DeCoSim: A method for Collaborative Simulation of Complex Systems

Khanh Nguyen Trong

Abstract— The simulation of complex systems increasingly requires the collaboration of related researchers: domain experts (e.g. experts in the studied domains), modellers and computer scientists. However, the actual methods of modelling and simulation allow to produce only simulators that are used locally and considered as standalone applications. This kind of simulator hampers the exchange of these researchers; especially for the domain experts who are usually geographical distributed and not expert at using support tools. Our research focus on the collaboration among these scientists where many issues need to be addressed, e.g. scenario definition, parameter manipulation and results analysis. In this paper, we thus present a method, namely DeCoSim, supporting the collaboration among different scientists in the simulation of complex systems. A case study related to the modelling and simulation of Intra-Urban Daily Rhythms is presented to show the efficiency of the proposed method.

Index Terms—. Collaborative Simulation, Participatory Simulation, Modelling and Simulation, Collaboration, WSBC, Groupwware

I. INTRODUCTION

Complex systems are systems with multiple interacting components whose behavior cannot be simply inferred from the behavior of the component [1]. These systems are usually qualified as an auto-organization: they produce emergent dynamics that cannot be predicted.

During the study of these systems, various skills and knowledge are usually required, which come from multiple disciplines. Therefore, the collaboration among various domain experts is necessary.

The simulation of complex systems that is considered as playing experiments that use simulators to reproduce dynamics of a complex system [2]. It also implies the negotiation and collaboration among domain experts, modellers, and computer scientists.

Take, for an example, the MIRO [3], [4] project in modelling and simulation of Intra-Urban Daily Rhythms. MIRO resides in sociodemographic discipline: individual daily activities. It is a branch of demography that studies social causes and implications of dynamic populations. It tends to borrow concepts and methods in the sociology, including social relations and generations. Therefore, the project demands the participation of both geographers and sociologists. MIRO is also interested in the distribution of services and its schedule such as restaurants, homes or offices, which requires the participation of economists. Besides, the knowledge of statisticians and computer scientists is necessary for the data processing and construction of computer models as well. In land use modelling and simulation, modelers try to understand the different properties of an urban system such as emergence, self-organization and nonlinear dynamic behavior [5]. Social scientists define it as a specific type of settlement that contains a large population, much diversity of land use and a dense, built-up area. Their collaboration allows them to integrate social science knowledge in terms of land use, demography and governance. Because social science models are indispensable for accurately explaining many processes, such as urban shrinkage [6]. In general, three following activities must be considered [7] in order to support the collaboration: the communication, the coordination and the collaboration. The first one is seen as the exchange of information; the second one is defined as the balanced and effective interaction of actions; and the third one relates to the joint working with another or others on a shared project. However, with the actual methods of modelling and simulation, the simulator is weak in supporting these activities. It is seen as a standalone application which:

- allows only a local manipulation. The players cannot change parameters, run simulations and analyze results from distance.
- has a unique interface for all players, while each one has different concerns, different point of views.
- supports only one interaction at a moment. If someone wants to change a parameter while the simulation is manipulated by someone else, they must wait until the action is finished.

Therefore, in this study, we will propose a method, namely DeCoSim, and tools that allow to identify/support strategies for collaborative simulation. The remainder of this paper is organized as follows. In Section 2, relevant research works are reviewed. In Section 3, our method will be presented. A case study will be illustrated in section 4. Finally, the conclusion of this work is given in Section 5.

II. RELATED WORKS

Recently, there have been many researches interested in supporting the collaboration of domain experts, modellers and computer experts around a simulator, such as [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17] ... Most of them are Web Based Collaborative Simulation (WBCS) that is an integration of web, simulation and collaboration technology.

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WBCS environment has many advantages such as wide usability, cross platform capability, maintainability, and upgradeability. Moreover, it can conveniently realize sharing of model library, collaborative modeling, separated services, and parallel computing [13]. In terms of where simulation & visualization is performed, there are three main categories of WBCS [18]: Local Simulation & Visualization, Remote Simulation & Visualization, and Hybrid Simulation & Visualization. For the first category, simulators and visualization components are downloaded to and run on the client browser. Thus, users do not need to worry about the network latency between user and simulators. But the simulation is dependent on the power of client machine.

In contrast, simulators and visualization components of the second category are stored and run on server side. Web server is used to submit parameters, and results are returned to client when the simulation is completed. The advantages of this approach is the power, high-end computers [13], easy maintenance for developers [20], its capacities of adapting existing simulation products [18]. The most disadvantaged of this approach is that users cannot observe dynamic processes of the simulation execution [21], [20]. They just submit parameters and wait for results as a ”snapshot” view, no interaction with simulators during the execution. The third category combines two of previous approaches in which simulators are stored and run on server side, while visualization/animation engine is delivered to client side during the execution. Therefore, on one hand, it takes advantages of more powerful hardware, maintenance is easier, the server’s workload is reduced, and on the other hand, users can observe the dynamic processes and interact with simulators during the execution. But, this approach can be influenced by network latency, and sometimes we need to install external libraries [20]. The application of WBSC includes military applications, scientific applications, education and training, and manufacturing [11], [29]. All WBCS in the literature fall into the three above categories. We are interested in platforms that is dedicated to research works. For example, with Local Simulation & Visualization (S&V) we have WebSimMIOR [30]; with Remote S&V we have Basic Support Collaborative Work BSCW [9], Web Based Simulation Center WBSC [31], the work of Wang et. al [11], GroupSim [10]; and with Hybrid S&V, we have the work of Wang and Liao [28] (in fact there were not many examples about Hybrid S&V in the literature [18]).

III. DECOSIM: METHOD TO DEVELOP A COLLABORATIVE SIMULATOR

In respect of the existence of different standalone simulators, we need a method to identify strategies of collaboration around them. The new method will mainly be based on modelling and simulation ones, but also relate to engineering software and CSCW (Computer support collaborative work) method. Since, it constructs, on one hand, a computer simulator, and on the other hand, a software supporting collaboration. Based on this literature and also to the response from the first question in the section II, we propose a method to build collaborative simulators, named DeCoSim, which has 5 steps as presented in Fgure 1. The participation of Modellers and Thematicians at all steps is the advantage of our approach. Each step of the process based on meta models and languages understood by both Thematicians and modellers, and on collaborative software tools, which assure the exchange between them. The detail of each step is presented in the following parts.

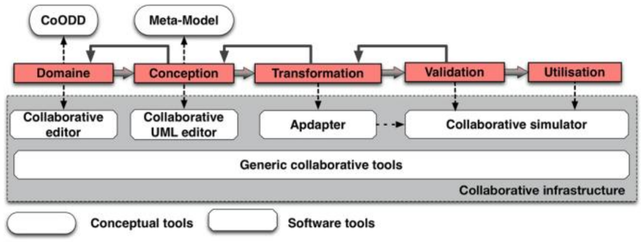

Figure 1. DeCoSim

A. *Creation of the domain model*

The purpose of our domain model is to provide an in-depth comprehension about studied systems. It should contain the information related to collaborations around a simulator. I in order to well describe this collaboration, the domain model must present the exchange around the thematicians, model, simulator, the roles, their experience and object and so on.

In addition, the model will serve as a mean of communication among Stakeholder-Thematicians. Therefore, this model should not be too technical; the suitable forms are natural language description, OWL (Web Ontology Language), or non-formal graphics. But, Stakeholdes-Thematicians usually come from different disciplines which may be not familiar with OWL and non-formal graphics. Thus, we chosen the natural language description for our domain model. In all of these existing approaches, we found that ODD [32] protocol almost responds to our requirement about the domain model. The protocol was introduced to standardize the description of Individual Based and Agent-Based Models (ABMs). It provides a domain expert friendly description to share knowledge about a model by pointing out scientific questions, the studied complex systems, model mechanisms, and so on. ODD protocol distinguishes seven categories, organized into three main groups: Overview, Design concept and Details. Each category determines the topic that designer has to provide. The Overview group has three elements: Purpose, State variables and scales, Process overview and scheduling which give an overview of general purpose and structure of the model. The second block (Design Concept) contains only one element, which talks about the general concepts theories, hypotheses, or modeling approaches of design of model. The Detail part consists of three elements: Initialization, Input, Sub-models which present the details that were omitted in the overview. More detail of ODD protocol can be found in [32]. Regarding to our domain model, ODD satisfies a part of the requirements regarding the information of the model. Therefore, we have extended this protocol to form our domain model: Collaborative ODD – CoODD, as shown in Table 1, more about the protocol can be found at [33].

Overview	Purpose
	State variables and scales
	Process overview and scheduling
Design Concepts	Design Concepts
Detail	Initialization
	Input
	Submodels
Simulator	General information
	Input Parameters
	Output
User's profile	User's profile
Application aspect	Application aspect
Collaboration	Responsibilities
	Collaborator
	Permission
	Collaboration template

Table 1. CoODD

B. Creation of the conceptual model

At this step, the conceptual model is used to support the collaborative development among Modeller-Thematicians and Modeller. It also support Modeller an in-depth comprehension about model. The suitable form of this model is formal graphics, such as UML.

Therefore, we reuse the meta-model proposed in our previous work [34]. A UML model will be created by Modellers. The Modeller-Thematicians help the modellers to analyze and understand the information presented in domain model. There are four kinds of Information which will be clarified: Inputs, Outputs, Roles (also their permission and responsibilities) and Tools. The Inputs and Outputs information is presented in Simulator block of the domain model; the Roles can be found in User's Profile block; and the last one is resulted from analysis of overall the news part of CoODD, particularly the Collaboration block.

A collaborative UML editor, CoUML, is developed to support the modellers in designing, also in exchanging between Modeller-Thematicians. It is inherited from an open-source tool, BeoModeller.

C. Transformation

At this step, the developer will integrate stand-alone simulators into our generic platform PAMS to improve its collaborative utilization. Since PAMS is developed from the idea of the meta-model, therefore the integration is simple.

Firstly, the developer needs to develop a driver that inherits the PamsAdapter. This driver allows PAMS to interact with the simulation platform by which the simulator is implemented. In fact, this step is required if the simulation platform is unknown by PAMS.

Secondly, based on the correspondence between the metamodel and PAMS presented in II, the developer simply puts the right information in the database (the parameters, the roles, the scenarios to execute simulation, the actions and so on) and upload necessary packages to run the simulator on the server platform PAMS:

- Putting the information Core Simulator, Variable and Action into the database of PAMS. It contains the information about model, simulation platform, input parameters, outputs, possible actions. We put also the information of role and participatory scenarios in the database.
- Creating the controllers in Logic Tier of PAMS and the adapter for simulation platform.
- Creating the access tools in Presentation Tier.

In fact, we have to realize only the first task. Because, in PAMS, we designed and developed a mechanism that allows to automatically generate the controllers and access tools based on information in the database. For the adapter, we need to develop only once for each platform.

Actually, the configuration is done manually by the developer. But, through an assistant, this integration can be carried out semi-automatically or automatically.

D. Validation

During this step, the transformed simulator is validated by the Modeller-Thematcians, developer and modellers. If a problem is found in the validation, they will discuss together to determine the error. Then the person who is responsible for the related step, will revise his/her work.

E. Utilization

The simulator is now open to the community and can be used by stackholder-thematicians. Thus, the simulator is accessible by all authorized members via a collaborative web platform PAMS.

IV. CASE STUDY

In this section, we are going to apply the method DeCoSim to create the collaborative simulator MIRO [3, 4].

A. Role of contributors

During the transformation, stakeholder-thematicians who also occupy modellerthematician role are three geographers and two geo-computer scientists. An engineer and a computer expert work as the modeller and developer.

Firstly, with the help of these Thematicians, the computer expert established the domain model CoODD of MIRO. Then, based on meta-model of collaborative simulator and domain model of previous step, a geo-computer and the computer expert designed the conceptual model. Next, as a developer, the computer expert configured the database of PAMS and deployed standalone MIRO simulator on the server of platform. After these steps, the transformed simulator is available on the server. Then, it is simultaneously validated by the the Thematicians. The detail of each step will be presented in the next parts.

B. Establishment of the domain model

The structure of this model has 11 elements as shown in table I. In this article, we present only a resume of the new parts of CoODD: Simulator, User's Profile, Application aspect, and Collaboration.

C. Establishment of the conceptual model

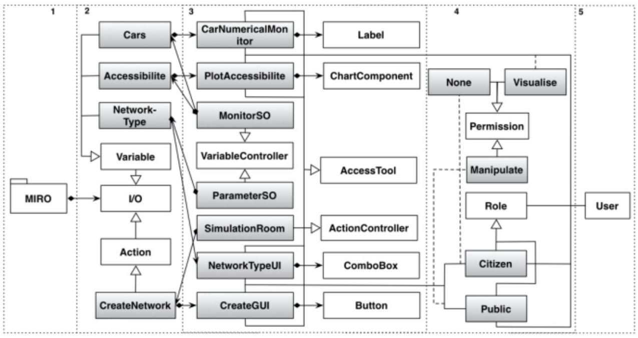

Figure 2. An extract of conceptual model

With the help of a geographer, we designed the conceptual model of collaborative MIRO simulator. From the domain model, input variables are the variables that are present in Input parameters block of Simulator part. Input actions are all buttons and events for interacting with the 2D map. Output variables are specified in Output block of Simulator part. They are usually the monitors that present a numerical value or a graph.

Each parameter, output, and action associate with a controller object (ParameterSO, MonitorSO and SimulationRoom) that informs or updates its status. Each one also contains a GUI that extends from AccessTool.

Based on the domain model of MIRO, we have identified the following roles:

• Planner: This role organizes city, calibrates the roads and controls the speed of mobiles.

• User: This role uses public transportation, moves on roads, etc. specified by Planner.

• Public role: It is a sub-role of the planner who organizes public services. This role can be divided into 3 roles: Road, ZAPA, and Public Transport.

• Economic role: It is a sub-role of the planner who organizes economic services. This role can be divided into Commercial Service, Public Service, and Office

• Citizen role: It is a sub-role of the planner who organizes services for citizen.

Each role has different permissions on the manipulation of parameter, monitor and action. These permissions correspond to their mission and object. For example, the installation of network is the mission of Public role; therefore, he/she gets Manipulate permission for CreateNetwork button. While Citizen role neither do nor see it, he/she gets a None permission. The Cars monitor and Accessibilite graphs are public for all roles, thus Citizen and Public have the same permission: Visualise, as shown in block 4 of Figure 2.

D. Transformation

From the designed conceptual model, as the developer, we integrated the standalone MIRO simulator into PAMS platform. As presented in the previous section, we have developed a dynamic mechanism which allow PAMS to automatically generates the objects in the part 3 of the conceptual model (see **Error! Reference source not found.**).

Therefore, we just map the information in parts 1, 2, 4, 5 of conceptual model into data tier of PAMS. Then, the new simulator is available for our platform PAMS.

E. Validation

After the Transformation step, the simulator is ready to use. A Geographer, a Geo-computer scientist and an Engineer helped me test and validate this new simulator. Several test sessions were organized. Through that some errors were identified.

The result of the case study, Collaborative Simulator MIRO is illustrated as in Figure 3.

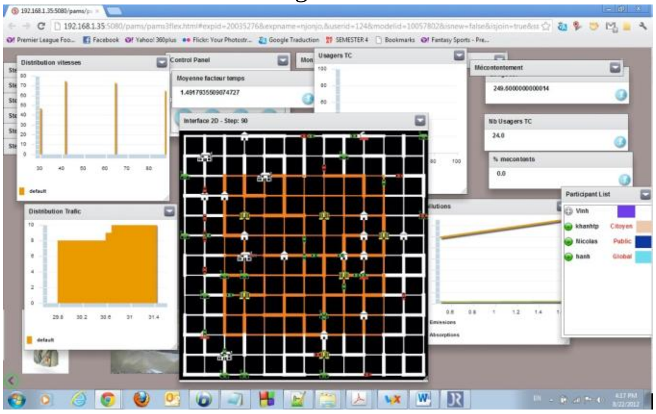

Figure 3. Collaborative Simulator MIRO

V. CONCLUSION

In conclusion, the simulation system of complex system is a work that requires collaboration among the involved researchers. However, due to the difficulties of geographical distance, different culture, experiences, time ... including the lack of specialized support tools. The collaboration among researchers is rare and inefficient. Therefore, in this study we propsed a model supporting remote collaboration between related scientists; (ii) tools/platform that relies on the open source solutions, supporting collaborative work in simulation. Besides, we also standardize a method that allows the creation a collaborative simulator, from a problem and an existing model. This simulator, on one hand work as a normal computer simulator (run the simulation process); on the other hand, it is also considered as a collaborative tool supporting collaboration in changing the input parameters, definition of scenario, analysis outputs and so on

REFERENCES

1. P. B. Silva, A. Coelho, and R. J. F. Rossetti, “A collaborative environment for urban landscape simulation,” in *Proceedings of the 2012 IEEE 21st International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*, ser. WETICE ’12. Washington, DC, USA: IEEE Computer Society, 2012, pp. 256–261. [Online]. Available: http://dx.doi.org/10.1109/WETICE.2012.13
2. J.-P. Treuil, A. Drogoul, and J.-D. Zucker, *Modélisation et simulation à base d’agents: Approches particulaires, modèles à base d’agents, de la mise en pratique aux questions théoriques*. Dunod, 2008.
3. S. Chipeaux, F. Bouquet, C. Lang, and N. Marilleau, “Modelling of complex systems with AML as realized in MIRO project,” in *Proceedings of the 2011 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology - Workshops, WI-IAT 2011, Campus Scientifique de la Doua, Lyon, France, August 22-27, 2011*, 2011, pp. 159–162. [Online]. Available: http://dx.doi.org/10.1109/WI-IAT.2011.195

4. P. Fosset, A. Banos, E. Beck, S. Chardonnel, C. Lang, N. Marilleau, A. Piombini, T. Leysens, A. Conesa, I. Andre-Poyaud, and T. Thevenin, “Exploring intra-urban accessibility and impacts of pollution policies with an agent-based simulation platform: Gamirod,” *Systems*, vol. 4, no. 1, p. 5, 2016. [Online]. Available: http://dx.doi.org/10.3390/systems4010005
5. R. Schaldach, J. Alcamo, J. Koch, C. KAlking, D. M. Lapola, J. SchAngel, and J. A. Priess, “An integrated approach to modelling land-use change on continental and global scales,” *Environmental Modelling & Software*, vol. 26, no. 8, pp. 1041 – 1051, 2011. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1364815211000570
6. D. Haase, A. Haase, N. Kabisch, S. Kabisch, and D. Rink, “Actors and factors in land-use simulation: The challenge of urban shrinkage,” *Environmental Modelling & Software*, vol. 35, no. 0, pp. 92 – 103, 2012. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1364815212000606
7. S. J. E. Taylor, S. Robinson, and J. Ladbrook, “Towards collaborative simulation modelling: Improving human-to-human interaction through groupware,” *In Proceedings of the 17th European Simulation Multicon- ference (ESM 2003)*, pp. 474–482, 2003.
8. C. Bravo, M. A. Redondo, M. Ortega, and M. F. Verdejo, “Collabo- rative distributed environments for learning design tasks by means of modelling and simulation,” *J. Netw. Comput. Appl.*, vol. 29, no. 4, pp. 321–342, 2006.
9. [A. Korichi and B. Belattar, “Towards a web based simulation group- ware: Experiment with BSCW,” *Information Technology Journal*, vol. 7, no. 2, pp. 332–337, 2008.
10. W. A. Filho, C. M. Hirata, and E. T. Yano, “Groupsim: A collaborative environment for discrete event simulation software development for the world wide web,” *SIMULATION*, vol. 80, no. 6, pp. 257–272, 2004. [Online]. Available: http://sim.sagepub.com/content/80/6/257.abstract
11. H. Wang and H. Zhang, “Using collaborative computing technologies to enable the sharing and integration of simulation services for product design,” *Simulation Modelling Practice and Theory*, vol. 27, no. 0, pp. 47 – 64, 2012. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1569190X12000664
12. K. T. Nguyen, V. T. Ho, and M. Nicolas, “Pams – a new collaborative framework for agent-based simulation of complex systems,” in *Lecture Notes in Computer Science*. Springer Berlin / Heidelberg, 2008, pp. 287–294.
13. X. Yin, Y. Wu, Q. Liu, and S. Wang, “A web-based, collaborative modeling, simulation, and parallel computing environment for electromechanical systems,” *Advances in Mechanical Engineering*, vol. 7, no. 3, p. 1687814015571226, 2015. [Online]. Available: http://dx.doi.org/10.1177/1687814015571226
14. C.-M. Lorenzo, “Teacher’s skill improvement by role-play and simulations on collaborative educational virtual worlds,” *Journal of Educational Computing Research*, vol. 50, no. 3, pp. 347–378, 2014. [Online]. Available: http://dx.doi.org/10.2190/EC.50.3.d
15. M. Marinelli, V. Positano, V. Lorenzoni, C. Caselli, M. Mangione, P. Marcheschi, S. Puzzuoli, N. Esposito, G. A. LAbbate, and D. Neglia, “A modular informatics platform for effective support of collaborative and multicenter studies in cardiology,” *Health Informatics Journal*, vol. 22, no. 4, pp. 1083–1100, 2016, pMID: 26547889. [Online]. Available: http://dx.doi.org/10.1177/1460458215609743
16. [M. D. Benedetti, F. Messina, G. Pappalardo, and C. Santoro, “Web-based simulations of multi-agent systems,” *SIMULATION*, vol. 0, no. 0, p. 0037549717706198, 0. [Online]. Available: http://dx.doi.org/10.1177/0037549717706198
17. S. Y. Diallo, R. Gore, J. J. Padilla, H. Kavak, and C. J. Lynch, “Towards a world wide web of simulation,” *The Journal of Defense Modeling and Simulation*, vol. 14, no. 2, pp. 159–170, 2017. [Online]. Available: http://dx.doi.org/10.1177/1548512915621974
18. J. Byrne, C. Heavey, and P. Byrne, “A review of web-based simulation and supporting tools,” *Simulation Modelling Practice and Theory*, vol. 18, no. 3, pp. 253 – 276, 2010. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1569190X0900149X
19. S. Narayanan, “Web-based modeling and simulation,” in *Simulation Conference, 2000. Proceedings. Winter*, vol. 1, 2000, pp. 60–62 vol.1.
20. D. S. Myers, “An extensible component-based architecture for web- based simulation using standards-based web browsers,” Master’s thesis, 2004.
21. [L. Peter, J. Thomas, D. Heiko, and R. Klaus-Christoph, “Towards a web based simulation environment,” in WSC ’97: Proceedings of the (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. XXX, No. XXX, 2017 Washington, DC, USA: IEEE
22. L. Whitman, B. Huff, and S. Palaniswamy, “Commercial simulation *29th conference on Winter simulation*. Computer Society, 1997. over the web,” in *Simulation Conference Proceedings, 1998. Winter*, vol. 1, Dec 1998, pp. 335–339 vol.1.
23. S. Fortmann-Roe, “Insight maker: A general-purpose tool for web-based modeling & simulation,” *Simulation Modelling Practice and Theory*, vol. 47, pp. 28 – 45, 2014. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1569190X14000513
24. M. North, N. Collier, and J. Vos, “Experiences creating three imple- mentations of the repast agent modeling toolkit,” *ACM Transactions on Modeling and Computer Simulation*, vol. 16, no. 1, pp. 1–25, 2006.
25. E. Amouroux, C. Quang, A. Boucher, and A. Drogoul, “GAMA: an environment for implementing and running spatially explicit multi-agent simulations,” in *10th Pacific Rim International Workshop on Multi- Agents (PRIMA)*, Thailand, 2007.
26. U. Wilensky and I. Evanston, “Netlogo. center for connected learning and computer based modeling,” Northwestern University, Tech. Rep., 1999.
27. S. J. E. Taylor, A. Khan, K. L. Morse, A. Tolk, L. Yilmaz, and J. Zander, “Grand challenges on the theory of modeling and simulation,” in *Proceedings of the Symposium on Theory of Modeling & Simulation - DEVS Integrative M&S Symposium*, ser. DEVS 13. San Diego, CA, USA: Society for Computer Simulation International, 2013, pp. 34:1–34:8. [Online]. Available: http://dl.acm.org/citation.cfm?id=2499634.2499668
28. Y.-H. Wang and Y.-C. Liao, “Implementation of a collaborative web- based simulation modeling environment,” in *Distributed Simulation and Real-Time Applications, 2003. Proceedings. Seventh IEEE International Symposium on*, Oct 2003, pp. 150–157.
29. J. Kuljis and R. J. Paul, “An appraisal of web-based simulation: whither we wander?” Simulation Practice and Theory, vol. 9, no. 12, pp. 37 – 54, 2001. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0928486901000325
30. K. T. Nguyen, G. Benoit, H. T. Vinh, and M. Nicolas, “Applica- tion of pams collaboration platform to simulation-based researches in soil science: The case of the micro-organism project,” in IEEE- RIVF International Conference on Computing and Telecommunication Technologies. IEEE-RIVF, 2009.
31. J. Henriksen, P. Lorenz, A. Hanisch, S. Osterburg, and T. Schriber, “Web based simulation center: professional support for simulation projects,” in Winter Simulation Conference (WSC’02), vol. 1, 2002, pp. 807 – 815.
32. V. Grimm, U. Berger, D. L. DeAngelis, J. G. Polhill, J. Giske, and S. F. Railsback, “The odd protocol: A review and first update,” Ecological Modelling, vol. 221, no. 23, pp. 2760 – 2768, 2010. [On- line]. Available: http://www.sciencedirect.com/science/article/B6VBS-510VJGG-1/2/a811be596d4e7965be4265dee29e9b0d
33. Trong Khanh Nguyen, Nicolas Marilleau, Tuong Vinh Ho, and Amal El Fallah. 2013. Method supporting collaboration in complex system participatory simulation. In Proceedings of the Fourth Symposium on Information and Communication Technology (SoICT '13). ACM International Conference Proceeding Series, New York, NY, USA, 61-70. DOI=http://dx.doi.org/10.1145/2542050.2542076 (Scopus index)
34. T. K. Nguyen, N. Marilleau, T. V. Ho and A. E. F. Seghrouchni, "A Meta-Model for Specifying Collaborative Simulation," 2010 IEEE RIVF International Conference on Computing & Communication Technologies, Research, Innovation, and Vision for the Future (RIVF), Hanoi, 2010,pp.1-4.doi:10.1109/RIVF.2010.5634008

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