Some Conceptual Problems in the System Dynamics Models Building Process

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Abstract

System modelling and simulation is a complex technological activity, which methodological and conceptual analysis could suggest some new and interesting perspectives about the philosophical subject of the relationships between knowledge and reality.

Of the three kinds of knowledge involved in the system dynamics model building process (mental models, reference modes and operational knowledge), mental models look like specially important, because they let us to express the ideas we have about the internal interactions we find in a real system and that produce a known behaviour. From this mental model, we build the formal model, the system dynamics model.

But, after that, it is very difficult to find out formal restrictions that let us to select a single model, because a behaviour can be generated by different structures (Searle 1980, 1984; Zeigler 1976, 1984). The internal realism

of Hilary Putnam (Putnam 1981, 1983, 1987) allows us to understand why there is not an unique model able to pick up every single aspect of a real system and to clarify the interactive character of the modelling process and the important role that mental models, as a kind of knowledge, play.

Introduction

When building a system dynamics model there are mainly three kinds of knowledge involved:

- the knowledge that experts have about the system that is going to be modelled (*mental models*), usually only expressed with intuitive terms and ordinary language, but other times using scientific concepts and the available theoretical knowledge too (Forrester 1986);
- the *quantitative empirical knowledge* that is gotten about the system (reference modes or empirical behaviours); and
- the *operational knowledge* that the modelist has when he/she gives a structure to these two knowledges, getting an special formal representation able to simulate the dynamic behaviour of the modelled system. That is system dynamics modelling skill.

The final product of a modelling is an abstract object, a model in system dynamics language, that with the help of very special concrete objects, computers, let to integrate, to extend and to make clear and operative the previous more or less intuitive knowledge.

It is essential that these three kinds of knowledge are coherently included in our models. While empirical behaviours give the quantitative data, mental models give information which is not so quantitative, and operational knowledge gives the basis to articulate all the informations, ideas and hypothesis.

Mental models

In system dynamics, the mental model is sometimes understood like a "poor" model, which is going to be improved by the computer model, and other times like the basis, and the real first step, of the modelling process. In spite of their apparent opposition, both ideas are partly true and important. Mental models must be clarified by computer models. From this point of view mental models are "poor" models. But, computer models must be guided by mental models too. And from this other point of view, mental models aren't so "poor". There is a basic and indispensable source of knowledge in the model building process (Meadows 1980, Randers 1980).

We assume that the mental model gives a description of the reality, expressed by a set of sentences in ordinary language, that describes the interactions inside the system. These sentences either describe the change in time of a magnitude or express the influence of the variations of a magnitude in another. This information comes from well-known theories or from the experts views.

We can point up three important attributes of the mental models:

1. *Interaction*: mental models are not fixed, they change with the experience and the discussion, and they can change when building models in system dynamics.
2. *Structural richness*: mental models are not simple. They have important information about the components of complex social systems.
3. *Fiability*: in general, the information that mental models provide about the structure of social systems is reliable.

A system dynamics model is the result of the formalitation of a mental model. This formalitation is not only quantitative. The most important point is to get a formal model that can generate the empirical behaviours, explain them and clarify the previous mental models. This formal model would be, in our case, a system dynamics model and it allows to understand how the behaviour is generated from the structure and explained by it. So, the role of our system dynamics models is not only to generate a certain behaviour but also to explain it making clear how this behaviour is generated. And to make clear this entails to connect with the way mental models focus real systems.

The problem that we find here, when we are modelling with system dynamics, is that it is very difficult to find out formal restrictions that let us to select a single model. Sometimes, we have several alternative models that can explain the same behaviour. Other times, we have to choose between a large and a small model. Searle (1980, 1984) and Zeigler (1976, 1984), from different points of view, have shown this.

Searle's "not duplication" and Zeigler's formalitation

Searle affirms that to simulate a process is not necessarily to duplicate the causal relationships involved in that process. He explains this with an analogy based on the digestion (and the stomach). To simulate a digestion is not to have a digestion. There is not a digestion without an stomach in a body. We could simulate a digestion, but that doesn't produce the digestion.

In our terms, to have a model able to simulate a system behaviour is not enough to know deeply a system. Searle says that simulation is not duplication, because to simulate a behaviour is not to repeat the genesis of that behaviour. Simulation is not explanation either: we can simulate a process without being able to give reasons for explaining why is happening what is happening, what kind of mechanisms are really working in the process that we have simulated. To give a simulation (it doesn't matter if this simulation is able to predict and control a process) is not to give an explanation. We can have a perfect simulation of a process without explaining the real process. This shows, against the classical view hold in philosophy of science, that prediction and explanation are not always symmetrical. Actualy, we can have the first without having the second. We can have quite good predictions but none explanation at all.

In system dynamics, mental models are a very important part of the knowledge about the real mechanisms of the system. An explanation must express those mechanisms that we want to explain. When this doesn't happen, we can refuse the simulation of the system as nonexplanatory. This is so, because a functional correspondence doesn't entail an unique structural correspondence. A behaviour can be generated by different structures. The problem is now, how can we identify an structure like the real generator of a behaviour.

Zeigler (1976, 1984) gives a hierarchy of system specifications that wants to explain the relationships between structures and behaviours. When we have an structure and some initial conditions, we get only one behaviour, but the behaviour could be generated by different structures. The problem with Zeigler's view is that it seems like if the only important thing, when we build an structure to simulate a behaviour, was the empirical behaviour. And we have seen that mental models, with all the information and meaning that they can provide, are really essential.

There is another important problem in Zeigler's formalitation (and common with most of system formalitations). This is that he assumes the existence of a model that structurally characterizes the universe of potentially acquirable data. He calls it a *base model.* This leads to a pretty problematic realistic point of view, that denies the potential existence of other alternative models.

Putnam's internal realism

Searle's point has suggested us some problems. The simulation of a process doesn't need to duplicate any of the causal relationships really involved in that process. To present a simulation, from which we can predict and control a process, doesn't require that we were able to explain why is happening what is happening either.

The ability of generating and extending into the future the available empirical data of a system, isn't enough to guarantee the existence of an structural correspondence between the structure that in the model generate those date and the structure of the real system that we are modelling. But, as Zeigler's view has shown up, a behaviour can be generated by different structures. The questions are: How can we select in a modelling process the structures that are able to represent the mechanisms that are really accountable of a given behaviour?. Where come the restrictions that allow us to distinguish the most realistic models?.

This problem appears in any kind of model. But it is specially important when we are talking about complex social systems in which our action policies are basic. These are the models usually built with system dynamics language. These models aren't only descriptive, they should be useful to manage actions. And this is going to be easier if there are more realistic for the users. System dynamics models aren't only predictors. If the internal structure of a model is completely different from the way users of the model think the real system is structured, that model is not going to be very useful to understant that system and is not going to be a good guide to manage actions.

The restrictions able to select the structures with more realistic content come from the pure and simple confrontation with real systems. Such a direct confrontation is impossible. Neither the processes of simulation and adjustment with some empirical behaviours, made indefinitely and each time more detailed, should conclude with the convergence of the models and reality. We have said that a same model can be generated by different structures. Formally, we shall always have a lot of potential models in any ideal situation of simulation and adjustment.

When we have available theories about the systems that we are modelling, it is easier to select the structures that are responsable of a given behavior. Theories guide the model construction, suggesting which are the really causal elements. But, in system dynamics model building process, the most usual thing is the absence of a precise and stablished theoretical knowledge, from which our models could be an application. Moreover, we build complex social systems models with system dynamics because we haven't got theories that were easily applicable. The problem of the more or less realism is the representational content of this kind of models is here decisive for their utility and efectiveness. When we don't have theories, mental models must get a very important role to choose the structures that are able to really generate some behaviours. These mental models should bring the minimal conditions of realistic adequacy of the structures.

Nowadays, there is an important perspective in the philosophy of science that studies the general problem of realism. This could be very useful here for understanding how mental models can select the structures that really work in a system. We are talking about the *internal realism* of Hilary Putnam (Putnam 1981, 1983, 1987).

In the perspective of the internal realism, it has only sense to adopt realistic compromises from the inside of our conceptual schemas. It can always exist an indefinite pluralism of alternative conceptual schemas, such that we don't know previously if they converge. Including an ideal situation of observation and empirical control, it could be possible the existence of several conceptual schemas that structure the experience in different ways. An unique adequate model for each real system (like the Zeigler's base model), or for the whole reality, would be a myth.

Mental models can be decisive to discriminate the realistic content of our system dynamics models, and in this sense could be alternative conceptual frames with fundamental discrepancies. However, mental models can change, for example, through the modelling process (Forrester 1986). The fact that different mental models tend to meet or not, isn't anything that could be determined "a priori". It depends on things such as rational discussion and dialogue.

The fact that it is not necessary the existence of an unique model doesn't suposse any obstacle for our mental fiability. Neither is an obstacle the fact that mental models never are able to pick up every single aspect, from every single perspective, of any real system. If the existence of the unique model is a myth, it is a myth too the existence of a full model, a base model. The mental models are not able to captivate the relationships that the owner of the mental model stablishes with the real systems, through the process of modelling, simulation, control and decision making, in system dynamics.

System dynamics models help us to know and calculate the dynamical consequences of the structures with which we mentually conceptualize real systems. This knowledge, gotten by means of the operational knowledge of system dynamics, makes more rich the previous mental models. This kind of interaction between mental models and system dynamics ones is very important. Because of that, system dynamics models are so useful in managing actions.

Is there any special characteristic in the mental models used in system dynamics that could justify the three attributes that we had pointed out at the beginning of this paper (interaction, structural richness and fiability)? We think so. System dynamics models are mainly complex social systems models, therefore informational networks, human decisions, changes of strategies and objectives, habits and preconceptions, change resistences, meaning atributtions, informational delays, etc., are essential. Without those structural elements, numerical data are blind. The structural richness and fiability of the mental models are properties that, in some way, run parallel to the class of structure of the complex real system that is going to be modelled has.

With respect to the first characteristic, interaction, there is an interesting point. It is usual to consider that the interaction between mental models and system dynamics models is easier if the system dynamics models are small and they have not *exogenous* components. But if these are our first objectives, the interaction can fail, because of the differences between mental models and system dynamics models. The small size and not exogenous character of our system dynamics model must be an objective conditioned to the basic insights of the mental models, not the priority one.

Putnam believes that it has no sense to ask what really exists out of our theories and conceptual frames. However, all of us are more realistic with regard to some things than to anothers. An adequate conception about realism must be compatible with these two claims. By one hand with the fact that all our knowledge is developed through our interests, relevance criteria, theories and conceptual frames. And, by the other hand, with the fact that we often adopt very realistic conmitments with some objects and properties. Putnam says that the assertion about real existence is relative to the general frame. But he mantains too that these conceptual frames don't lead us to a radical relativism. Our conceptual schemas can be very diverse, but we can have objective truth criteria inside them. There are not absolute criteria but it doesn't mean that there are not criteria. Putnam's view pushes away the point of view of "God's eye" in science and philosophy. Putnam calls his position *internal realism* or *pragmatic realism.* This is very important for us.

System dynamics models are constructed upon the intuitive and presystematic knowledge of the experts in those systems. If the system dynamics models are explanatory and allow us to know better (not only to predict and to control) the systems modelled, this explanation and this increase of knowledge are always internal to the conceptual frames of those experts. From the externalist philosophies of science (with God's eye), this is neither an explanatory nor a genuine knowledge. But from Putnam's internalist view it is so. The reason is that every knowledge and every explanation are internal for him. The conceptual frame of the experts in the complex system that is being modelled is the common sense frame, the common sense in relation to the actions developed into a social system.

Putnam thinks that it is not possible to observe the difference between the common sense world and the world of the science. In the case where the more important things to know are the developed actions, the possible decisions, etc., this conclusion is revealing. And this is just the case of the complex social systems we want to model in system dynamics. There shouldn't be any other way of access to the structure of complex social systems but the intuitive representation that, from this structure, have the subjects involved in those systems. At the end, their decisions and actions, guided by their mental models, are the responsible for that structures.

Conclusions

In this paper, we have tried to show that actual philosophy of science, specially Putnam's internal realism could help us to understand some problems that we usually meet when modelling with system dynamics.

In the internal realism it has no sense to suposse a passive reality, ready-made and structured independently of our knowledge and actions, from which our models could be only copies. That is the same in system dynamics, where the knowledge from mental models is an important part of the final formal model. There isn't either an unique version, an unique and total model, able to pick up every single aspect of a real system. But, although the question about what structures really produce a certain behaviour makes no sense from the outside of our conceptual choices, from the inside of these conceptual schemes this is sometimes decidible and not a matter of mere convention or of some sort of conceptual relativism.

In short, Putnam's perspective let us to clarify the interative character of modelling process, the non existence of absolute valid models, the continuous reelaborations of the models and the contribution of modelist, of the experts and of the very reality to the models building process.

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