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Using high-level 3D Graphics library in agent-based simulation platform

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Abstract. Agent-based modeling is used to study many kind of complex systems in different fields such as biology, social simulation or optimisation problems. Visualization of the execution of a such complex systems is crucial in the capacity to apprehend its dynamics. The always increasing complexification of the requirement asked by the modeller has highlighted the need for more powerful tools to represent and visualize simulation at different spatio-temporal scale on different architectures. The techniques available for visualization of model execution enhances the capacity to interpret, understand and explore a model, in particular to extract abstract data or discover imperceptible dynamics. In this paper, after presenting the apport that can provide a high-level graphic library in the understanding of complex systems, we present the feature made available by the latest technologies integrated in an agent-based simulation platform, GAMA.

Keywords. Agent-based modeling, visualization, interaction, 3D, real-time rendering

Introduction

Computer simulation enables to understand our physical world and opens new field such as communication, social network that are now impossible to conceive without a computer [1]. In this context, Agent-Based Model (ABM) community, which is a subset of the greater simulation community[2], has a big role to play in a better understanding of everyday life system especially in social and economics systems[3]. This understanding is facilitated by the use of generic and immersive methods to visualize and interact with a model. With the recent advanced in computer graphics, people are more and more used to handle realistic representation of natural behavior and manipulate them through different kind of interface starting from a computer screen to an embedded systems such as smartphone or other pads. In the context of simulations, and especially agent-based simulation, using a high level 3D graphics library enables first to provide a more immersive experience with a new dimensions to present results secondly to handle a huge amount of agent compared to basic graphics library and finally to allow a high level of precision dealing with vertex in 3D defined with floating point. Those tools has two purposes a) it helps the modeller in the task of modelisation, b) facilitates decision makers tasks by offering them the possibility to visualize and interact with the simulation. It is therefore surprising that, in agent-based simulation platform, few tools exist to help visualize simulations in a standardized, interactive and immersive way whatever the medium used (computer, embedded systems, etc.). In already existing platforms (NetLogo, StarLogo, Mason, Repast, Swarm, Anylogic), language for visualization exist [4] but most of them lack tools for building,observing and interacting with models [5]. Unfortunately, the representation only stay focus on the agent representation and do not propose any abstraction and multi-level representation or only by using ad-hoc solution and post simulation treatment not yet standardized.

The already existing platform Gama [6], an agent-based, spatially explicit, modeling and simulation platform proposes new tools to visualize and interact with a simulation. Those tools use the latest available technologies in terms of visualization and interaction offered by the OpenGL Framework [7]. We present here the latest tools developed in Gama version 1.6. The results presented below have been successfully implemented in the Gama platform [12]. Gama is an open-source simulation platform for building spatially explicit agent-based simulations that provides a rich, yet accessible, modeling language based, GAML (GIS & Agent-based Modeling Language), that allows to define complex models integrating entities at different level of hierarchy [13]. Gama is deployed across heterogeneous platforms, supports a variety of renderers (e;g OpenGL via JOGL, mobile devices via WebGL and JavaScript) and interaction paradigms (e.g mouse-based or touch-based interaction).

1. New way to visualize agent-based model

Building a visualization is like building a visualization model on the model itself and the construction of this ”visual” model need its own language and need to be independent of the execution of the model. A dedicated language for visualization allows to describe graphical primitive (from simple geometry to more complex objects) to construct a sensitive representation of the model, allowing feedback on the model and its dynamic from the visualization, and offering modellers a simple way to declare it. A complete understanding of a model cannot be dissociated from (1) basic visualization concepts, such as: overview, zoom and filter, details on demand. (2) basic interaction concepts to help the user to adjust the model during the simulation through the use of probes, dynamic filtering, highlighted details and different level of details representation [10]. Above the model representation, a model is included in a scene which is completed by at least one camera position (a viewpoint), its orientation, its field of view and a description of different phenomenon such as lighting, shading, transparency with a given resolution both in time and space [11]. We present here our approach using computer graphics and visualization concept starting from geometric representation of 2D and 3D object in a 3D environment to graph visualization, digital elevation model, GIS data integration and multi-level representation. The different techniques described below, implemented in the platform Gama, not only helps the user (modeller or decision makers) to build aesthetic visualization (which is hard to systematize) but also offer most of the common metaphors for visualizing agent-based models.

From Data to Form

We use GAML as a Domain Specific Language (DSL) to encapsulate a set of visualization concepts that extend the already existing agent-based language. In Gama, primitive shapes are manipulated through basic mathematical operations used to control, transform 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 and can finally be inserted in iterative structures. Vector data are used as input/output of the simulation and can be modified by the use of operator to compute distance, surface, geometry intersection, union and other spatial algorithm.

Once agent aspect have been defined GAMA creates a 3D scene and displays all the agents present in the model with their respective aspect on different layer. Any location in the model, therefore any agent, can be reach thanks to Arcball Camera that enables to rotate the model in the three dimensions by using the mouse [14] and zoom in/out. Any agent can be selected by the use of either the selection or picking tools. The focus tool enables to reach directly a given agent knowing its id or name. The layer control is a smart way to make visible layer or not in the 3 dimensions. Finally when a user wants to share his work or record a given step of the simulation with a given point of view the snapshot tool is here to capture the model at a given spatio-temporal step. All the features described above are summarized in figure 1.

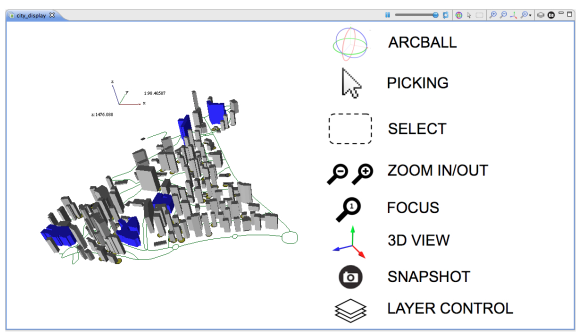

Figure 1. GAMA Graphical User Interface

Integration with GIS Data

A large scale of geographical vector datasets are now available and used to face problem that integrate spatial dimension. Using this type of data is now often required to make the simulations closer to the field situation and allows to use tools, like spatial analysis, coming from Geographic Information Systems (GIS) to manage these data. In Gama, any geographical object can be consider as an agent with its own internal state and behavior and it can go further by easily converting any agent to a geographical object by spatializing it. Some of the already existing platform support geographical data [15] but GAMA offers much more in term of GIS services and in operations on geographical vector data [12]. We use functions from GeoTools (a Java GIS software library) to import and export data and Java Topology Suite (JTS) for Data manipulation. As the integration of GIS data is seamless and straightforward it is very easy to develop model mixing data coming from GIS and built-in agent in a 3D environment like any other platform. Figure 2 is an illustration of the mixing of GIS data (city transport network) with the integration of building agent.

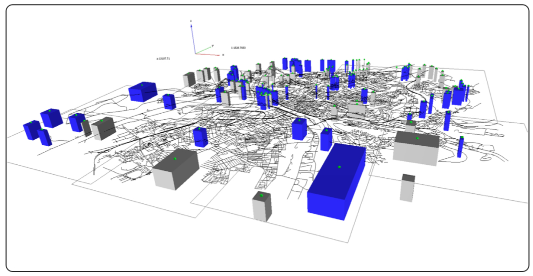

Figure 2. GIS integration in ABM

Graph Agentification

With the increase of study on real world or synthesis network over the past ten years (e.g scale free network [16]), graphs are now part of the ABM paradigm. Graphs offer a powerful way to represent structured data and can be used for different purpose in the field of pattern recognition and machine learning and are essential to manage, process and analysis huge amount of data [17]. They provide powerful tools for analysis through visual exploration, discovery of patterns, correlation and abstraction. Above the classical usage of graph through well known indicator such as diameter, degree distribution, clustering coefficient, Gama goes beyond , as for GIS data, with the agentification the graph by giving states and internal behavior both to node and edge. In a multi-level agent based graph, a graph at a given level can be considered as a node of a higher level graph.

Multi-Level Modeling

Complex system is by definition mixing different entities at different levels of organization and the visualization of those different level is crucial for the good understanding. Recently new research has been produced in considering entities at different levels [18]. This approach focus on how to describe the articulation and influence of different levels. In this kind of approach, a powerful visualization toolkit is, among other statistic tools, one of the more intuitive way to understand, describe and perceive the multi-level paradigm. Gama meta-model has been design to take in account simultaneously several levels in the same model [13] , and we are working on the way to visualize those different spatio-temporal scale. The 3D integration in GAMA not only enables to move and manipulate the world (the model) in an interactive and intuitive way but also provides new way to visualize it. Indeed, we can easily represent multi-level model using multi-layer rendering. Layer can be then placed on different z value as shown in figure 3 and thus representing different levels.

2. Usability and Results

GAMA is being used as a decision-support tool for natural resource management in the MAELIA [19] project. This project aims at studying the social, economic and ecological impact of water management in the Adour-Garonne Basin (France). To this purpose it

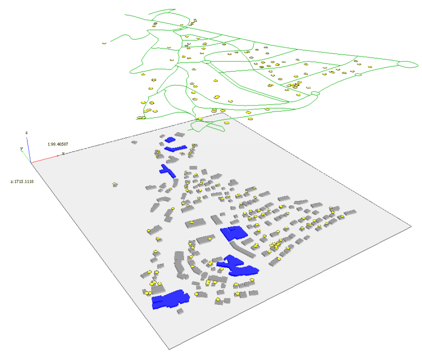

Figure 3. Multi-Level 3D representation.

needs to integrate a huge amount of geographical data that cannot be understood without advanced visualization features. In particular, to visualize various views of the same model with georeferenced or aggregated data and to display at the same time the areas with water lacks, the agricultural activities and the plant growth states with a spatial representation and time series of water flows aggregated at the level of the whole basin. GAMA is also used as a decision-support tool for studying daily urban dynamic in the MIRO project [20]. The Miro model addresses the issue of sustainable cities by focusing on one of its very central components, daily mobility. ABM has been developed and applied to Dijon and Grenoble in France. In this application we imagine 3D visualisation associating data, space and time such as proposed in time-geography domain. Proposing this kind of visualisation in the simulation will open new perspective of the geography domain.

3. Conclusion

3D technologies and high-level graphics library both open new way to develop and visualize agent-based model. They are essential for a better design of model but also to a better understanding and spreading of models. We have shown here the latest tool developed and implemented in GAMA. In future work we'd like first to improve our visualization interaction library by providing more efficient rendering and a more flexible language to use it, secondly to work on method that enhance the understanding of a simulation by displaying meta data above a simulation. Future work will focus on the new way to share simulation where a model could be played at runtime (online) or in a replay mode (offline) and where any agent can be inspected at any spatio-temporal scale during the simulation on different devices such as computers, embedded devices.

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