Integrated modeling: from models to theories and back

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Short abstract

"A is a model of B for X if manipulating A allows to answer the questions of X on B" (Minsky 65). It follows that the formal structure A, the system B, and A being a model B depends on X and his questions. Integrated modeling is thought as the process of putting together several models (say A^1 to A^n) or to build a new model A' which subsumes the models which would have been designed separately. We argue the main limitation lies in the lack of explicitation of how A^i or A' relates to B^i or B' for the Xs performing integrated modeling. To make the relationship between A and B formally explicit, we need a formal proxy of B. The usual proxy is the set of observations we have about B. We suggest that another proxy of B is the theory in the philosophical sense of a conceptual explanation of how the system B behaves associated with its ontology. We argue that the theories in the philosophical sense must be made explicit because integrated modeling is about articulating theories and not only about integrating models. From our experience in multidisciplinary contexts, we are using ontologies, and combining and articulating these becomes the heart of the integrated modeling process. The formalism (differential equations, multi-agents systems, etc.) is chosen after and associated with the ontologies. Both the articulation among theories, and the process of abstraction between the theories and the chosen formal structures is in the center of the integrated modeling process.

Extended abstract

"A is a model of B for X if manipulating A allows to answer the questions of X on B" (Minsky 65). This rather broad definition entails that A has to be able to be manipulated. It is more or less the case for mathematical structures (in a broad sense: i.e. from differential equations to algebras as used in computer science) and we shall assume that A is always a formal structure in the following. It also entails that to which extent A is a model of B depends on the questions and on the modeler X. It finally entails more indirectly that the object or system B under study depends also on X and his questions.

Very often integrated modeling is thought as the process of putting together several models (say A^1 to A^n) or to build a new model A' which subsumes the models A^1 to A^n the disciplines/points of view/modelers would have designed separately otherwise. We shall assume here that building A' or a given combination of models f(A1,...,An) raise the same issue: how to deal with the multiplicity of Xs? Just imagine combining dynamical graphs (A^1) talking about social networks (B^1), sets of linear programming equations (A^2) talking about optimal decision (B^2) and some differential equations (A^3) talking about meta-population dynamics (B^3), each of these carried out by different people (or the same from different points of view).

We argue that the main limitation in doing so lies in the lack of explicitation of how A^i or A' relates to B^i or B' for the Xs aiming at making integrated modeling. The main symptom of it is the mix up of the discourse on A and the discourse on B in most papers talking about modeling (not necessarily integrated ones).

In order to formally explicit the relationship, one must first describe what is B. A first step is clearly to define the object B' either as some combination of the B^i or straight from the hopefully integrating question. The problem is that B', however obtained, and the B^i are "out there". To make the relationship formally explicit, we need a formal proxy of B. The most widely used proxy (and the closer we have) is the set of observations/data/measurements we have about B. It is, among other uses, usually directly confronted to the data obtained from the model for calibration or validation purposes.

We suggest that another proxy of B is the theory. Here, we use the notion of theory in the philosophical sense of a conceptual explanation of how the object under study (B) behaves associated to its ontological commitment: what is supposed to exist? Any model originates from a theory (or world view) on how things should be and behave. Thomas Kuhn describes how these world views are made explicit when a science is in crisis with competing theories, and implicit inbetween (the so-called normal or paradigmatic science). When the world view is implicit, the theory is often confused with the (or set of) canonical model(s) associated with it. In this case, how a model maps to the theory is taken from granted. Hence the physics a set of equations itself is usually called a theory.

We argue that in integrated modeling (up to multi-discipinary research), the theories (in the philosphical sense) can no longer be taken from granted and must be made explicit because integrated modeling is about articulating theories and not only about integrating models.

From our experience of modeling in multidisciplinary and multiactor contexts, we are investigating the use of ontologies for formalizing the discursive theories about the objects and the processes. These ontologies are graphically represented as UML class diagrams because there is no standard graphical notation for ontologies in general. Building such ontologies is used as a first step in the modeling process. Combining and articulating these ontologies becomes the heart of the integrated modeling process. Only after is the formal apparatus chosen (differential equations, multi-agents systems, etc.) and associated with explicitly chosen aspects of the ontologies. Of course, one could start from existing models and "reverse-engineer" them into theories. Therefore both the articulation among theories of the B^i or the building of the theory of B', and the process of abstraction between the theories and the chosen formal structures is made explicit and is part of the discussions among the participants of the integrated modeling process.

This line of research still is preliminary, the first step has been to build a tool called MIMOSA (http://mimosa.sourceforge.net) for supporting this process. A number of co-modeling processes are already on-going using this tool in order to explore the modelling process itself.