A KR Multi-Hierarchies/Multi-Views Model for the Development of Complex Systems

Abstract: Recent methodologies in knowledge representation are oriented towards the construction of multiple representation models. The concepts commonly used in describing levels of granularity of knowledge are based on conceptual and symbolic levels. We propose to describe the conceptual level of a KR system by introducing multi-views and hierarchical levels which allow to represent explicitly a complex KBS.

1. Introduction
The resolution of complex technical problems as design, diagnostic, planning or process control requires separates phases for reasoning (Davis, 1982) (Genesereth, 1982). In each phase, for the same modeling domain, in general different models are necessary (Booch, 1997). Furthermore, for each model, one or more conceptual views are associated. A view has for goal to reason on concepts and aspects relating to a certain stage. However a conceptual view, in its complexity, can improve for its representation, a hierarchical approach that leads to different abstract levels or comprehension levels. Therefore, we present in this paper a knowledge representation Multi-Hierarchies/Multi-Views (MHMV) Model which allows complex systems to be tackled in this way.

The remainder of this paper is organized as follows: Section 2 describes the notions of the KR MHMV model. Section 3 presents the basic concepts for representing the MHMV model and details the MHMV link concepts and its reuse. Finally, Section 4 concludes this article.

2. The KR multi-hierarchical/multi-views model
In the proposed KR MHMV model a complex system is described according to the following concepts:

2.1. Model
A model is a representation of a given system with respect to a given set of problems. In general, to two different classes of problems will correspond, for the same system, two different models. So each class of problems leads to a specific domain of modeling. So we consider that a model is a simplified representation of the structure and behavior of a real system designed to support and facilitate reasoning concerning the system.

For example, a digital circuit system can be represented by a digital-behavior model for function-related applications such as simulation and by a thermal model for heat dissipation applications.

2.2. Views
During a particular application in a particular domain of modeling, a number of conceptual views of the modeled system may be required. During the design
process of a digital system, for example, three separate views are considered by the designer: behavioral, structural and physical (Nestor, 1982) (Vaneleemput, 1977).

Due to the complexity of the views, it is often necessary to decompose a view at different hierarchical levels of comprehension. Defining a suitable hierarchical level reduces the amount of information to be considered to manageable proportions.

However, this decomposition of a view of a model (Gribble, 1998) (Wang, 2000) in hierarchical levels is not necessarily isomorphic to the decomposition of others views of the same model.

2.3. Hierarchical levels

In the KR MHMV model we have identified three kinds of hierarchy in a same view:

a- The abstraction hierarchy in a view: represents an appropriate comprehension level for the view decomposition. An abstraction level permits to limit the content and the sense of information to consider. Details that are not pertinent are relegated at a lower abstraction level. The abstraction level of a view includes:

- the data structure model
- the tools used by the application builder to specify the reasoning type at this level

b- The description hierarchy: enables to have a finest description of a same behavioral element belonging to a given abstraction level by keeping the same specifications of its inputs and outputs and decomposing it according to different sub-structures. So, each abstraction level is composed of one or several description levels. This hierarchy has a meaning only in behavioral views.

c- The conceptual hierarchy: permits to organize the concepts by generality levels. Each description level is composed of one or several conceptual levels and is associated to it a library based on a conceptual hierarchy. This library constitutes the base of reusable components.

3. MHMV model representation

In the KR MHMV model, we have extended the graph formalism in such a way that hierarchies, views, links can be clearly defined. The extension of the graph formalism consists of the following concepts:

3.1 Basic concepts

- Node: is a unit of description of a basic element or a function belonging to a given hierarchical level of a model view. A node component is composed of a connector and the description of its structure and/or its behavior.

- Graph: is a representation, based on a logical or physical structure of the modeled system, which consists to inter-connect elementary node components considered like that with regard to the level of abstraction where the system is represented. A graph component is composed of a connector, nodes, links, and transfer links allowing the information transferability from the graph connector to its nodes connectors and vice versa.

- To each node can be associated a sub-graph which represents this same node at a lower abstraction or description level of hierarchy.
- **Link**: considered as a component, is composed by a *source connector*, a *destination connector*, *semantic links* (association, composition, inheritance, …) and *transfer links* which give information about the transformation of information leading by the link.

- **Connector**: is associated with graphs, nodes and links components and is composed of ports. It represents a well-defined interface between a graph, a node, a link component and the surrounding environment.

- **Port**: is an entity attached to a node/graph/link connector and is the only means by which data can enter or leave nodes, graphs or links components.

### 3.2 Link component in KR MHMV model

A *link component*, in addition of its connectors, is specified by semantic links (the description of the relation types between the two linked components) and transfer links (the transferability of information between components).

a- *Semantic links* allow the definition of semantics for inter-component references. In many models, the composition link, for example, conveys strong semantics (Rumbaugh, 1988) (Kim, 1989): a composition link can, for example, be reflexive, transitive, exclusive or shared, dependent or independent, predominant or not. We think that all this information may be included in the reified concept of semantic link and then be specialized according to different kinds of semantic links.

b- *Transfer links* are carried out using their connectors. They may be explicitly established by:

- defining correspondences between ports of their source and destination connectors,

- attaching appropriate translation functions to these correspondences.

### 3.3 Reusing transfer links for different semantic links and as adapters

A question that springs to mind is: why separate transfer link from semantic link? The answer is that it enhances reusability as the same transfer link can serve two or several different semantic links. The idea is to separate the semantic properties (structural, behavioral) of a link from its operating mechanism (information transferability, information propagation). For example, the *derivation* link used for evolution management in object design permits linking versions of a component to the initial one. A version can be derived by deletion of, addition to, or modification of an existing component. Many methods have confused derivation link with inheritance (since inheritance permits addition and modification). Some alter the inheritance link so that it fits derivation, using inheritance with exceptions or adding constraints. We can reuse the transfer applied to inheritance, adopt it so that it can support information-deletion and reuse it for this link.

Otherwise, the transfer link can also serve as an *adapter* between two MHMV components with the same or different types among nodes, graphs and links components exactly like a digital component adapter.

We consider in the KR MHMV approach that the node/graph/link components must be defined in free-context, according to an abstraction level or description level and constitute the fixed part of a potential reuse and adapted to a given context (in-context) thanks to a transfer link (adapter) which constitutes the variable part of a reuse.

### 3.4 Links Classes in KR MHMV model

Several kinds of links occur in the KR multi-hierarchical/multi-views model definition:
Inter-levels link allow passage from abstraction, description or conceptual level to inferior or superior one. In inter-level links, we have identified general links as inter-abstraction levels, inter-description levels and inter-conceptual levels links.

For inter-abstraction levels links, we distinguish, for instance, the expansion links which allow transformation of input/output information node/graph to the lower abstraction level. Compression links represent the opposite links compared with expansion links. The inter-abstraction levels links are based on the semantic links of UML association links (Muller, 1997) with mapping and arithmetic transfer links.

Among inter-description levels links, we can mention composition links which represent the existing links between a node belonging to a description level N and nodes corresponding to the same element at the lower adjacent level. The aggregation link represents the opposite link. The inter-description levels links are based on the semantic links of UML composition and aggregation links (Muller, 1997) with identity transfer links.

Inter-conceptual levels links are based on the semantic links of UML inheritance links with identity mapping transfer links. Thanks to the explicit description of a transfer link, we can build for example different kinds of inheritance: strict inheritance, inheritance with exception, inheritance with renaming, ...

Intra-level links: They are existing links between two nodes belonging to the same conceptual level.

Inter-views links: They are composed of change views links and exchange of information links between two views. In the transformation of a view in another one, we can distinguish two cases:

a- the transformation is established between two descriptions of the same level of abstraction belonging to two different views. This transformation is generally algorithmic. For example the passage from an algebraic description of a boolean function to a logical gate representation.

b- the transformation is established between two different levels of abstraction of two models views. This transformation is generally based on inter-abstraction levels links and heuristics. For example, the passage from the physical view to the structural one.

The different KR MHMV links presented before can be obviously instantiated, specialized and completed by the user according to his needs.

To tackle the use/reuse problem of models, we have defined the MHMV link component as a composite object composed of semantic and transfer links which allow to specify separately different semantics relationships and information transfers between components. This description is made by an external and independent way from the connected components (free-context). Therefore, we have defined, an ontology for semantic and transfer links (Oussalah, 1999). This ontology is used in the KR MHMV model. One of the most important contribution in KR MHMV model is to be able to describe in an independent way all views and abstraction levels of a model and to link them via the different KR MHMV link components.

In our basic framework, we proposed two kinds of predefined semantic links: inclusion and association, and four kinds of transfer links: arithmetic, mapping, user and logic links. These different links can then be completed according to the application needs.
4. Conclusion

We have defined a KR model for developing complex systems. The KR MHMV concepts defined are generic and can be applied to different types of systems. We believe that the KR MHMV model can contribute to the creation of better quality solutions in the area of complex systems design.

The main contribution of our work is, firstly, the explicit description it offers of the different KR MHMV concepts; second, the possibility to extend and adapt these concepts; and finally the natural use of the graph formalism for representing them: there is no gap between the defined concepts and their implementation.

References


