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

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Abstract. This paper focuses on the collective design and immediate execution of an agent-based model (ABM) by dynamically interpreting activity diagrams of agent behaviors. To reach this objective, we have implemented an ABM of livestock producers facing drought conditions in Uruguay. The first step consists in implementing a standard ABM with pasture growth, herd dynamics and simple agents roughly imitating 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 model design. In order to make this assessment more lively and efficient, we have conceived a tool for drawing diagrams and interpreting them immediately. Thanks to this new opportunity, the actors have quickly understood how the model worked and were able to criticize and modify it. Thus, this innovative modeling tool enables the involvement of stakeholders in co-designing ABM for participatory foresight studies. We hope it will facilitate the emergence of new and more efficient practices for farm management that account for 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 corporations in their strategic management (example: Shell's Planning Department, [2]), prospective analyses have been subsequently applied to land use issues and agricultural development over the last few years. The prospective approach encompasses many tools such as operation research or management sciences. The resulting simulation models are increasingly used by building various land use scenarios and simulating their mid to long-term consequences on agricultural and natural stakes.

In recent years, several modeling approaches have emerged with 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 in defining the desired scenarios and the sustainability indicators. As indicated for 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 a participatory approach is to help people reach collective decisions and to improve the actors' adaptive capabilities.

Within the scope of Serious games, some ground-breaking initiatives 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 an avatar which is fully controlled by humans). As they are centered on the individual, agent-based simulations (ABM) enable the user to assume the role of an agent 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 increasingly commonplace, the earlier phase during which the conceptual model is designed, remains more challenging and, so far, little work has been performed dedicated to the process of participatory modeling [9].

This paper describes a new experiment that involves the stakeholders more heavily in the collective design of a scientific model. This experiment is thus a further step towards participatory modeling.

2 How to foster stakeholder involvement?

Simulation models are useful when exploring, explaining and assessing the complex interactions between ecosystems and human activities. Usually, they are mostly used to enhance the scientific understanding or to recommend corrective policy actions [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]. We, on the other hand, argue that sustainable development cannot be imposed through top-down regulations only.

In recent years, several modeling approaches have emerged that seek to involve 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 be only based on expert knowledge and model results. Although there is still a great faith 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 set the range of possible outcomes but, alone, they can not develop adequate solutions. When complex socio-environment problems are concerned, seeking new alternatives requires the involvement of the stakeholders.

Thus, we support the principle of an exposed and unambiguous modeling that must assume its choices without imposing its points of view. A model is just one representation of the world. It is urgent to give up the naive view 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 modelers' choices and to present them in the most comprehensible 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 players who take part nevertheless in the process of development. In the field of renewable resources which requires the responsibility of every one, the decision seldom depends on only one person. It requires on the contrary that all those who influence the global dynamics by their behavior, participate actively in the decision making process. Indeed, better involvements in the stakes as well as the appropriation of a decision improve the process of the decision and lead to a greater implication of the actors. Therefore, the purpose of ComMod 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, strengthening of the actor's role in the decision).

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

The *Sequía* project aims at understanding the drought phenomena in Uruguay and at developing a participatory methodology to improve the adaptation capacities 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 has the highest number of cattle per capita (3.8) per country and produces about 600 thousand tons of beef a year. In 2010, 65 per cent of total beef production was exported. Based on extensive systems with outdoor grazing in natural pastures, Uruguay produces premium quality beef and targets high value markets.

The *Sequía* project was initiated because of severe droughts that affected the north Uruguayan region in the last century. The 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 a weakened beef production sector causing numerous bankruptcies.

Even certain farmers were less affected by these extreme situations, it was unclear how they worked exactly 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 on strategies among farmers and members of the 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 using different drought strategies. The purpose of the ABM 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 interactive simulation was planned. In that version, agents are strong simplifications of farmers' behaviors. For simplicity sake, two kinds of producers were considered depending on their corresponding drought strategies: a "CC" Producer who focuses on cattle health or on the corporal condition score and a "Pasto" Producer who makes drought-related decisions by assessing grass availability and climate.

Whatever his strategy, a producer owns a 500 ha farm composed of one single pasture (of a non-defined spatial dimension). The grass grows according to the logistic equation which parameters change according to seasonal and climatic 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, which are impacted by grass height and which lifecycle is more finely modeled (Figure 1 shows possible cow state and its transitions).

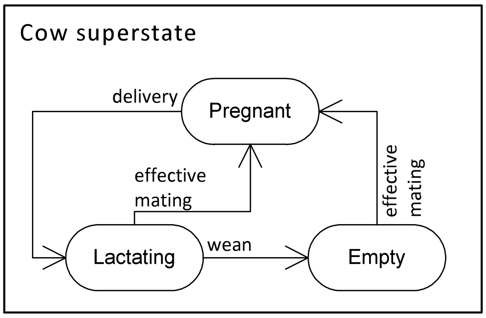

Fig. 1. UML State-transition diagram of cow super-state representing a fragment of cattle lifecycle

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

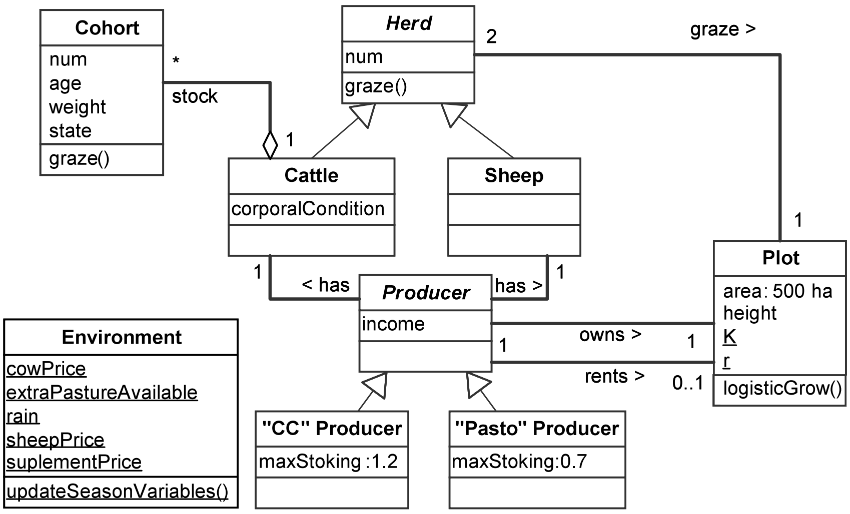

Fig. 2. UML Class diagram presenting a simplified view of the model

As the farmers have distinct seasonal activities, the time-step for the simulations corresponds to one season. But a one-day sub-step is needed to more accurately represent 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. They play the role of one climatic and market scenario for which various farmers' management strategies will be examined.

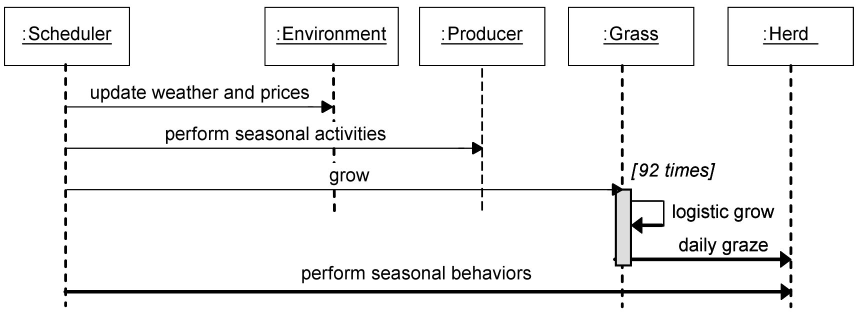

Fig. 3. UML Sequence diagram representing task scheduling of a seasonal step

Eight farmers' behaviors were defined (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 physical condition of his cattle to guide his managing choices, the "Pasto" producers choose their activities according to the grass height and by trying to stay under a low stock threshold. The following figure describes a "Pasto" Producer's behavior in winter. The "CC" producer' behavior in winter is quite similar to this one, except that the guards (squared brackets) of the main decision points concern the physical condition of the cattle.

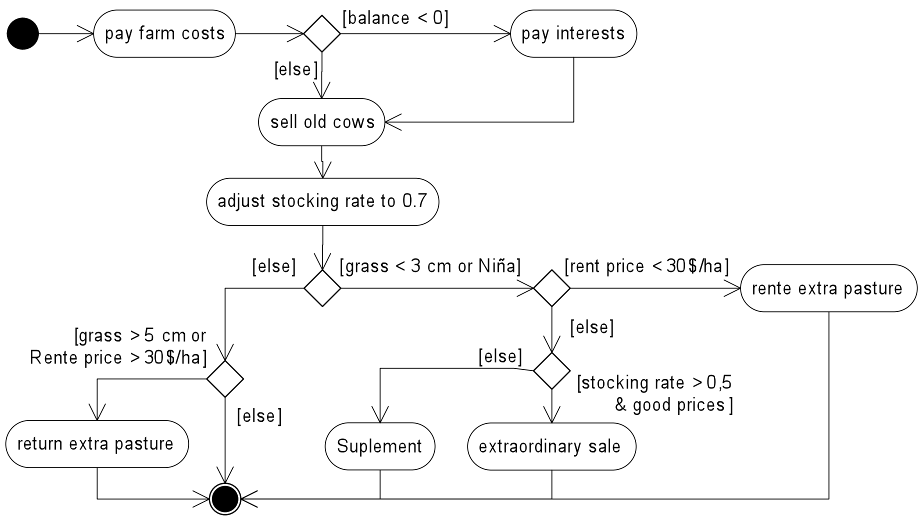

Fig. 4. UML Activity diagram showing the winter strategy of a "Pasto" Producer

Several output parameters were defined, like producer's income and cattle mortality so that system evolution can be monitored.

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" in order to validate grass growth as a function of climate; the second "wild model" introduced cattle and is focused on grass-animal interaction; and finally, the "management model" includes the producers and their different behaviors (drought strategies).

The first results show that during drought phases, "Pasto" Producers are generally better equipped to face these stressful periods than "CC" producers; they succeed in reducing the mortality rates and they are faced with less serious economic problems. But, outside these specific periods, they are less economically viable. 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 in 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 was performed at the end of this long process.

Several participatory workshops were organized with livestock farmers from the Basalt region of Uruguay, who were seriously affected by drought. The objectives were to present the project's purpose and to clarify the management difficulties due to climate changes. As an 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 redesigning the model. Due to criticisms leveled at the agents' behavior, which were considered overly caricatural, changes were made on a collective basis.

5.2 Executable activity diagram editor

To immediately assess the consequences of changes, a new tool was created that enables the drawing of simple activity diagrams and to execute them without any need for translation into code. Indeed, this diagram editor allows the creation of 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 being saved, a diagram is not compiled into programming language[1] but is interpreted by the simulation which does not require developer skills.

For simplicity and user friendliness, the elements available on the diagram editor are restricted to initial and final nodes, simple activity nodes (without parameters, or the ability to handle an activity output), transitions and decision points (Fig. 5). It does not include more sophisticated features such as swimlane, iteration and concurrency notations that are nowadays specified by the current version of the UML 2.0 standard [20]. As stated initially, the purpose of this executable editor is to facilitate understanding and usability so that it may be used by non-computer engineers

The decision points do not comply exactly with UML notation but are rather like the old flow chart diagrams for which the question is written into the diamond and from which only two transitions emerge indicating the fulfillment (true) or the negative answer (false).

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

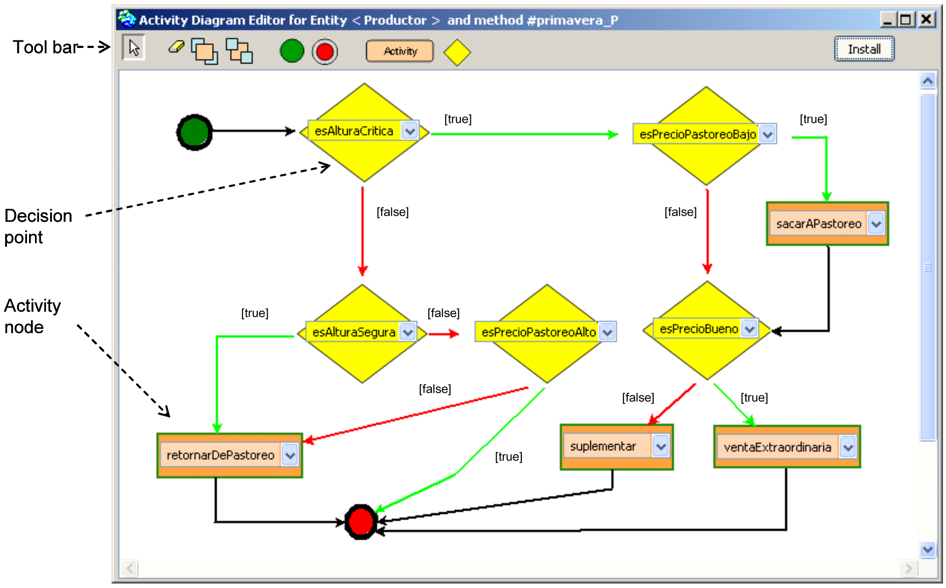

Fig. 5. The executable Activity diagram editor showing the spring strategy for a collectively designed Producer

By selecting an activity node or a decision point on the tool bar, the user can add a new element on the diagram. Thereafter, 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 within the target class and its super-classes[2] (Fig. 6).

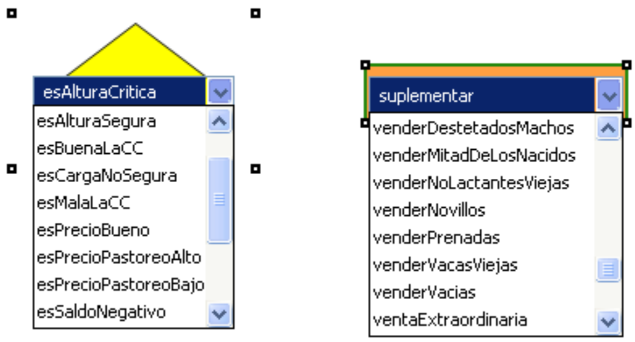

Fig. 6. Example of drop down menus for decision point (left) and activity node (right)

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[2] For instance, thanks to Smalltalk code organization in methods' category (also called "protocol" for which included methods share a close semantic), the methods of a decision point are collected by inspecting the "testing" protocol.

The design is incremental: saving a new diagram generates a new method of the agent that is immediately available and can be called in turn (future drop down menus will display this new method 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 may generate new behavior without any programming skills.

6 Discussion

6.1 Diagram limitations

The executable activity diagram editor does not avoid the modeler to program his ABM. At that time, the objective of this tool is not to generate an entire simulator which eliminates the coding phase. Its principal aim is to facilitate the collective modification 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 to not discourage potential users. This is the reason for which it does not contain all the UML 2.0 notations. In exchange, this simplicity enables anyone to participate more actively in the modeling process with greater efficiency thanks to the immediate assessment of his/her modeling changes or proposals.

6.2 Experimental results and conclusions

The use of the executable editor revealed two interesting behavioral features. First of all, by being able to modify agents' behavior, users could play with the model and therefore better understand its logic. The immediate outputs obtained after any modification of the model often acts as a stimulus for participants and increase their awareness of its underlying mechanisms. This leads to new questions about how the model operates, but also this has triggered discussions and debates about on how best to address climate crises. In conclusion, although the agent's strategies proposed by the first version of the model had often seemed too simplistic initially, many farmers afterwards categorized themselves as "CC" Producers.

The second feature concerns simulation difficulties related to time management. By testing alternative strategies with the executable editor, the participants realized that in drought conditions, the agents were always reacting too late. For instance, in case of bad corporal condition of the herd or in case of lack of grass, the decision to feed the herd with supplement did not apparently 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). The consequence being that we intend to correct the model by reducing the time step duration or by adding triggers event when mortality exceeds a given threshold.

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

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 when attempting to explain a model. They act as media 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 for non-computer scientists [21]. It has to be independent from any platform or programming language and should not display technical features (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 is more a means to encourage the questioning of existing knowledge and stimulating new ways of learning.

In the case of descriptions of land use strategies, activity diagrams can be used to explain complex practices. In experiments conducted by [22], such diagrams have been used very effectively to interview many Uruguayan as they facilitate communication, thus enabling clear and unambiguous explanations.

The executable editor tool we have developed reflects the same rationale. It does not seek to prevent the members of a modeling project from programming the simulator. But the consequences of new practices devised by the actors can be more quickly assessed. 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 assisting Uruguayan livestock farmers facing frequent and destructive droughts due to climate warming, we have created a new modeling tool. This executable editor is used to modify or create activity diagrams that are immediately executed during runtime simulation. This design support tool does not eliminate the need for programming, but it allows the organization of graphically predefined activities and conditions in order to describe and simulate the behavior of an agent.

For our case study, the use of this tool has significantly facilitated communication with and between farmers on the drought phenomenon. It has also enabled a better understanding of the model by opening the black box [17] and has even allowed the identification of some simulation bias. In reference to the social validation of scientific models [23], the executable editor facilitated end-user acceptance of decision making model thanks to the collective learning process involved.

Finally, it has contributed to the identification of better adaptive strategies so that the resilience of livestock producers can be improved. Indeed, enabling the actors to modify the behaviors of the agents and immediately assess the consequences, allows the readjustment of inherent concepts to better match the stakeholder perceptions. The direct feedback response facilitates a recursive design that can lead to significant changes in the conceptual model.

We consider the executable diagram editor as a promising tool since it can be used to strengthen the collective ABM design process so new sustainable practices can be identified in a truly collaborative manner.

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