A Platform for System Dynamics Modeling

– Methodologies for the use of predefined model components –

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Extended Abstract

Introduction:
In the following a platform for System Dynamics models is developed. The platform is designed to support the formal model building process with predefined, standardized model-components. The purpose of the platform is threefold:

- first to increase efficiency and effectiveness in the modeling process,
- second to create an environment where existing knowledge of structure, behavior and policies is documented in a reusable form and
- third to contribute to the diffusion of System Dynamics modeling.

The research presented here, focuses on methodological considerations. In order to build models with predefined components, different methodolgies are integrated. The predefined components are based on the concepts of generic structures. They allow to vary the level of resolution of the resulting component-based models.

The platform integrates methods and concepts to develop System Dynamics models with predefined submodels. Figure 1 depicts the architecture of the platform. Generic structures form it's foundation and are used as predefind model structures. The six columns represent methods and concepts that carry the modeling platform. These are: 1. transferability/reusability of generic structures, 2. problem orientation of the resulting component based models, 3. object orientation, 4. hierarchical modeling, 5. reference modeling, and 6. validation of component-based models. The platform integrates the methods and concepts, in a way that generic model structures can be used as predefined models and submodels.

In the following the foundation and columns of the platform are briefly described:

Concepts of generic structures:
Generic structures belong to the most fundamental and important concepts in System Dynamics. From a theoretical as well as practical point of view their characteristics correspond to central goals of the field of system-modeling. Generic structures are generalizations of behavioral insights in complex systems, and can be seen as building blocks of an integrative behavioral theory of social systems. The development of generic structures can be persued all the way through the history of System Dynamics.

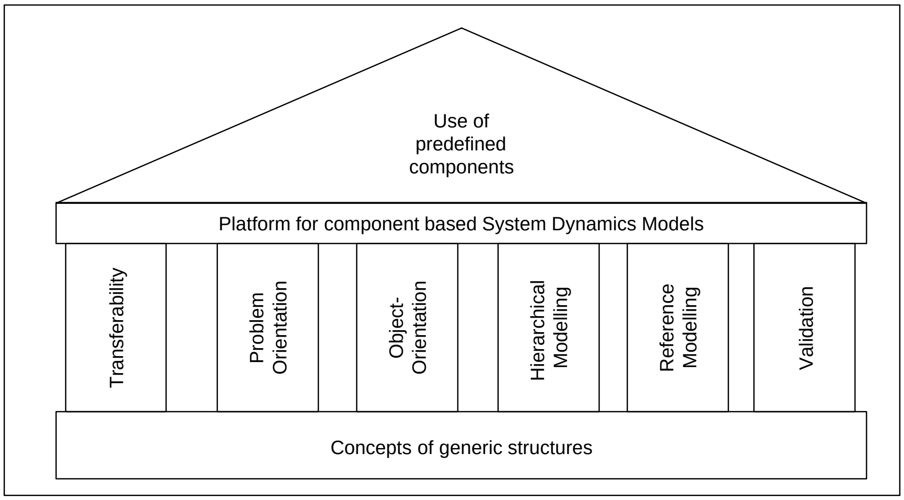

Figure 1: The platform for System Dynamics models

Despite their importance, there is no general definition or common standard of generic structures in System Dynamics. Recent work has significantly advanced the scientific discussion in this field, redefining and identifying three main concepts. The present research takes these insights as a starting point. In order to operationalize generic structures as model components, further subconcepts of generic structures are identified. They serve as building blocks for models of social systems.

Transferability:
An important property of generic structures is their transferability. It is the prerequisite for their reuse as model components. In the context of the platform discussed here transferability is differentiated in transferability "within fields" and "across fields". Transferability within fields means domain and problem specific structures, e.g. model components of production processes. Transferability within fields means multiple applicable structures, from first order systems to e.g. Vensim-moclecules.

Problem Orientation:
One problem of component based modeling is the missing problem orientation of the components and of the resulting models. The focus on the identification, provision and/or implementation of reusable model structures (components) leads to the tendency of neglecting the problem orientation that is crucial for all modeling efforts. The consequence is that systems instead of problems are modeled. This is a typical weakness of component-based concepts in System Dynamics. The boundaries of a model are determined by its purpose for which a problem centered perspective of reality is necessary. Without this perspective the boundaries of a model cannot be precisely delimited. The platform for System Dynamics models contains two types of components that ensure problem orientation at the beginning of the modeling process.

Object Orientation
Object orientation is seen as the counterpart of problem orientation–both views complement each other. An analysis of literature shows that aim and utilization of

generic structures in System Dynamics and classes in object oriented modeling are the same. This is of great importance for the conceptualization of model components and for their identification in the modeling process. The latter is a central challenge for the use of catalogues of components in formal model building and therfore for the platform apporach: How can an appropriate model component be identified and selected? A possibility to deal with this problem is object orientation. The object oriented perspective is a natural way of thinking and a better approximation to human mental models than stocks and flows. People think in objects, deal with objects and speak of objects. For the platform it is crucial to consider the predefined components as classes and to design and name them corresponding to an object oriented view of reality. Design patterns from the field of software-engineering offer a useful example how to document reusable solutions for specific problems.

Hierarchical Modeling:
The theory of hierarchical systems and System Dynamics can be fruitfully combined. The purpose of hierarchical modeling is to explicitely model different layers of aggregation for one problem and/or domain and to analyze the different layers. Findings in cognitive psychology indicate that this form of representation is closer to mental models of humans than pure two-dimensional representation of systems. System Dynamics models tend to concentrate analyses and documentation solely on one layer. The hierarchical development, representation and documentation increases comprehensiveness and facilitates reusablity of entire models and their components. Thus it is suggested to introduce the concepts of hierarchical modeling to System Dynamics. Predefined components lend themself to support this approach. In general, in simulation two different forms of hierarchy can be differentated: hierarchy through specialization or classification, and hierarchy through different levels of detail. The former uses the principle of heredity; the latter devides classes in disjuncitve subclasses: a class consists of the sum of it’s subclasses. The platform approach focuses on subclasses–while the principles of heredity are also applicable, as other research studies have already shown. Using pedefined components, system models can thus be stratified, displaying different levels of aggregation.

Reference Modeling:
The notion and concepts of reference models originate from the disciplines of discrete event simulation and software engneering. In recent years reference modeling has seen wide-spread attention in literature and practice (e.g. ARIS or SAP-reference models). Reference models are designed for different domains and applications. In the context of simulation reference models serve as design patterns for new models. They are used as systematic solutions for recurring and reusable structures and processes. The primary benefit of reference models is an increase in efficency and quality in the model building process. The field of reference modeling serves as conceptual framework for the reuse of models and parts of models (components) in the context of the platform. On the basis of the definition of predefined model components and the definition and characterization of reference models in descrete event simulation, it can be shown that properties and concepts of the latter are applicable to generic models in System Dynamics. This is no surprise considering the original aim of our field:

> „A person applying the industrial dynamics approach to actual corporate problems seems to do so by drawing heavily on his mental library of the systems which he has previously studied. If

> others are to be able to do the same, such libraries of examples must be put in orderly written form. Such a series of structures would identify those relationships which are found repeatedly in industry... Such a treatment of systems should concentrate on the minimum structure necessary to create a particular mode of behavior."
>
> (Forrester, J. W. Industrial Dynamics–After the First Decade in: Forrester, J. W. (Ed.). *Collected Papers of J. W. Forrester*, Cambridge (Mass.) 1975.)

Validation:

The predefined model components are based on the concepts of generic structures. Generic model structures have greater potential refutability than models which apply to only a small number of cases because they provide more opportunities for corboration or refutation. However the tests of model validation remain very important: component-based modeling approaches contain the danger of fitting the problem to the components at hand, rather than designing a specific model for a given situation. Therefore structural validation plays a crucial role. The structure of each single component and of the resulting model has to be compared–and eventually adjusted–to the system and problem that are analyzed.

Summary:

One of the central questions of all modeling efforts is the determination of the level of aggregation and of the boundaries of a model. How deep is the level of detail? How expansive are the boundaries? The proposed platform-approach offers flexibility in the design of component-based models. Aggregation and boundaries are the two dimensions which define a model's level of resolution. Which level of resolution is chosen depends on the problem at hand and the purpose of the model. The level of resolution is not known in advance. The use of predefined components with the platform for System Dynamics models offers the possibility to vary the level of resolution. As submodels the components allow to move between different levels of resolution.

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