Design Criteria of a Modeling Environment based on the Notion of Functional System

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Abstract:
After elucidating the notion of functional system characterized by its activity invariant with respect to both time and environmental influences, the paper describes the design criteria, methods and formalisms of a modeling environment developed in the dynamic system theory paradigm, for the formulation and solution of modular, hierarchical models.

Key words:
functional system, organized complexity, structured models

Introduction
Design and analysis of large and complex systems requires new approaches in modeling and especially in formal modeling since classical dynamics is not sufficient to model problems of organized complexity (Weaver,1948). As a matter of fact:
a) the classical formalisms do not foresee the possibility of representing hierarchical relations and different time scales. These latter being necessary, in our opinion, to represent peculiar features of complex systems such as variable structure, self-organization, feed-forward mechanisms, etc.;
b)it is not possible to manage descriptive complexity without a tremendous increase in uncertainty.
For the above reasons, we proposed an approach to dynamic modeling (Delaney and Vaccari, 1989) based on the notion of functional system ((Vaccari 1986, 1998a, 1998b;Vaccari and Delaney 1999), on Bertalanffy's hierarchy principle (Bertalanffy 1968), on the development of discrete event simulation in the systems theory paradigm (Delaney and Vaccari, 1989; Zeigler 1976),and on the possibility of using different formalisms in the same model.

The Notion of Functional System
A system is defined as a set of subsystems/component related so as to form a unit. The above definition evidences two fundamental aspects of systems: unitarity and recursive decomposability. A system, its unitarity and existence as a specific entity are recognizable (by an observer) inasmuch as it invariantly exhibits certain characteristic properties and/or behavioral patterns, the invariance being, moreover, characteristic of the system as a whole. We will use the term functional system to designate an entity that attains the 'status' of system precisely because of the activity it invariably performs. An activity can be thought of as the set of all possible behaviors of a functional system...
Being systems, the subsystems must possess characteristic invariants. However when it is part of a larger 'total' system, a subsystem's invariants will generally be 'sacrificed' to some extent in favor of the total system invariant activity…" (Delaney and Vaccari,1989, p.1-3).
The term ' functional system' denotes an entity that is perceived as a system not because of what it is but because of what it always does (its invariant activity) where 'always' means for all times and under all environmental conditions in a given context. When the system activity is not invariant with respect to both environment and time, the functional system disintegrates in some sense. This terminology is based on the consideration that a complex dynamical system may assume several different functional roles each of them characterized by its invariant activity. A dynamical system in this conception is a set of potential functional system in as much as it can perform different activities in different environmental contexts. (Vaccari 1998a, p. 59)
.Functional systems might be 'variable structure system', i.e. systems having subsystems/ components, which only exist under certain circumstances (as a function of the system dynamics, they go in and out of existence); systems whose law of behavior depends on dynamically varying conditions; systems

whose coupling schema depends on dynamically varying conditions. (Vaccari and Delaney, 1999, p.667).

Modeling Problems of Organized Complexity

In our approach holism and reductionism are complementary in the sense that one global model is conceptualized and formalized as a structured model, i.e. a set of N generative models described by N formally independent laws of behavior, connected by coupling input-output relations. Here the strategy adopted for reducing descriptive complexity is to conceptually break the system (that we conceive as a functional system, FS) into appropriate functional sub-systems (FSS) amenable to be formally modeled separately and solved simultaneously taking into account their interactions. In this way it is possible to avoid drastic assumptions and simplifications which amounts to minimize loss of information while obtaining a consistent reduction of descriptive complexity;. as Klir (1991) states: conceptualizing systems as structured systems/models possibly of higher orders, is certainly an efficient way of managing complexity.

The generative models forming a structured model (to which we will refer as sub-models) might be structured models themselves; in such a case we obtain a second order structured model and it is possible to recursively define higher order structured models. This possibility to represent a sub-model, in turn, as a structured model allows hierarchical representations in a well established theoretical framework such as systems theory.

The above ideas have been incorporated in a systemic environment designed for the formulation and solution of structured dynamic models (to which we refer as macromodels) characterized by modularity and hierarchy (Vaccari et al.,1998, 1999).

The Formulation of the Macromodel

It seems convenient to conceptualize and describe systems/processes characterized by organized complexity as functional systems whose invariant activity emerges from the interplay of different types of FSS's.

From a modeling perspective the above implies the adoption of a reductionist attitude in the analysis phase in the sense that it is necessary to identify independent FSSs and their invariant activities in the context of the system identified by the observer/modeler. Each invariant activity will be synthesized independently in a specific submodel. However in the synthesis of the global model an holistic attitude will be adopted whereby all the submodels representing the FSSs will be connected by means of a coupling schema which relates the submodels to each other.

More precisely**:**

The conceptual formulation of macromodels implies the definition of:

a) the generative models , their coupling schema which includes the connections at the same level as well as intra-level connections.

b)the representation form of the structured model and the specification of its syntactic and semantic components

c)the formalism to use at the implementation level.

Concerning item a) the generative models constituting a structured model must represent two types of functional sub-system : i.e. sub-models representing physical functional subsystems and sub-models representing cognitive functional sub-systems, these latter containing knowledge and control mechanisms identified by the observer.

The coupling schema, formalized in terms of input/output variables, defines functional and structural relations among the generative submodels.

Concerning item b) a convenient form to describe the structured model is a graph of the type functional block diagram' whose syntax is specified in declarative form according to a specific data structure , while the semantic of the blocks in the diagram is specified in algorithmic form in a library of procedures/ functions .

Concerning item c)we used the discrete event formalism which can practically represent any continuous/discrete model and it allows the representation of different time scales.

The Modeling Environment

The environment consists of:

A data structure SYS.BDS where the user must specify a specific macromodel in the form of a functional block diagram, each block representing the model of a functional subsystem.

A composition algorithm which generates the macromodel in algorithmic form using a library of procedures representing the invariant activities of the functional subsystems and the block diagram defined in the data structure mentioned above.

The nucleus, BDSIM, which generates the solution of the macromodel corresponding to a devs structured model of first or higher order.

A data structure EXP.FR where the user must specify the experimental conditions (initializ., termination, iteration, etc).

A data structure OBS.FR where the user must specify the 'observations' to compute and the type of displayment required.

Graphical interfaces to visualize the macromodel specified in SYS.BDS as a graph of the type block diagram.

In the above environment the structured model to be solved is given in input in declarative form as a functional block diagram while the invariant activities characterizing the FSSs are specified in algorithmic form in a library of procedures.
In the context of this paper very important features of the environment are modularity and hierarchy.
Modularity is very desirable in that it is useful for managing descriptive complexity.
Hierarchy is another principle of well known utility in complexity management and to model typical features of complex systems such as anticipation, autorganization, selfreference etc.
Other basic features of the environment are: model specification in system theoretical terms; program architecture dictated by causality considerations; enforcement of strict separation of model and experiment-oriented specifications as input by the user.

Conclusions

Systems characterized by organized complexity typically involve human cognitive activities and their modeling must go beyond classical dynamics (DST).
In order to represent peculiar features of complex systems such as variable structure, self-organization, feed-forward mechanisms, etc. a formal dynamic model must be able to manage hierarchical relations of different nature as well as different time scales.
However the DST paradigm in its broad sense constitutes a convenient framework for the formulation and solution of macromodels meeting the above mentioned requirements as exemplified by the general purpose modeling environment we describe in the paper.

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