Modelling of complex systems with AML as realized in MIRO project

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***Abstract*—In this paper, we propose a modeling approach for a spatial complex system. The targeted system is the city with its mobility patterns. The goal of MIRO project is to study service accessibility in the city. In fact, we simulate the city with multi-agent systems using them to represent each part of the system (individuals, buildings, streets, ...). The MIRO team is composed by scientists of several domains (computer sciences, geography or economy), so we want to construct a model of the city to share knowledges of each domain. The next step, we will use verification approach in order to validate the model and then the simulator because we want to generate simulator from model.**

Thus, we propose a method for modeling such complex system. This method is based on AML (Agent Modeling Language) that is a language well adapted for modeling multi-agent systems. We, then, present a spatial AML meta-model coupled with a method. The use case is the MIRO project.

***Keywords*-Simulation; agenda; model; Multi Agent System;**

I. Introduction

We think that the town and its mobility patterns is a complex system: it is constituted of numerous distributed entities with their individual behaviour and the interaction of these entities raise a global behaviour that is not predictable.

In this article, we propose to use a modeling approach to describe a complex system. The system simulates daily mobility in the real city described into the Miro project[1]. The choice of model is a critical element of the project because model can be used as a shareable artefact between scientists of several domains (topology, geography or economy). A second topic of the project is to propose a verification method for the multiagent system. This verification will help the validation of the model and then allow the simulation. In this article, we address the model aspect.

A. Computer sciences modeling point of view

The modeling is a good practice to describe a system. Model allows to give more explicit elements and it removes ambiguities. In the context of the project, we will work with scientists of several domains (topology, geography, economy or computer sciences) and we must use the same artefact (model) to describe the system associated to project. The key element is to reduce formal or mathematical aspect sand replace it with more user friendly aspects. The second criteria is the model can be use as input to realize an agent-based simulation. So, we decide to compare (see Sec. II-B) several model providing by the computer science to answer of the two mains criteria.

B. Miro project overview

The Miro project proposes a method and tool to explore urban inhabitant's daily agenda management in order to study accessibility of the city through the services that are available for the citizens. The agenda of inhabitant is composed by several tasks characterized by money spend, time spend, localization and happiness associated. The inhabitant must move in the city to realize each task. So the trip includes interaction between inhabitants and it allows or not to realize tasks (more details of entities are done in Sec. II-A).

In the following, this article will be decomposed into 3 sections. In regards of real system needs for Miro system, the second section describes the choices for the model language. The third section presents the modeling choice and model realized for the Miro system. We finish with a discusion.

II. Modeling Needs

A. MIRO project analysis

Given our studied complex system and the modeling point of view, we should distinguish the focused population dynamics from system life dynamics. Indeed, everything in a complex system could not be described in a same model. Which dynamics should be highlighted? Which one should not be taken into account? The modeler have to make choices depending on the aims of it researches, its habits and so on.

In the case of the Miro ANR project, we want to reproduce Dijon and Grenoble dynamics by using a bottom up approach based on agent paradigm. Due to modeling and computing limitations, describing each Dijon's inhabitants (nearby 150 000) and Grenoble's inhabitants (nearby 160 000) by an agent evolving in a virtual world representing the city with its constraints and opportunities may be amazing. For that reason, we have to consider a synthetic population evolving in an virtual world, a synthetic description of the city. The former (the synthetic population) should be composed of agents organized into socio-economical groups chosen to be close to the real population. The latter (the virtual world) must reproduce the architecture of the town (by using a

[1]Miro project web site: http://miro.csregistry.org

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Geographical Information System) and its internal dynamic by using, for example, macro-level traffic model such as LWR [3].

We also intend to develop a KIDS (Keep It Descriptive Stupid) model in which individual, social organization, environment and interaction have a major role in simulation. Note that, in the following, we will identify each requirement by circled numbers (for example ①). These aspects must be taken into account in our model ①. As consequences, we need an agent based approach readable by domain experts (geographers) ②, that introduce and give an highlighted representation groups ③, agent and high described environment ④ associated with a GIS ⑤. In addition, we have to prevent large scale simulation by using technics coming from distributed system domain ⑥. Next steps in the miro project is to use models to allow the validation ⑧ and to generate automatically the simulation ⑨.

B. Available modeling approaches

Many and many approaches are proposed in the literature to build up Agent Based Model (ABM) and to play simulation. Several researches aim at creating generic tools based on agent paradigm to help users that want to create models or/and softwares. We can divide these researches into three levels:

- methodologies that help users with the modeling process, such as: *GAIA* [8], *TROPOS* [2],
- Meta-models and languages that provides the support to express the descriptions. Most of them are based on the evolution of the object concept (*e.g. AML* [1] or *Modelling4all* [4])
- toolkits that implement a basic agent representation and its management functions, usually in library shape: *REPAST* [5], *GAMA* [6].

Due to these specificities, modeling approach do not have the same goal and an equivalent expressivity. Thus, we are able to classify modeling into three categories : (i) generic approaches (e.g. GAIA, AML) allowing modeling complex system coming from various research areas; (ii) domain oriented approaches (e.g. GAML) allowing modeling complex system sharing few key elements (e.g. space representation); and (iii) domain specific approach such as DSL (Domain Specific Language) containing every element for a narrow research area.

C. Modeling choice

Given modeling needs of our case study, we identify requirements of an ideal agent based modeling approach to model a complex system such as a city. Note that criteria quoted by ① answer requirement defined at the end of the section II-A. We enlarge these requirements to situated agent modeling domain and define criteria as followed:

- *Methodology*: is the approach propose a methodology.
- *Model (①)*: does the approach contains formalisms (meta-model) to describe a system.
- *Simulation dedicated toolkit (⑥)*: does the approach is associated with a simulation plate-form.
- *Complex system ready (⑦)*: does the approach could be used to study a complex system.
- *Interdisciplinary (②)*: manipulated concepts and formalisms must be understandable by major scientific community.
- *Generic*: if the approach could be applied to a wide research area.
- *Grid computing compliant (⑥)*: does the approach allow large scale simulation.
- *Automatized model transcribing (⑨)*: does the approach contain tools to transform automatically conceptual model into implemented model.
- *Group/role concept (③)*: does the group concept is included in the approach.
- *High described space (④)*: does a real space could be described in details.
- *GIS integration (⑤)*: does the approach allow importing data coming from GIS.
- *Model validation (⑧)*: does the approach introduce verification aspects to facilitate the model validation.
- *Modeling GUI*: does the approach contain a graphical user interface to model.
- *Development GUI*: does the approach contain user friendly development interface.

Given methodologies, languages and tools enumerated in the section II-B with compare them according to criteria forementioned. Results of this comparison is sum-up in the Table I.

The Table I shows that, as far goes our knowledge, there are not any methodology, language and toolkit supporting requirements established in the section II-A. Nevertheless, our experience shows that AML could be extending to support them and associated with a toolkit such as Madkit to provide an achieved methodology. We did this choice in this project because, first of all, AML is user friendly language readable by computer scientists and domain experts such as geographers. Then, this language could be associated with OCL (Object Constraint Language) that may allow us defining model validation facilitator (to make some validation) and distribution guideline (to facilitate simulator deployment on a grid). Finally, AML language was applied in various case studies and is well known by the scientific community.

III. AML model for Miro

Previously, we have presented a large choice of tools and methodologies available to model the system within the context of Miro.
Our choice is AML, so we will present more details in this section. Then we present the sub-part AML addressed with a meta-model and the instantiation on Miro project.

A. AML Presentation

As Radovan Cervenka and Ivan Trencansky said in [7], *"The Agent Modeling Language (AML) is a semi-formal visual modeling language, specified as an extension to UML 2.0, for specifying, modeling and documenting systems that incorporate concepts drawn from Multi-Agent Systems (MAS)*

Features	Gaia	Tropos	Adelfe	Auml	Aml	Smal	modelling4All	Madkit	Repast	Mason	Netlogo	Gama
Methodology	X	X	X									
Model	X	X	X	X	X	X	X		X		X	X
Simulation dedicated toolkit							X	X	X	X	X	X
Complex system ready				X	X		X	X	X	X	X	X
Interdisciplinary				X	X		X				X	X
Generic	X	X	X	X	X	/	X	X	X	X	/	/
Grid computing compliant	X	X	X					X		X	/	
Automatized model transcribing		X	X				X			X	X	
Group/role concept	X		X		X			X				X
High described space							X	X	X	X	X	X
GIS integration									X	/	/	X
Model validation						X					/	/
Modeling GUI		X	X		X		X		/		/	/
Development GUI		X					X				X	X

Table I
COMPARISON OF MAJOR APPROACHES (X FOR HIGH LEVEL INTEGRATION; / FOR LOW LEVEL INTEGRATION)

theory."

AML offers a large set of tools to capture and model the MAS and his properties and a support for the human mental process of requirements specification and analysis of complex systems (e.g. mental aspects and context). AML also gives tools for the abstraction of architectural and behavioral concepts associated with multi-agent systems.

B. Our AML Meta-Model

In this part, we propose a new meta-model based on AML which contains only the entities that we need to model our system.
Figure 2 presents the elements that compose our meta-model and their associations.

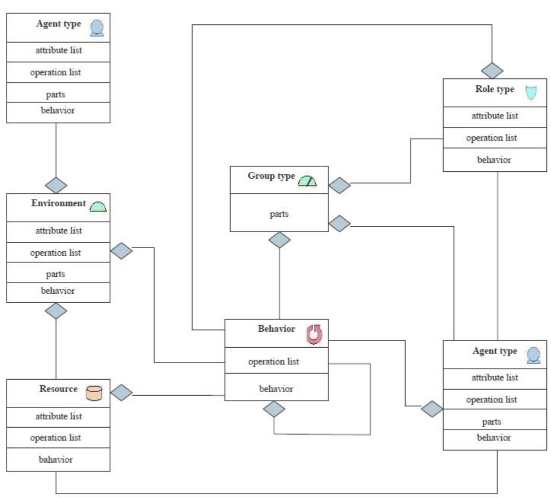

Figure 2. Our AML meta-model

The environment being the global entity of the system, so we associated the resources.
The Parts of the environment contain the resource(s) of the system. The attributes are the global variables of the system, for example the number of each kind of entities that compose the system. The operations are those who allow the modification of the environment's attributes.
A special kind of agent is also attached to the environment. These agents are used to model buildings and services to which inhabitants can access as a resource. They can have one or more attribute(s) as opening hours or address for a restaurant. With this meta-model we can describe all the structure of the complex system as the environment, the agents, the groups, the roles, the ressources and the behaviors associated to all entities of the system.

C. Miro model

In this section, we will describe how we have modelized the different entities of MIRO project. On the base of the figure 1, we present the instantiation of our AML Meta-Model to MIRO project. Due to the length limitation, we only present the modelization of the global system and the inhabitants, all the other entities are modelled in the same way.

1) The global system: To model the city as our system in Miro, the global entity used is the *EnvironmentType*. The city contains the inhabitants seen as agents composed by a mind and a body, with their agenda as a resource of the agent. Building and services are modeled as another kind of agent without the differentiation between the mind and the body, the streets and the transports as other resources of the environment.

2) The inhabitants: To model the inhabitants, we use the *AgentType*. The agents are defined with two parts: a mind and a body, respectively as an *AgentType* and as a *ResourceType*. The mind is associated to agent itself. So we decide to define a *citizenAgent* (the mind), it's the part of the agent which takes decisions and give these to its body. The body is the representation of the agent in the environment as resource. It's the link between the environment and the agent, it also interacts with other agents and gives collected informations to the mind of the agent.
In the following, these agents will be called *citizen-agent*.
The mind contains all the informations on the inhabitants as his localization, pedestrian speed, etc. It also knows the behaviors that the citizen-agent is able.

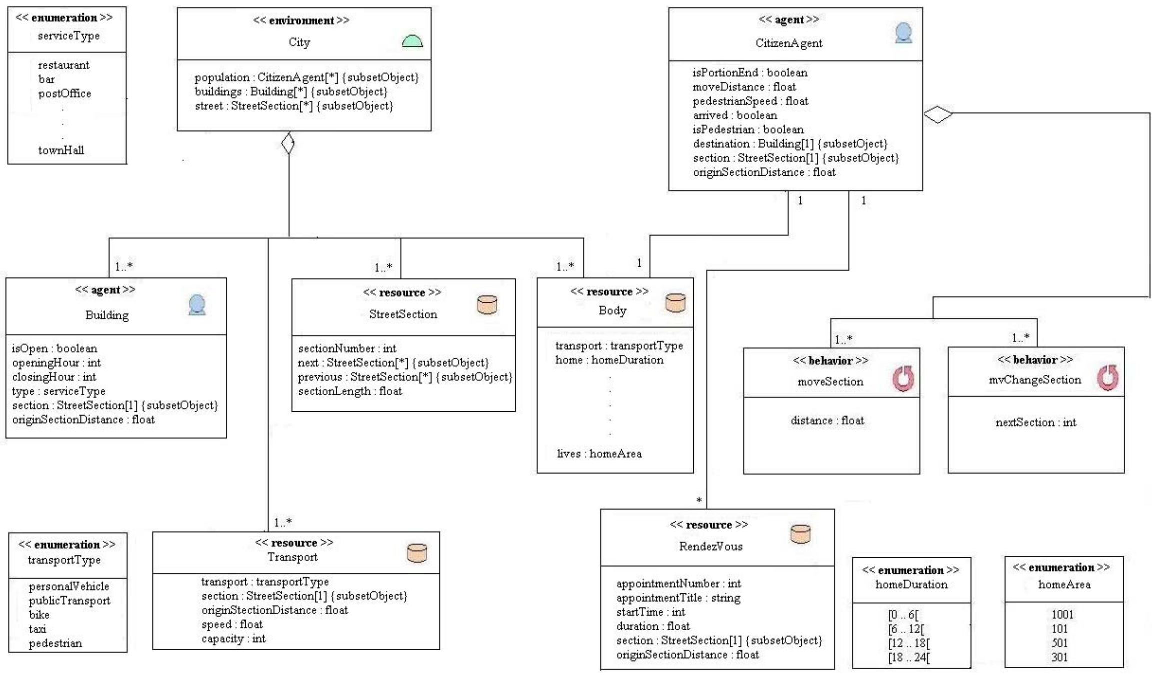

Figure 1. Miro AML Model

The body contains the attributes necessary to the life of the agent in the city as the transports type, the localization, etc. We choose this representation to simplify the view of the agent and to anticipate the problematic of distribution of the simulation which be generated from the model. Therefore, only the body of the citizen agent moves from a part of the simulation to an other, so the management of the distribution is more simple.

IV. Discusion

On future challenge of our works is to introduce three important aspects: model validation, code generation and large scale simulator distribution. These aspects are forgotten in major modeling processes. Nevertheless they are important to ensure the quality of produced models and simulators of complex systems.

We have to work on a validation approach that will use verification techniques on the model to ensure that the system and the agents are well designed. We think about the use of an action language associated with AML to verify agent and system properties. Moreover this language needs to allow interaction description. Thus, we will have a structure aspect of our model with AML and a dynamic aspect with this action language.

Then, based upon this complete model, we will be able to automatically generate code for simulators. We want to automatize this step in order to be sure that the generated code is the exact reflect of the model.

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References

[1] Radovan Cervenka, Ivan Trencansky, and Monique Calisti. Modeling social aspects of multiagent systems: the aml approach. In *AOSE*, Ultrecht, Netherland, 2005.

[2] A. Chopra, F. Dalpiaz, P. Giorgini, and J. Mylopoulos. Modeling and reasoning about service-oriented applications via goals and commitments. 2010.

[3] Li Jia, Chen Qian-Yong, Wang Haizhong, and Ni Daiheng. Analysis of lwr model with fundamental diagram subject to uncertainties. *Transportmetrica*, 2011.

[4] Ken Kahn and Howard Noble. The modelling4all project a web-based modelling tool embedded in web 2.0. In *Proceedings of the 2nd International Conference on Simulation Tools and Techniques*, Simutools '09, pages 50:1–50:6, ICST, Brussels, Belgium, Belgium, 2009. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).

[5] Michael J. North, T. Collier Nicholson, and Jerry R. Vos. Experiences creating three implementations of the repast agent modeling toolkit. In *ACM Transactions on Modeling and Computer Simulation*, volume 16, pages 1–25. ACM, 2006.

[6] Patrick Taillandier, Duc-An Vo, Edouard Amouroux, and Alexis Drogoul. Gama: a simulation platform that integrates geographical information data, agent-based modeling and multi-scale control. In *Proceedings of PRIMA 2010*, Lecture Notes in Artificial Intelligence. Springer-Verlag, 2011. To appear.

[7] Ivan Trencansky and Radovan Cervenka. Agent modeling language (aml): A comprehensive approach to modeling mas. *Informatica*, 29:391–400, 2005.

[8] Micheal Wooldbridge, Nicholas Jennings, and David Kinny. The GAIA methodology for agent-oriented analysis and design. In *AAMAS*, pages 285–312, Netherland, 2000.