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HOW A CONCEPTUAL FRAMEWORK CAN HELP TO DESIGN MODELS FOLLOWING DECREASING ABSTRACTION

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ABSTRACT

In this paper we propose a framework, named DAMMASS, standing for Decreasing Abstraction Methodology for Multi-Agent Social Simulation, elaborated for the design and the implementation of individual-based social models. Its main characteristic is modularity. It recovers two major features. The first feature is the modularity of the modelling process: following the decreasing abstraction methodology uses a collection of models growing from very simple and abstract models to more complex and realistic ones. The second feature deals with the modularity of a given model in the frame of social and ecological modelling, it is described in term of four kinds of sub-models: Agent, Relation, Environment and Organization. The implementation of the framework will enable the management of the modelling process as well as the management of each sub-model.

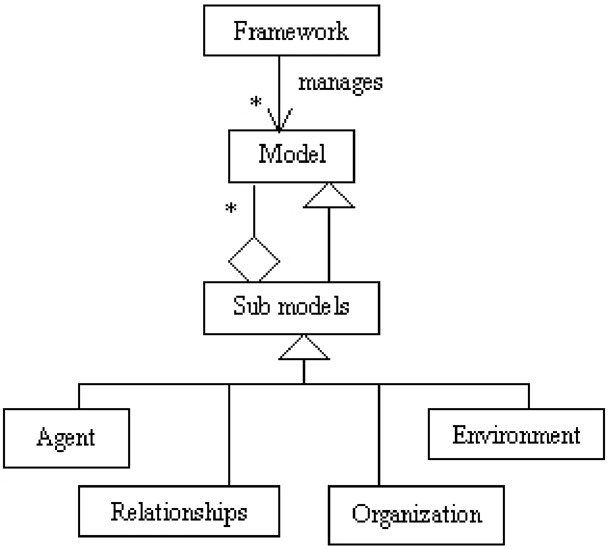
INTRODUCTION

Aiming at favouring a better management of the modelling process, our paper proposes a new framework, DAMMASS, for the modelling and the simulation of individual-based models. Even if our domain concerns mainly the design and implementation of social models which reflect sociological properties, the framework proposed can be interesting for modellers that use individual-based models especially when they are faced with complex interactions (Atlan 1979) between their modelled entities. Our experience in the domain of social modelling based on stochastic simulation of individual-based models within a multi-agent system approach (Deffuant et al. 2000; Amblard and Ferrand 1998) leads us to propose a particular framework, DAMMASS. This framework enables the management of the modelling process as a set of models growing in computational complexity and to manipulate the different entities we encounter, Agent, Relationships, Organization and Environment at the same level as sub-models.

Decomposition of Social Models

It is stating the obvious to say that modelling complex systems may imply the building of computationally complex models. It stays over years a challenge to manage this complexity in the model design and implementation using efficient modelling methodologies (Overstreet 1982; Nance 1987; Zeigler 1990; Wagner et al. 1996; Zeigler et al. 2000). If the latter were used in the past to overcome the low computing power, the methodologies are used now to brave the computational complexity and the lack of tractability of the modelled entities.
A taxonomy for modelling systems introduced the multimodel terminology in the middle of the eighties (Ören 1984) and the technique called multimodelling is mainly derived from the multiformalism approaches (Zeigler 1979). A multimodel is considered as a composition of different homogeneous or heterogeneous submodels at several abstraction levels. This approach helps the building of hierarchical models of real-world systems which cannot be simulated easily by using one monolithic model (Fishwick 1993; Fishwick 1995). Design patterns were largely discussed during the nineties in the software engineering community (Gamma et al. 1995). They are largely used to increase software productivity by software reuse. They rely on object-oriented concepts to represent structures of software abstractions at a high level. The role of design patterns is to provide structures of software design that can be copied or adapted for a new system, describing how to accomplish certain tasks in the realm of software development. According to Pree (Pree 1994), the design pattern concept can be viewed as an abstraction of the imitation activity of novice programmers that create parts of a program, though not directly, by copying parts of programs written by other more advanced programmers. Generally, this imitation paradigm helps us to reduce the complexity, in many real-life situations as well as in software development. Patterns can help in producing "good" object-oriented design in an environmental modelling context (Campos and Hill 1998). Various patterns can be used for multimodelling (Hill et al. 2000), despite this abundance there is currently a need for design frameworks that enlighten clearly the different parts of the model. Frameworks are seen as software macro-

architecture, whereas patterns are micro-architecture. We propose a design tool with the assumption that a model is a collection of sub-models, each of them could reflect different assumptions made about the agents, the interaction processes, the environment or the organizations. Within this framework the reductionism could help us as a methodological tool to design classes of entities in a model. The main classes we identified are Agent, Relation, Environment and Organization. They are seen recursively as sub-models and in this way can be composed of several sub-models (cf. Fig.1).



Figures 1: UML Meta-Model for our Framework Using the Composite Pattern of (Gamma et al. 1995)

General Models, Specific Models and Collections

The major complexity source we isolated from the literature within the modelling of social systems is for one part the emergence feature of social phenomena and for the other part the diversity of the causes, given a specific social system, leading to this emergence. Facing with this constraint to model social systems, scientists mainly have two kinds of approaches. On the one hand, some build very simple models, motivated by the observation of emergent properties from particular features of the agents behaviour for instance cooperation, segregation or influence (Schelling 1960; Axelrod 1997; Epstein 2001). On the other hand, some build specific models, aiming to model a specific social phenomenon given a specific context of study, and trying to fit with the gathered expertise and data (Images 2000; Nowak and Vallacher 1998). The aim of the modeller, which is either to model a social phenomenon in general or to apply it to a specific social system, classifies his model into one of the two categories.
Recently, an observed tendency goes to models that are more or less a collection of models (Epstein and Axtell 1996; Axelrod 1997). Starting from a very simple model, they add properties in order to capture more and more properties of the social system modelled. As a consequence models grow more and more in computational complexity. There is a need for a framework that does not take as a starting point the achievement of an isolated model but that helps the modelling process by enabling the manipulation of the whole set of models composing the modelling process (cf. Fig.1).

COUPLING THE VOWELS APPROACH AND DECREASING-ABSTRACTION METHODOLOGY

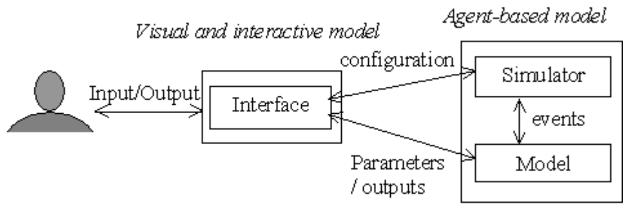
When modelling complex systems, we often have recourse to reductionism and we have then to decompose the system into parts. It follows that the model is then a set of coupled sub-models. The decomposition into several parts, in a way to be understandable and well-included into a modelling process, have to be done following a general framework that organizes the sub-models. Then, we follow the VOWELS approach (Demazeau 1995). Compared to other framework often focused on the agent design with different levels of organizations (Ferber and Gutknecht 1998; Campos and Hill 1998), the VOWELS methodology is mainly characterized by the primitive, recursive, and equal use of Agents, Environments, Interactions, and Organizations sub-models in order to solve problems or to simulate systems.
As this approach gives us a frame to decompose a given model, we then have to define clearly an associate modelling process that enables the classical simulation steps of design, implementation, verification and validation. Moreover, because we believe that a family of models teaches more to the modeller than a single one, the modelling process has to give the way to pass from one model to another one following the growth in complexity and the decrease in abstraction. For the modelling process, we then choose the decreasing abstraction methodology (Lindenberg 1992). We begin with very simple but abstract models figuring general features and we add properties in order to model more realistic phenomena. It is the way followed by (Epstein and Axtell 1996) in Sugarscape, beginning with a very simple model of the environment with very few properties of their agents (move and eat) and increasing the features of the environment, adding resources for instance and going further in the behavioural design of the agents (reproduction/death, metabolism, cultural patterns). The ending point of the process is a model as complex as necessary but as simple as possible.
This approach enables to validate more securely the final model, because it furnishes a more complete depiction of the real system, at different grains. The first simple model enables us to understand the basic dynamical properties of the model, we make them fit with general properties from the sociological literature for instance, defining then a similarity between the structure of the real system and the structure of the model. For instance diffusion of opinions in a population may imply clusters of opinions shared by sub-groups of individuals then the basic model may express this kind of dynamics (Deffuant et al. 2000). We then add step by step more properties (several competing opinions, weights on each opinion) to the model in order

to fit with the specific target system, comparing the model outputs with expert advices and gathered data. The grain of the model is then increased step by step until the model seems too detailed compared with the observable data of the modelled system.

DAMMASS: A FRAMEWORK PROPOSAL

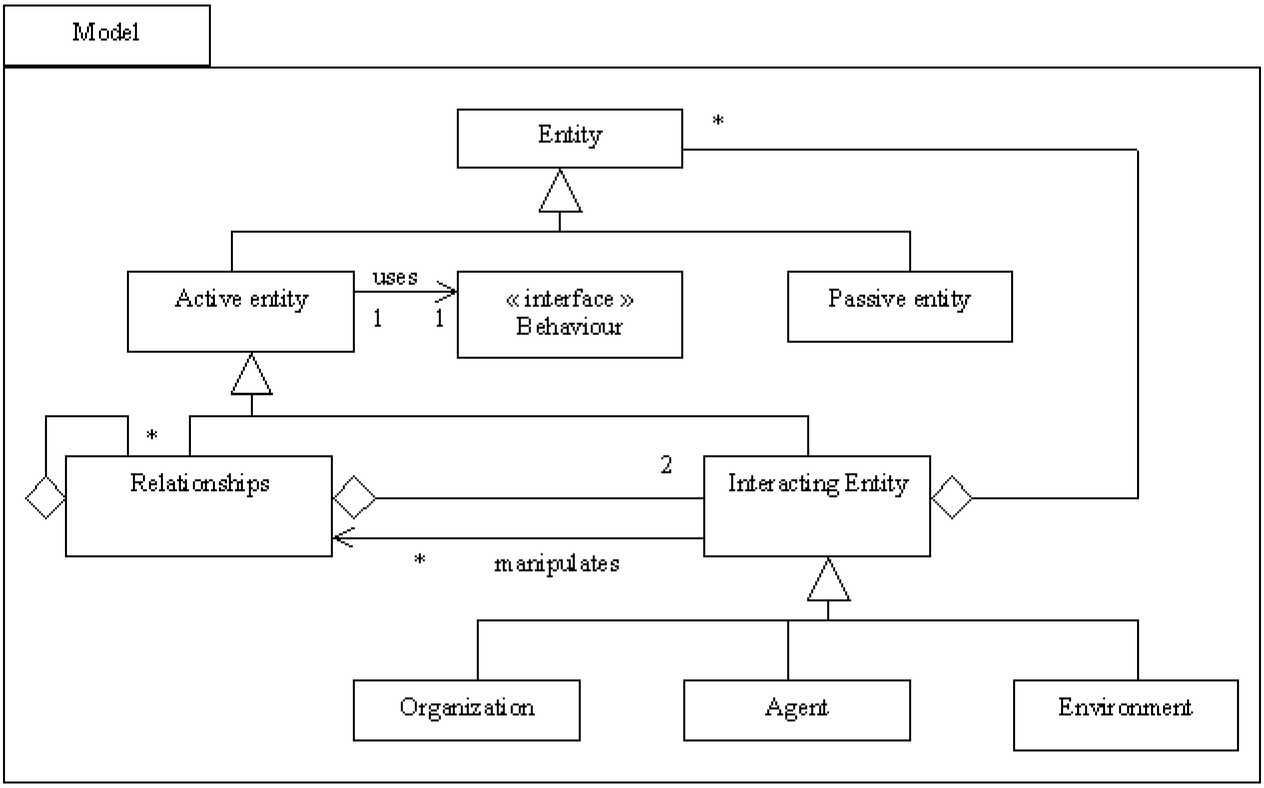
The Framework Proposed

In order to conform to the conditions enounced above, we retain the following framework architecture for the design and the simulation of multi-agent social models (cf. Fig. 2).



Figures 2: General Architecture of the Framework from (Campos and Hill 1998)

This architecture derived from the famous MVC (Model View Controller) is detailed in Campos Ph.D. thesis (Campos 2000) and is divided into three parts. The Simulator manages all the features concerning how to run the model. The Model part detailed below (cf. Fig. 3) contains all the classes concerning the model itself. The Interface enables a user to parameterise the Simulator and the Model independently, to observe the simulation running and the simulation outputs.



Figures 3: The Model Package of the Framework (UML notation)

Going further within the Model part, let us detail the model package. *Entity* is the generic term to point out an object of the model, it has states and updating methods to pass from one state to another one. We categorized the model entities into *active* and *passive* entities. *Active entities* are schedulable directly by the simulator, they have a certain *behaviour* at discrete time step whereas *passive entities* actualise their state from a model's internal event. We then divide *active entities* into two sub-groups: *relationship* and *interacting entities*. *Relationships* link two interacting entities and each one of them can act on the relationships they are involved in. Relationships can be recursively designed as a set of relationships in order to model different kind of interactions happening between two given entities. In the same way an interacting entity can be designed recursively as a set of entities in order to model several level of organization. Interactive entities are themselves divided into three sub-categories: *Organization, Agent,* and *Environment* that states for the components of the chosen modelling methodology VOWELS.

Four Axes to Increase Realism

Applying the decreasing abstraction methodology enounced above, we are able, given an existing model to decrease its abstraction with the aim to increase its realism along one (or more) of these four axes:

- *Agent model design*: the internal properties of the agent, as for instance its representational system or its reasoning system, can be more detailed. It includes the possibility to add new behaviours to the agent model.

- *Relation model design*: the interactions that may occur between interacting entities (Agent, Organization and Environment) can be more detailed. It may concern the exchanges between two interacting entities, or a more detailed communication protocol between two agents. In fact there are as many relation axes to increase realism as possible relationships between the different classes of entities.

- *Organization model design*: it implies an increase of the features taken into account for the organization, for instance the introduction of levels into the existent organization or of new group behaviours in the model.

- *Environmental model design*: the increase in realism may correspond to the addition of environmental criteria (grass, water, nitrogen level) and their dynamics.

The feeling that these axes are independent is quite a mess. This decomposition implies at the evidence some dependences between the axes. For instance, we identify a major coupling between the agent model and the relation model in that increasing the grain of the interaction model often implies to increase the grain of the agent model. To figure out this dependency, the interaction model can stand for the mean that agents can influence each other opinion, then the influence process puts in relation the interacting agents own opinions attributes. Increasing the interaction model complexity may then imply to introduce new attributes or variables, as information transmission, and potential corresponding dynamics in the agent model, as the treatment of this information to build or reinforce opinions. Anyway it is not always the case and the increase in complexity of the interaction model may sometimes be a change in the model structure of this influence. We can then progress from an averaged influence of the agent acquaintances to a threshold model of influence where the agent is influenced by its neighbours if the difference between their opinions is below a given threshold, that is an attribute of the interaction. We then increased in realism the interaction model and kept the preceding attributes of the agent model unchanged.
The chosen axe to attain the next model depends a lot of the modelled system. Anyway, some rules or heuristics can be overviewed briefly. Given a model that uses each one of the four preceding components, it intuitively seems to be a pitfall to increase too much the complexity along only one of the axes without doing the same along the others, it seems that a good model may have a certain homogeneity concerning the complexity of its components. Another heuristic that could be pointed out is that when we have to increase the realism of the model, it often occurs that we begin to increase the realism of the interaction process. This latter is often the one that drives the most the model dynamics and, as underlined upon, often implies changes along the other axes.

DISCUSSION AND PERSPECTIVES

In order to help the design of models following decreasing abstraction approach, we propose a framework, DAMMASS, that takes into account a hierarchy of entities organized in models. The consecutive collection of models enables on the one hand to keep the trace of the modelling process in order to develop a final deliverable model. On the other hand it enables to deliver a collection of models from very simple ones to more realistic ones. It enables to enlighten the general social phenomenon studied, and the general dynamical properties of the roots models. It enables also to better understand the growth in complexity of the models in order to fit more with the reality observed, putting in foreground the assumptions taken to pass from one model to another.
At the model level, the framework proposed enables, adapting a reductionism by classes of entities, to grow up in realism a model in one or more of the four directions that are: Agent, Relation, Environment or Organization design. This decomposition enables clearly to identify the way the model grows in complexity and to manipulate nearly independently the sub-models corresponding to the decomposition.
The main perspective concerns obviously the implementation of this theoretical framework in order to obtain a generic platform for the simulation of social models corresponding to an individual-based approach. The main applications we envisage are models of social structure dynamics, relationships and organizations having an independent dynamic. These models will be coupled with a physical environment by the mean of a Geographical Information System in order to study the link that exists between geographical repartition of the population and the social network dynamics of the latter.
A mean-term objective is to build, from this platform, models from independent modules corresponding to the sub-models of the decomposition.
To compose the modules in order to build new models, there is a need to find plugs between modules, we envisage the possibility to degrade the model, using inheritance properties of the framework, to find, given a set of modules, the less abstract model that can run without more implementation. At the evidence, the elements are not totally independent and there are relationships between the modules, for example a very detailed interaction model may not run with a very simple agent model, so we must found a degrade mode to make it run. The final product may enable to explore the combinatory of the whole set of sub-models developed during the modelling process.

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