Human/Simulation interaction on Complex Systems. Visualization and decision support

Mid-Term Report

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This thesis, directed by Pr. Alexis Drogoul, co advised by Pr. Jean-Daniel Zucker, Pr. Ho Tuong Vinh and Pr. Bui The Duy, is part of the framework of the usage of complex and multi-scale models for environmental decisions support using modelling and simulation tools. It studies the role of visualization and interaction in human-computer interface on the study of complex systems, more especially agent-based model (a class of computational model for simulating the actions and interactions of autonomous agents). Agent-based model (ABM) plays a key role in an increasing number of approaches addressing the modeling of complex systems. The new requirements for high-level realistic visualization and online analysis tools raise key issues that are yet unsolved: how to explore, visualize and communicate agent-based models as they are used more and more in the spatial domain. The first results of this thesis are applied in applications on which UMI 206 UMMISCO/IRD is working on (e.g fight against the invasions of brown grasshoppers in the delta Mekong, assistance on conception of planning of territory policies introduced by climate change) with different partners, among which, the Institut Francophone pour l'Informatique (IFI), the Vietnam National University of Hanoi (VNU) and the University of Can Tho with the DREAM team associated to the IRD.

1 Introduction

Spatially explicit agent-based models and simulations are playing an increasing role in the modeling of natural and social complex systems. The size of the resulting models and the number of interacting processes they encompass raise a number of issues, among which the observation and understanding of their dynamics by users. Supporting multiple viewpoints and multiple levels of observation has thus become an essential activity in the development of complex agent-based models [6, 12]. Human integration through visual technics leads to a faster data exploration, better results and more accurate feedback between the user and the model (see Figure 1).

However recent academic research failed in this direction. Most of the proposals rely on ad-hoc approaches that embed the definition of levels and viewpoints in the models

themselves [2], making them difficult, if not impossible, to change and to reuse in other models [1]. In ABM, which is by definition a mixture of different entities at different levels of organization, visualizing structures emerging as a result of the interactions among the components of the system is one of the hardest challenges for research in information technology [4]. If new research has been produced considering entities at different levels and focusing on how to describe their articulation and influence there is still a lack of generic integrated analysis and visualization tools running online (the existing one [8] are not always accessible for non-expert user). Bringing 3D to agent-based can be achieve in two ways but there is still a lack in that domain [3]. The first one is to couple an agent-based platform (Netlogo [11], Repast [7]) with a 3D visualization toolkit. The second one is to build an agent-based models in 3D animation and rendering packages or virtual environment.

To overcome this limitation, our work proposes solutions and tools to advocate the visual model exploration by using visualization and interaction tools in the modeling process. We introduce a framework based on the notion of *pluggable* observer agents, which can be added to or removed from any model without disturbing its functioning to support the definition of flexible, adaptable and reusable visualization components. We take advantage of the third dimension to represent and enhance ABM simulation using abstraction concept (clustering, spatio-temporal aggregation, multi-layer representation, etc). Such an approach facilitates the online data analysis using different level of layer representation and to do simulation assessment and scale up by representing emergent structure during the simulation [9]. The framework has been implemented in the agent-based simulation platform Gama [5, 10] and evaluated by plugging observer agents provided with spatio-temporal aggregation operators into different existing models.

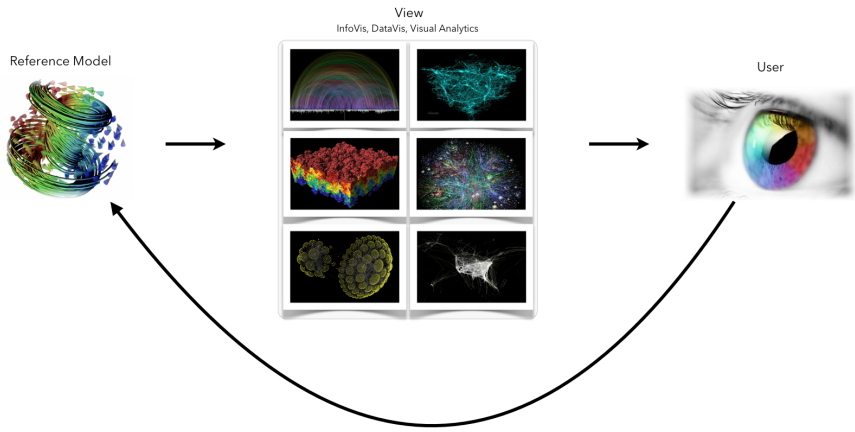

Figure 1: Smart visual information, combined with user interaction, can support users in making sense of large amounts of information.

2 Material and Methods

Our work is divided in three main steps. (i) set an experimental environment around the model and the simulation to understand model dynamic thanks to a visual feedback and interaction. (ii) separate the execution of the simulation and its representation. (iii) propose a new way to abstract and generalize dynamics by using dedicated graphical agent and data-mining tools for multi-level online data analysis.

2.1 Virtual experimental environment around the model

An immersive experimental environment allows connection between modelers and their models and the data being explored. In most of the interactive process user adjusts visualization parameters, interacts with the visualized objects and scenes by the use of basic manipulation such as selection, translation or rotation, extracts feature from the original dataset and finally modifies the data to be visualized.

To provide the user the most immersive environment when visualizing and interacting with its model, the use of high-performance graphics library is required and our choice naturally went to the use of OpenGL library for its high-performance and its cross-platform capabilities. In such an environment the user can observe, manipulate or alterate the model at any timestep of the simulation. Such representation constitutes a miniature laboratory where the attributes and behaviour of agents, and the environment in which they evolved, can be altered, experimented with, where their repercussions are observed over the course of multiple simulation runs. The model is included in a 3D scene with a camera used to reach any point of the model and to provides the most immersive experience (See Figure 5). In the modeling process, vector data are used as input/output. Primitive shapes (point, line, polygon) are manipulated through basic mathematical operations used to control, transform(translate,rotate,scale) and combine properties of visual elements to describe dynamics properties (size,texture, shape, orientation, color, text). Conditional structures are then used to control the flow of the program (relational, conditional, logical) and can finally be inserted in iterative structures.

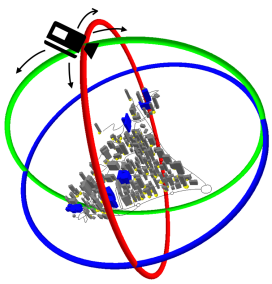

Figure 2: Represent, Abstract, Interact

2.2 A Model-View/Controller approach to separate the visualization and the execution of agent-based simulations

As in software engineering, the execution of simulations and their visualization need to be separated to allow different viewpoints and analysis processes. The main goal of our approach is to offer modelers a simple way to do so on a reference model whose reference system is any real domain (complex system, biological, etc.). In that kind of model it is not natural to add representation or interaction element because those element do not represent entity or concept of the given domain but notion linked to other domain. Thus, view model are built on top of a reference model to easily represent abstract data coming from the simulation above the proper model representation using a dedicated agent-based language (GAML). View models are agent-based models whose reference system is another model and where the tasks of agents are to represent visual information to users. These view models allow to extract knowledge from running simulations, for example by representing interactions and macro structures. These view models use proxy agents (delegation pattern), whose visual representation evolves without changing the model represented. Agents in view models can also be used to represent abstract properties of agents in the reference model(s). Finally, view models can wrap controllers, which support user interaction with the reference model.

In this mind building a visualization is like building a view model on top of the reference model itself where it becomes easy to isolate key agent of the reference model (proxy agent) to build new view model without altering the reference model. With this approach, the reference model is not aware of the model build on top of it and many models can exist on top of a reference model in order to represent it in different way by using successive level of abstraction as shown in Figure 2.

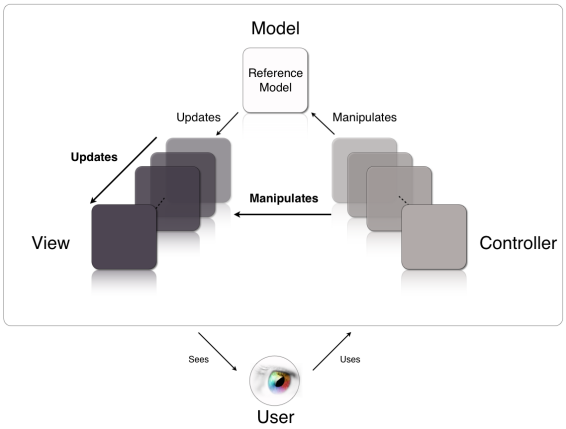

Figure 3: We propose an approach based on the MVC (Model View Controller) pattern, where all the concepts are built using agents

2.3 Abstraction and generalization: Multi-Level Online Data Analysis and Visualization

Agent-Based Simulations generate massive loads of data, which are usually analysed at the end of simulations in a batch manner. In large scale model it is hard to have a clear idea of all the interactions occurring between agent. Interaction analysis is part of the different frameworks to explore a complex systems where macro-level dynamics and structure are caused by the interactions of a relatively high number of agents. While we traditionally work with two-dimensional static representation, modern technology allows us to work with three-dimensional dynamic one. We propose a framework for Multi-Level Online Data Analysis and Visualization (MODAVI), an exploratory tool to address the problem of online analysis and data abstraction during an ABM simulation. The MODAVI approach supports representing the interdependence between various interacting entities to be observed as abstract agent. Such an online mining tool may be used to explore any kind of interaction between agents. MODAVI is at the boundary between visualization and analysis as it describes and represents indicator to both assess and explore a model. It goes beyond visualization as the information displayed is the result of mining algorithms such as clustering that are performed on the stream of data from the ABM simulation. This tool provides new exploration capabilities and strategies to generate, analyze and visualize a large amount of alternative simulation experiments.

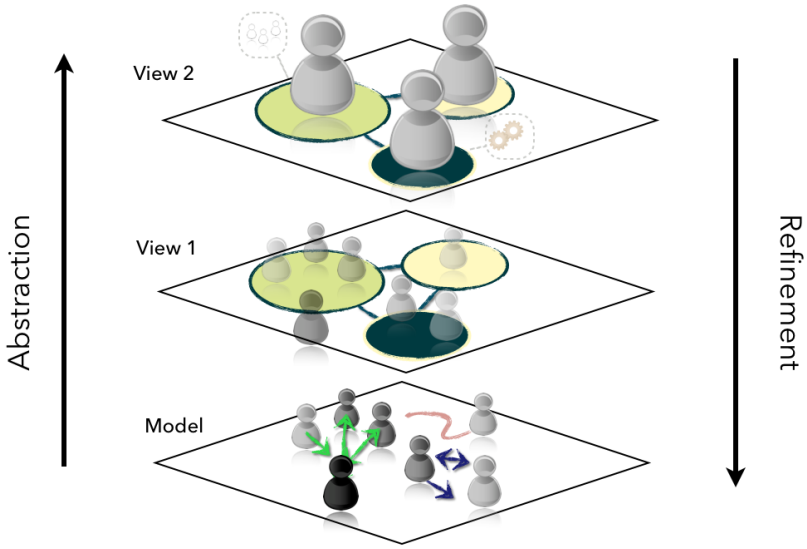

Figure 4: Use multi-layer to represent different level of abstraction. Operators are used to make information less detailed (hiding elements of a system description) or to mask informations (building equivalence classes of elements, generating hierarchies of elements descriptions, combining existing elements into new ones)

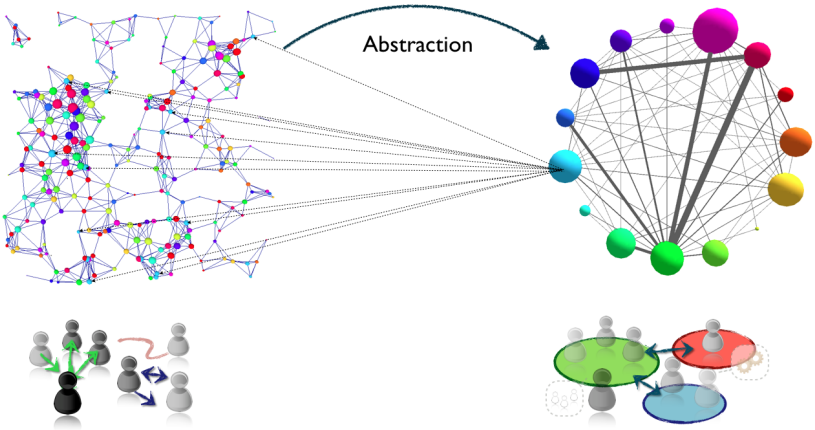

Figure 5: View Model 1: A graph representation of a running simulation where nodes and edges are agents. View Model 2: a graph representation abstracting some features of the previous one where nodes and edges are other agents

3 Results

Once integrated in the GAMA simulation platform, our work has been successfully applied in different domains. One of the actual big challenge we are currently working on, is the reconstruction and the digitization of historical phenomenon in the city of Hanoi at the beginning of the 20th century. The aim of this project is to understand the decision that has been taken during those exceptional events and especially to understand the role of a given part of the political actors implied in the decision process. In this application, GIS data are coupled with historical data and then integrated in our ABM platform to produce knowledge in a new manner. The main goal of this project is to understand the event that appears during the big flood in 1926 by modelling river, dykes and the political actor behavior during this event.

The contribution of this thesis in this work starts from the realistic rendering of the city of hanoi as shown in Figure 6 using GIS data, map digitization, digital model elevation and population data to recreate the property of Hanoi in 1926. Another contribution is the possibility to interact with the simulation at runtime to see for instance the impact of a dyke breaking by just clicking on it to break it, or the impact of the construction of dykes by adding non existing dyke on a given part of the river. Finally, the multi scale online analysis MODAVI has been applied on the representation of the flow of message occurring during the flood event. Messages coming from different parts of the administrative hierarchy is represented as a new layer on the already existing representation of the city as shown in figure 6 where aggregated and instantaneous graph are displayed on top of Hanoi map. This work has been done in closest collaboration with historian that were not familiar with modelling process and our approach to propose 3D interactive environment where agent can evolve promises to be a challenging but prolific approach.

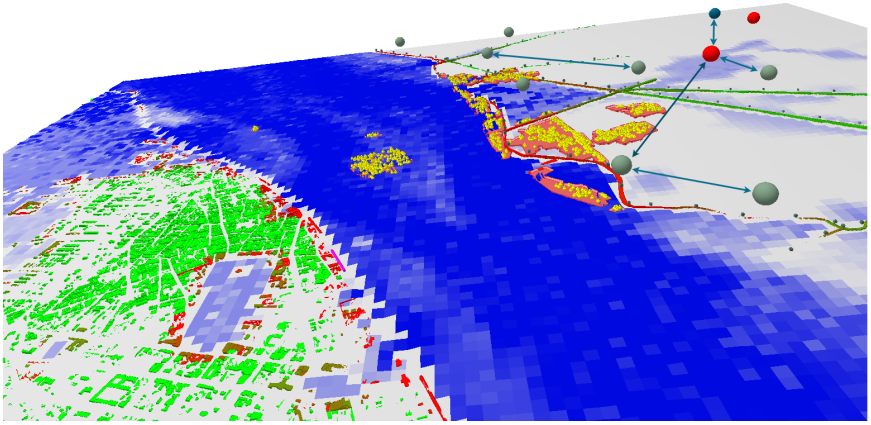

Figure 6: ARCHIVES PROJECT

4 Progress

The thesis started in October 2011. The first months spent in France have been dedicated to bibliography and to the identification of new HCI tool to interact in an original way with a dynamic content among them the simulation platform Gama. Since January 2012, a collaboration has been elaborated at the Institut Francophone pour l'Informatique in Hanoi. The main part of the work consists in the development of a multi-platform 3D library integrated as a plugin in Gama. During this period, mainly effectuated in Hanoi, collaborations have been done with people from Can Tho university working on applied models such as brown hopper invasion in the mekong delta and its hydrological modelisation. This exchange has made emerged new needs in term of visualization and are currently developed in Gama. The first version of the 3D library has been successfully integrated and tested in the Gama 1.5 version. Since september 2012, in addition of the work spent to enhance the 3D library for the version 1.6, we are working on more elaborated abstraction integrated tool integrated using GAML language to enable the user to specify more specific and complex needs. We also work on graph representation and its usage in multi scale online analysis and visualization of interaction that can appear between entities. The second year has been successfully dedicated to the writing of article that has been accepted in different international conference (see Publications). In addition of the article a demo video presenting the main Gama feature has been accepted in two main conference in autonomous agent AAMAS 2013 and artificial intelligence IJCAI 2013. The project ARCHIVES mention above has been started in March 2013 and most of the effort has been spent on new visualization feature developpement specific for this project and the first result has been successfully applied in a summer school in Dalat in July 2013. The future work of the thesis has to face different challenges to provide new mappings for fundamental visual data exploration (3D space navigation, select objects or subspaces); applied those interaction techniques to different variety of scientific domains and above any complex simulation and develop collaborative and immersive environment with HPC.

Publications

- **A. Grignard**, A. Drogoul, and J-D. Zucker. A Model-View Controller approach to support visualization and online data analysis of Agent-Based Simulations. RIVF 2013 (to appear)
- **A. Grignard**, A. Drogoul, and J-D. Zucker. Complex Systems Simulation Online Visual Analysis and Assessment using dynamic aggregation operators. SoCPaR 2013 (to appear)
- **A. Grignard**, P. Taillandier, B. Gaudou, D-A. Vo, N-Q. Huynh, A. Drogoul. GAMA 1.6 : Advancing the art of complex agent-based modeling and simulation. PRIMA 2013 (to appear)
- **A. Grignard**, A. Drogoul, and J-D. Zucker. Online Analysis and Visualization of Agent Based Models. Computational Science and Its Applications. ICCSA 2013. Springer Berlin Heidelberg, 2013. 662-672.
- A. Drogoul , E. Amouroux, P. Caillou, B. Gaudou, **A. Grignard**, N. Marilleau, P. Taillandier, M. Vavasseur, D-A. Vo, and J-D Zucker. "GAMA : a spatially explicit, multi-level,agent-based modeling and simulation platform (demonstration)" in PAAMS 2013.
- A. Drogoul , E. Amouroux, P. Caillou, B. Gaudou, **A. Grignard**, N. Marilleau, P. Taillandier, M. Vavasseur, D-A. Vo, and J-D Zucker . "GAMA : multi-level and complex environment for agent-based models and simulations (demonstration)", demo track in AAMAS 2013.

Communications

- A. Drogoul, **A. Grignard**, E. Amouroux, P. Caillou, B. Gaudou, N. Marilleau, P. Taillandier, D-A Vo, J-D Zucker. GAMA : multi-level and complex environments for agent-based models and simulations (demonstration). AI Video Competition, IJCAI 2013.
- **A. Grignard**, E. Amouroux, A. Drogoul et J-D .Zucker. "De la visualisation avancée à l analyse temps réel de modèles à base d agents", Workshop SimTools 2013.
- **A. Grignard**, A. Drogoul, J-D. Zucker, Using high-level 3D Graphics library in agent-based simulation platform. New Directions in Agent Research Workshop , KES-AMSTA 2013.

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