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A meta-model for specifying collaborative simulation

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Abstract—Major researches in the domain of complex systems are interdisciplinary, collaborative and geographically distributed. The purpose of our work is to explore a new methodology that facilitates scientist's interactions during the simulation process. Through the analysis of the collaboration and multidisciplinary in a simulation project, we have identified the needs of a generic specification (meta-model) of simulator that will be integrated in a collaborative platform. This meta-model is a combination of three basic definitions : simulator , role and user. Accordingly, our meta-model has been developed to help identifying collaboration in simulation. In this paper, we will present our meta-model and an application of it in a simulation project.

Index Terms—Meta-model, collaborative simulation.

I. INTRODUCTION

One of the major research activities aims at studying various complex systems such as human systems (town, train station, ...) or ecosystems (soil, forest, sea), for a better understanding of real phenomena (urban mobility, soil carbon dynamics, fisheries, epidemic and so on). In this context, scientist intends to establish a model (a representation of the studied complex system) to reproduce, by simulation, interesting dynamic. After, simulation results are discussed and compared with real data.

During the simulation process, scientific exchanges among computer scientists, modellers and domain experts are highly recommended. Collaboration is needed, on the one hand, to define experiments parameters and scenarios, on the other hand, to analyze results of experiments. In addition, in the context of participatory simulation, collaboration could be observed during the running of the simulation: users are the actors of the experiment, they do action and modify the experiment involving while the simulation is running.

Many and many simulators have been developed to study various complex systems. ... Some of them are dedicated to the participatory simulation domain [1]. But major of them are standalone software without any tools allowing distant collaboration. Consequently, it is difficult to exchange around experiment because the scientists are geographically distributed. In this context, the collaboration tool occupies an important role.

The purpose of our work is to provide a conceptual approach to identify collaboration around a simulator, and to propose generic tools that permit to transform a standalone simulator into a collaborative simulator. These tools should facilitate

exchanges about simulation among scientific communities which are more and more geographically distributed around the world.

The aim of this paper is to present the meta-model of the simulator that will be used in simulation process. Firstly, we shall present the collaboration problem in simulation process. Secondly, we provide the detail description of meta-model. Finally, a case study is described demonstrating how the meta-model is applied.

II. THE COLLABORATION IN THE SIMULATION OF COMPLEX SYSTEMS

As said before, a simulation project is a teamwork rather than a task done by a single and isolated scientist [2]. The collaboration is highly required in simulation of complex system.

A. DIFFERENT ROLES IN A SIMULATION PROCESS

In a participatory experience, users are actors of the simulation. Each user has a personal expertise of the simulated complex system. They modify the evolving of the simulation according to their opinions to achieve their personal goal.

Thus, either in a playing experiment context or in a participatory experience, different user roles could be identified. In this context, a role determines several tasks realized to achieve a goal [3]. One or several roles could be associated with simulation participant.

According to Robinson *et al.* [1], the taxonomy of role found in a simulation could be sum up by only five basic roles presented by the table I. Based on the responsibilities of each user, they identify five basic roles. In these roles, the *Doer* and the *Done for* is the most important. They usually control simulation and their activities affect directly the result of simulation. The *Done with* also impacts to simulation, but not as much as the first two categories while the latter two have little or no involvement.

B. THE COLLABORATION IN THE SIMULATION PROCESS

In the experimentation step, the computer model which is based on experimental data is parameterized to find a solution/or an understanding about the problem studied. At this step, the computer model is executed many times by changing the parameters. Often, all project members are involved in this

TABLE I
THE BASIC ROLES IN A SIMULATION PROJECT [1]

Role		Concrete User		Responsibility
Name	Definition	Name	Definition	
D	Doers	D1	Project manager	Responsible for managing the process; may not have specific modelling skills
		D2	Modeller Model user (in later stages)	Develops the model (conceptual and computer). Experiments with the model to obtain understanding and looks for solutions to the real world problem
DF	Done for	DF1	Model receiver	The problem owner and recipient of the results; directly or indirectly funds the work
		DF2	Model user (in early stages)	Recipient of the model
DW	Done with	DW1	Data providers	Subject matter experts who are able to provide data and information for the project
		DW2	Modelling supporter	A third party expert (software vendor, consultant or in-house expert) provides software support and/or modelling expertise
DT	Done to		Those interviewed for information	A wide group of people from whom information is obtained
DWT	Done without		Management, staff, customers	Beneficiaries of the project, but not involved; in some cases they are not aware of the project

step. They exchange to determine suitable inputs (simulation parameters), good scenarios to realize. . . To identify interesting experiments and scenarios, the participants spend many times to exchange their opinion. In addition, the scientists are usually geographically distributed. In this context, the collaborative tools are indispensable.

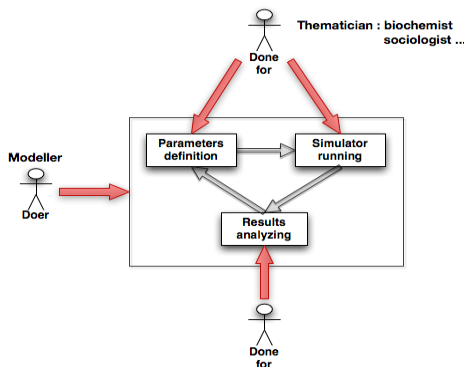


Fig. 1. Simple simulation process

A simulation task can be represented as a process of three iterative steps : (i) parameters definition; (ii) simulation running and (iii) results analyzing. Firstly, the *Done for* proposes a set of parameters. Then he/she runs the simulator with the new parameters and lastly, the obtained results will be analyzed. If the results are not good, he/she will try with other parameters. The *Done for* is usually a thematician who has a good knowledge about the problem studied. In this process, the *Doer*, concretely the modeller, is responsible for guaranteeing the function of simulator.

The key factors for success of a simulation modelling process is also the capabilities of collaboration among the participants. The collaboration will reduce the cost, time as well as improve the project performance.

C. Related work

Many models have been developed for collaborative work. Some of them are still the active research field for now. Task model is a one of the bases model to represent CSCW. Penichet

[4] proposes a task model for CSCW. This model describes "the tasks that should be performed to achieve the application goals" by giving them a good characterization. This model is a new "composition" of existing task models in order to have a better, more complete and more effective task model.

Another solution that recently attracts many attentions of researchers is role-based model that built above the task model. Kahina et al [5] presented a role-based model that is a combination of roles, tasks, actions and resources. A role is a representation of responsibilities and rights where responsibilities are actions a role player must perform and rights are actions he can perform. A task is a set of actions to be performed while actions is considered as tasks components. A role can be perform by one or many users at same time. A task can require one or more roles to be performed.

Concretely, there are some efforts that are trying to bring the collaboration to simulation. Each approach has its own pros and cons. In the following, we will illustrate some related researches.

Web-Sim-MIOR [6] was first attempt to provide collaborative web tools dedicated to model and simulate complex systems. The Web-Sim-MIOR portal is based on the generic NetLogo platform and allows users to run simulators on their own computer via their web browser without installing anything. This platform lacks many collaborative tools such as video conference, chat tool, forum, blog

In [6], [7], Nguyen et al have been developed a platform that supports for collaborative simulation, it's PAMS. This platform provided an unique interface for several simulators in GAMA [8], NetLogo [9] and Repast [10]. The users can manipulate simulators and realize experimentations collaboratively. One of the difficulties they had encountered is the integration of new simulators in their collaborative platform because each simulator has its own specification. In order to reduce this inconvenience, a standard specification is needed for simulator.

III. NEW META-MODEL FOR COLLABORATIVE SIMULATION

Our research aims to provide a conceptual approach to identify collaboration around a simulator. In this section, we will present the meta-model of our collaborative simulator.

A. Basic concepts

We are interested in the role-based model (see section II-C). Based on the identification of different roles, all collaborative functions and tools can be discovered. The new meta-model is based on three basic concepts : simulators, users, roles. Figure 2 presents a diagram of this models.

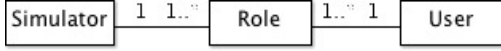


Fig. 2. Core concept

1) *Simulator*: A simulator is a computer model (see section II) that is written by a simulation language and can be executed on a platform. Simulator is used by Doer (modeler and model user).

2) *User*: We define user as a representation of modeler and different scientists. They use simulator to obtain understanding and looks for solutions to the real world problem. They participate an experiment by executing simulator many times with different sets of inputs. Each user has got a predefined permissions. These permissions correspond to a simulator access rules granted according to user roles.

3) *Role*: The role is an abstract representation of an user function, service or identification within a group of experiment. Each user can handle several roles, and each role is handled by one or many users. The role notion always relates to the permission notion. For more details about roles, reads can refer him to the table I. Note that, four kinds of roles can be found in a simulation process : D1, D2, DF1, and DF2 (see table I).

B. Simulator meta-model

Around concepts of User, Group, Role, we have created a collaboration meta-model of simulator (figure 3) that allows describing a simulator and users' interactions and usages.

This meta-model is based on a UML class diagram. This language was chosen because it is understood over the scientific community and simple to use.

The core of diagram is a class called *Simulator*. All simulators must extend this class. This class is a combination between three parts : base functions, Input, Output.

In this meta-model, we separate input, output (I/O) from the core of simulator. This separation allows us to easily manage the operations about I/O.

We identify two types of I/O for a simulator: (i) *Variable*; (ii) *Action*. *Variable* represents for all parameters involving input parameters, output parameters and in course of simulation parameters.

Take an example of Ants model [9]. In this model, "a colony of ants forages for food. Though each ant follows a set of simple rules, the colony as a whole acts in a sophisticated way". The *Variables* are population of ant, diffusion rate, evaporation rate ...

Action represents all activities that affect simulator. It can be the simulation activities like : Load model, setup model,

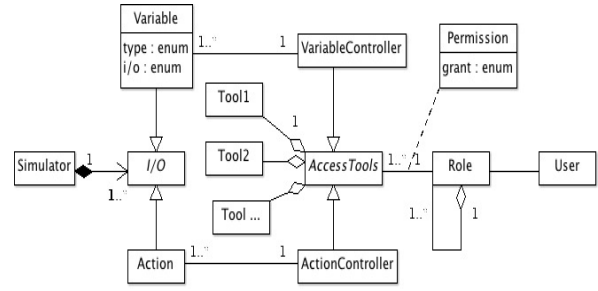


Fig. 3. Simulator meta-model

start, stop, step simulation, or activities about analyzing the results ...

These I/O is controlled by *VariableController* and *ActionController* that extended from *AccessTool* class. *AccessTool* that is an abstract of tool related reading, writing, editing simulator. *AccessTool*'s using is assigned according four roles. One role can use inly one or many tools, it depends completely on its permission.

This meta-model is the most important part of our approach. It permits to define generic interface for different kinds of simulator. Moreover, this meta-model is enough abstract. The I/O part is separated from the core of simulator. It allows us to work with various kinds of data, to add new activities, new types of I/O that do not influence to the other parts.

IV. APPLICATION

In this section, we are going to apply our meta-model to introduce collaborative features into a simulator reproducing urban dynamic. We base this case study on the Miro simulator.

A. Application

The MIRO project proposed an individual-centered approach of daily urban mobility. The object of this multi-disciplinary project is to create a multi-agent prototype to evaluate, by simulation, the influence on the collective function of the urban space, and the individual behavior towards the construction and implementation of activities's daily programs.

The users of MIRO are geographically distributed. Therefore, the next version of the simulator will support many participative and multidisciplinary scenarios. For example, consider a scenario for collaboration between researchers in which they use the simulator to simulate : Mr. X, Y and Z are respectively researchers in mobility science, town planning and transport service, they locate in Paris and Hanoi. To find a solution for the overload of Hanoi's infrastructure, they use MIRO simulator.

Each researcher is interested in variables that concern with their domain (see table II).

They connect to share workspace and participate in the experiment. Via this simulation board, they can manipulate the parameters that they are interested in and observe their revolution. Thanks to collaborative simulator, they can modify

TABLE II
VARIABLES THAT THE RESEARCHERS INTEREST

Variable	User	Signification
NumberAgent	X, Y, Z	To find a suitable number of agent for the exist environment
MaxSpeed	Y	The speed limit for all mobiles
OpeningTime	Z	The opening time of services

and see the modifying of parameter. When they want to discuss about a parameter, the collaborative tools (Video conference, whiteboard, chat ...) will help them to overcome the geographical distance.

Due to time constraints Mr. X has to leave. They both decided to resume this discussion later. So they recorded the session. Three days later, returning to the site, the conversation started and resumed in the state where it had been left earlier...

From this scenario we are going to create a simulator by identifying different components that are correspondent to the classes in figure 3.

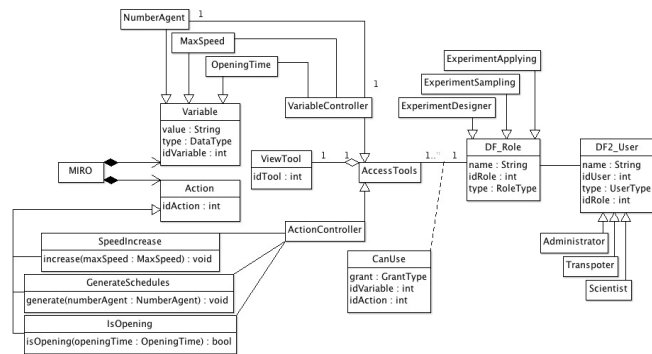


Fig. 4. An extract of MIRO simulator class diagram

This model involves three types of user : mobility scientist, town planning and transport service. They do not develop the simulator, they only use it to find the solutions. In this case, their role is DF, and they are DF2 - Model user.

The mobility scientist creates the experiment and is interested in number of agent. He changes this parameter and run simulation until the simulation executes stably. The transport service realizes the experiments by changing parameters about the bus service. The town planning acts as an administrator that manages and applies the solutions, he cares about route's parameters.

Each researcher focuses only on the parameters that they want to know. Therefore, their simulation board has a little bit of differences. In the result part of simulation board, there are only the results that concern with their parameters. Consequently, the representation of each *Variable* by a class is the best choice.

MIRO simulator has a number of variables and actions that users can perform. Each variable and action is represented by a class extended from I/O class. Respectively, variables and actions have a controller to manage their activities. The UML class diagrams, presented by the figure 4, represents 3

input parameters, and 3 actions with their controller. Three parameters are : (i) *NumberAgent* - the number of agent; (ii) *MaxSpeed* - The speed limit for all mobiles; (iii) *OpeningTime* - the opening time of service. Respectively, these parameters are used by three actions : (i) *SpeedIncrease* - The increase of speed but can not exceed the speed limit; (ii) *GenerateSchedules* - Generation of schedule for all agents; (iii) *IsOpening* - Determine the service is opening or not.

The core functions of MIRO will be implemented in *Simulator* class. This class will use variables and actions that are defined in the previous section to : (i) generate a virtual city; (ii) generate the agents and their schedule; (iii) simulate the activities of agent belong their schedule.

V. CONCLUSION

We have argued in this paper that a modelling and simulation work is by nature a collaborative task: it needs the participation of various domain experts that are usually geographically separated. The need of a general interface for a simulator appears obviously. We have illustrated these points by exploring some actual modelling and simulation projects. Different roles and users in a simulation and modelling project also have been identified. We thus have proposed a new meta-model for a simulator, based on the relation between three objects : simulator, role and user. We also illustrate how the meta-model can be used to build a simulator with MIRO model. In the future, we will base on this meta-model to create a methodology for multidisciplinary and collaborative simulation problem.

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