.

6.2 Experiments results and conclusions

Using of the executable editor revealed two interesting features. First of all, the possibility of modifying the agents' behavior allowed playing with the model and better understanding its logic. The immediate outputs of the model after a change stimulate the participants and make them paying special attention to their underlying mechanisms that are not always obvious. This leads to new questions about how the model operates, but also this has triggered off discussions and debates about the ways to react to climate crises. In conclusion, although the agent's strategies of the model had seemed too much simplistic at first, many farmers have afterwards recognized themselves as "CC" Producers.

The second feature relates with highlighting of simulation difficulties related to time management. By testing alternative strategies with the executable editor, the participants realized that in case of drought, the agents were reacting always too late. For instance, it appeared that the fact to supplement the herd didn't prevent it from collapsing. The participants understood that during crises, the agents had to act more frequently than only once per season (see Fig. 3). This will lead us to revise the model by reducing the time step duration or by adding triggers event when mortality exceeds a given threshold.

Therefore, this new tool enables to greater involve the stakeholders. Its immediate reactivity allows rapid assessment of changes in the model. So, the participants are more likely to understand how the SMA works and to take part in its design. This kind of recursive design allows meaningful feedback and reveals the model's weaknesses and advantages.

6.3 Opening the black box and facilitating participative foresight

As stated by [20], the primary design goals of the UML are to provide users with an "expressive visual modeling language to develop and exchange meaningful models" that are independent of particular programming languages. It is specified that UML is not intended to replace programming languages.

Even if UML diagrams are used to design an ABM, they are also useful to explain a model. They act as supports for discussions to share points of view and to facilitate communication among scientists, modelers and development actors. Based on simple graphic notations, a diagram should be understandable even by non-computer scientists [21]. It has to be independent from any platform or programming language and should not display technical feature (interface, buffer, database, etc.). The displayed items should only belong to the targeted thematic. The stakeholders need to understand them in order to assume ownership of the model and to criticize it. As Popper has explained for theories, a good model should be refutable. Criticizing a model is not negative; it's rather a means of questioning existing knowledge and stimulating new learning loop.

In the case of descriptions of land use strategies, activity diagrams allow explaining complex practices. In experiments conducted by [22], many Uruguayan farmers have been successfully interviewed using such diagrams as ways to communicate, enabling clear and unambiguous explanations.

The executable editor tool we have developed remains in this perspective. It does not seek to prevent the members of a modeling project from programming the simulator. But it enables to quickly check the consequences of new practices devised by the actors. We conceived it as a collective and recursive design tool to enhance self-organization capacities and to facilitate adaptive management.

7 Conclusion

Within a project dedicated to assist the Uruguayan livestock farmers who face frequent and destructive droughts due to climate warming, we have created a new modeling tool. This executable editor enables to modify or create activity diagrams that are immediately executed during runtime simulation. This design supporting tool does not prevent from programming, but it allows organizing graphically predefined activities and conditions in order to describe and perform the behavior of an agent.

For our case study, the use of this tool has helped the communication about the phenomenon of drought. It has also facilitated the understanding of the model by opening the black box [17] and has even allowed pointing out some simulation bias. In reference to social validation of scientific models [23], the executable editor allowed legitimizing the decision making model with the end-users through a collective learning process.

Finally, it has contributed to seek for better adaptive strategies in order to improve the resilience of livestock producers. Indeed, enabling the actors to modify the behaviors of the agents and immediately assess the consequences, allows adjusting the concepts to better matching the actors' perceptions. The direct feedback facilitates a recursive design that can lead to significant changes of the conceptual model.

We consider the executable diagram editor as promising tool since it becomes possible to enhance the participation of the stakeholders in co-designing ABM in order to find collectively new sustainable practices.

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