Multiple-View Integration in Product Data Modeling: Applying STEP Standard

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Abstract

The multiple-view modeling of a product in a design context is discussed in this paper. We study the existing approaches for multiple-view modeling of a product and we give a brief analysis of them. Then we propose our approach which incorporates the multiple-model approach in STEP standard current works based on a single model. We propose a meta-model inspired by this approach for a multiple-view design environment. Next, we validate this meta-model with a case study. Finally we conclude and give some perspectives of this work.

Keywords: product data modeling, multiple-view modeling, product data integration, STEP, functional model.

1 Introduction

Design is a multidisciplinary activity. The designer has to study the product in different ways. Therefore, he has to know many different involved disciplines. For example, a building can be studied in different ways : as a set of elements, a set of rooms having an internal and an external form (architectural view), a set of electrical equipment (electrical view) , ... (Figure 1).

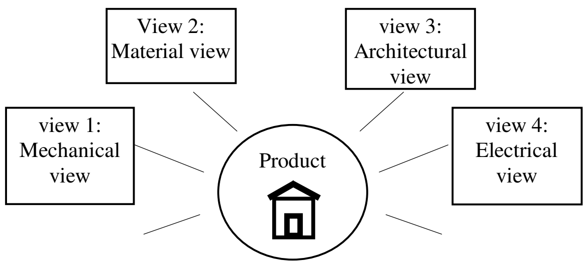

Figure 1. Multiple-view of a building.

For a complex product, a multidisciplinary team and thus the cooperation of several experts is necessary to make a complete model of the product. This model has to be able to cover all experts' intents. The problem of modeling of information in this environment is called a *multiple-view* modeling because each expert studies the product in his own viewpoint and gives his special description of the product. We call each of these descriptions a " model " of the product.

Actually, there exists two distinct approaches for multiple-view modeling:

Multiple-Model Approach. In this approach, a product is defined by several models, each describing a particular viewpoint (Figure 2). Usually these models are dependent, so the changes of one model could influence the others. If we ignore dependencies, some inconsistencies between data are possible and product model will not be reliable. It is important therefore, to consider this dependency in the product model.

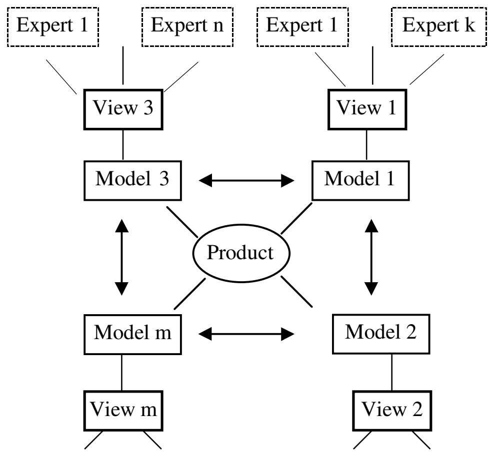

Figure 2. Multiple model approach

Rosenman and Gero[1] applied this approach to design a building. Their models are based on the functional decomposition of the product. They defined some *constraints* to relate the views and to preserve the consistency of the model. However, the relation between functional part and structural part of their models is not clearly represented.

Nederveen and Tolman[2] also studied an example in the same domain. They called each view model, an *Aspect Model*. The relationships between aspect models are guaranteed by a common model called *Kernel*.

Although they did not represent the functional model of products explicitly but they used it implicitly for distinction of views.

In both works, the expected functions of product have an important role to guide the designer in the design process.

Single model approach. In this approach one single model is defined for all of the views (Figure 3). Development of such a model is not always possible because the modeling is based on different combinations of some so-called *primitive elements* and the definition of the primitive elements depends on the views and change from one view to another.[1]

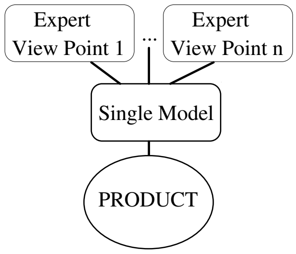

Figure 3. Single model approach

Many current works for representation of products in CAD systems use this approach [3]. There is also some recent works for the definition of standard product data model that have been led to STEP (International Standard of Exchange of Product Data Models) [4].The major problem of this approach is that it produces a fixed and static representation of product. The other disadvantage is that all representations of product entities have to be explicitly stated. This includes both graphic representations and representations of other properties. The current practice is to represent merely the structural properties of an object so the information regarding the product's intended functions is lost.

In the following we describe our work which integrates the multiple model approach to STEP standard current works based on a single model approach. The advantage of our approach permits us to benefit from the normalized representation of STEP as well as the representation of functional properties and dynamic concerns that are essential for modeling of a collaborative environment.

2 Basic concepts in multiple-view modeling

Each model represents the information about the product from a particular viewpoint. A view deals with the designer's intents and physical laws related to the view [5]. A product performs several expected functions. These functions can be grouped in some distinct sets (Function Sets [1]) so that each set is related to one and only one view. The functions of each set also belong to one view and only one.

Regarding the design process, each function in such a set, called a *main function,* is decomposed into several functions less complex to perform. These are called *sub-functions*. A sub-function can also be decomposed into other sub-functions. So we will have a hierarchy of functions for each main function. Unlike main functions, sub-functions can be shared by several functions (main or sub-functions) and consequently by several views. For this reason a physical object (called " object " in the rest of this paper) can be presented in several views. An object performs one or more functions. A function is also performed by one or more objects.

Sometimes in design process, there exists some concepts which can not be expressed as functions but as remarks related to a function. They are called *modifiers*[6]. A modifier is associated with a function. For example the function of a pencil is " to write ". If we explain this function as " to write easily " the adverb " easily " is described, in a model, as a modifier. A function can be associated with one or more modifiers. During the function decomposition, modifiers can be translated or transformed to other ones. Therefore, the relationship between the functions in a functional hierarchy is not limited to the decomposition relationship. There is also some relationships which satisfy modifiers. Some relationships are noted below [6]:

- Enhanced-to relationship: relationship between two functions in order to reply to a modifier. If A Enhanced-to B then a new function B is necessary to satisfy a modifier A1 defined for function A.

- Described-by relationship: relationship between two modifiers. It indicates that a modifier is detailed into one or more concrete modifiers.

There is also a Conditioned-by relationship. A conditioned-by B means that B is necessary for A [6].

3 Meta-model

By now, we have defined some necessary concepts of multiple-view modeling. Some of these concepts represent the information related to point of view, function and sub-function, object or product and relations between these concepts.

In the following we describe our meta-model representing these concepts. Our meta-model is described by EXPRESS-G notation, that is a graphical language developed by ISO 10303 STEP (Figures 4).

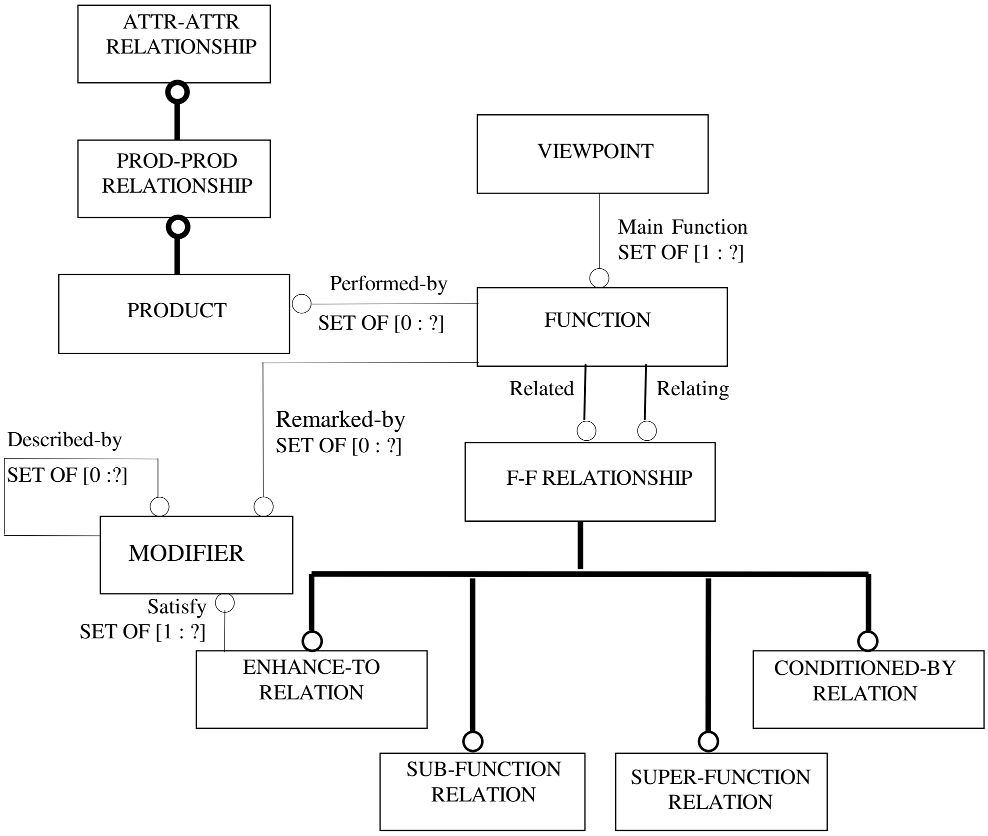

Figure 4. A meta-model for an integrated multiple-view model of a product.

We have chosen EXPRESS in order to present the models in a normalized form. The EXPRESS-G basic notation used in the figures includes : rectangles, thick & solid lines, and normal lines which present respectively entities, super/subtype relationship, required attributes. The direction of a relation is determined by an open circle and means a one to many relationship [7].

In this meta-model VIEWPOINT is an entity which represents a product view. Several functions are related to each viewpoint. The functions are represented with FUNCTION entity which represents both main functions and sub-functions. The relations between functions are represented by a F-F RELATIONSHIP entity which represents all kinds of function relationships. The SUPER-FUNCTION RELATION and SUB-FUNCTION RELATION represent function decomposition. ENHANCED-TO and CONDITIONED-BY relationships are also defined as two sub-types of F-F RELATIONSHIP .

Modifiers are presented with MODIFIER entity. A modifier describes a function. We represent this, by a relation called Remarked-by. Described-by relation represents the modifiers relationship during function decomposition.

PRODUCT entity represents an object realizing a desired function. We use the product description of STEP in our meta-model. Figure 5 shows the structure of the STEP product model [8]. The definition of a product in the STEP product data model is any physical object which is produced by either natural or manufacturing processes. Any part or assembly that contributes to a product is also considered to be a product. A car is a product while its wheels and engine assemblies are considered as other products. Furthermore, each of these products can be further decomposed into smaller components or products.

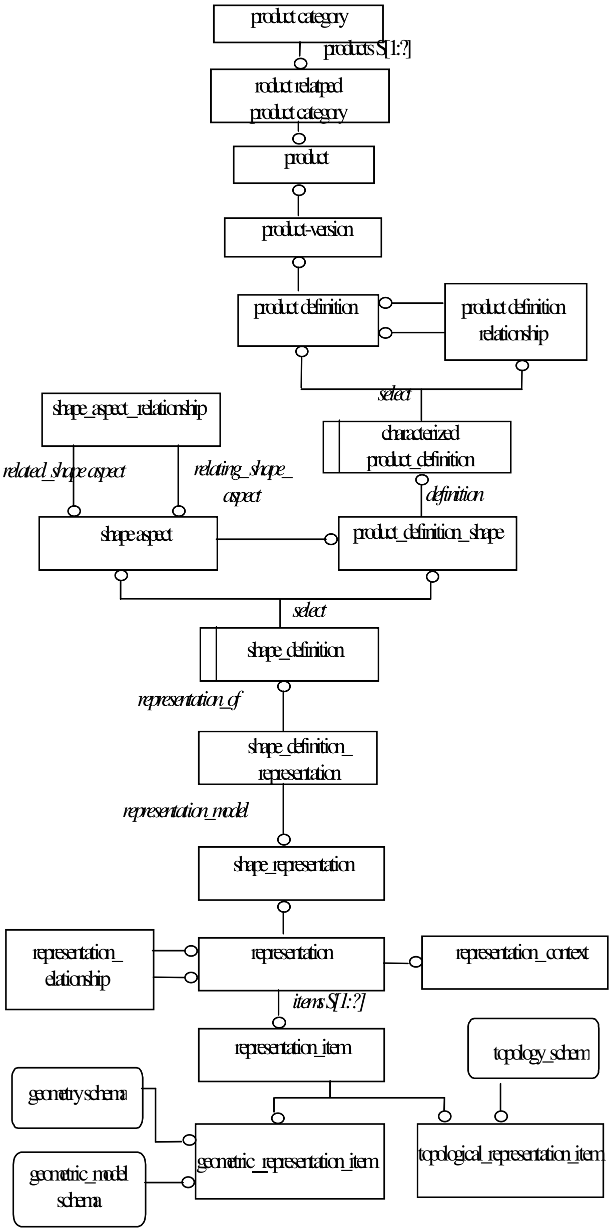

Figure 5. STEP product model.

The product model should be able to describe the product during its life-cycle, hence, each version or history of the product can be described and is traceable in the model. The instance of product version entity is used to describe the products at different times. To support the connections between a product and it's related information, for example on assembly, tolerance and shape representations, the entities of product definition and product definition relationship are defined. The product relationship can be used to define assembly relationships where the relating product represents the assembly and the related product represents an element of the assembly. Products can also be designated as belonging to specific product categories. The configuration of relationships between different products (product's structure) does not adequately function as a complete product information. The geometric representation of product is essential for engineering analysis. Figure 5 also shows the relationship between product structure and product shape representations. This view has been extracted from part 41 (product description and support), part 43 (Representation structures) and part 42 (Geometrical and topological representation) of STEP documents. In shape-definition-representation, the relationship between the product and its shape representations is provided. Product-definition-shape is used to identify any instance of product-definition. The representation entity makes reference to a geometric representation item, which may be a geometric shape model (which includes several types of CAD models). Shape representations can also be organized into relationships with other shapes using the representation relationship. For example, a shaft and a bearing can be geometrically related.

Some relationships are not considered by the STEP product data model, so we define a PROD-PROD RELATIONSHIP. An ATTR-ATTR RELATIONSHIP is also considered for representing partial relations between two objects.

4 Case study

We validate our meta-model with a case study of Rosenman and Gero [1]. The instance of this meta-model is shown in figures 6. For this example, we analyze the functions and their relationships. This analysis result in the product functional model. This model is related then to the structural data model.

The example is a two-storey apartment. Three subsystem spatial, climate control and stability of this building is considered as three views and therefore as three instances of VIEWPOINT entity of our meta-model. The main functions related to SPATIAL VIEWPOINT are ACTIVITY-SPATIAL-FUNCTION and SPACE-SEPARATION-FUNCTION. The main function related to CLIMATE_CONTROL VIEWPOINT is EXTERIOR-FILTER-FUNCTION. The main functions related to STABILITY VIEWPOINT are GRAVITY-STABILITY-FUNCTION and LATERAL-STABILITY-FUNCTION. Each of these main functions is decomposed into sub-functions. For example, the SPACE-SEPARATION-FUNCTION is decomposed to two sub-functions SEPARATE-SPACES-FUNCTION and PROVIDE-ACCESS-FUNCTION (figure 6(a)).

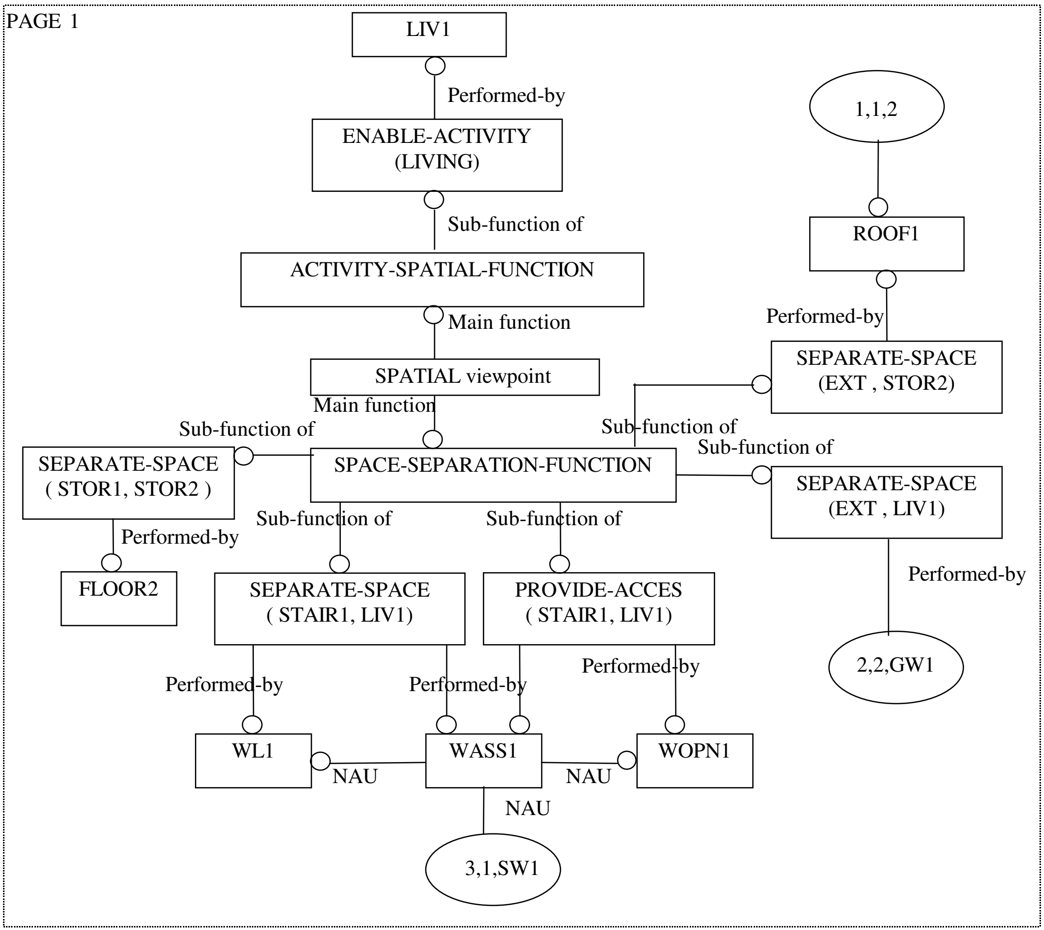

Figure 6(a). Instance of meta-model for the spatial view.

The apartment model namely BLDG1 contains 13 building elements as below:
the floors of apartment : FLOOR1, FLOOR2, FLOOR3 ;
the internal walls : WL1, WL2, WL3, WL4 ;
the wall openings : WOPN1, WOPN2, WOPN3, WOPN4;
the glass walls : GWL1, GWL2 ;
the element aggregations : WASS1 (aggregation of WL1 and WOPN1), WASS2 (aggregation of WL2 and WOPN2), WASS3 (aggregation of WL3 and WOPN3), WASS4 (aggregation of WL4 and WOPN4).
Other elements can be defined related to each viewpoint. For example, structural engineer defines the shear walls namely SW1, SW2, the floor slab namely SLAB1, SLAB2, SLAB3, etc. The functions related to SW1 are SUPPORT (SLAB2), SUPPORT (SLAB3) and RESISTANCE-LATERAL-FORCE (50). SW1 is the element of the apartment BLDG1. The parts of SW1 are WASS1 and WASS2. These pieces of information are represented as the instances of product-definition-relationship entity of STEP. The shape of SW1 and its material and other information are the instances of STEP product model entities. The structural engineer based on his view of building as a force-resisting/ force transmitting object sees SW1 and he does not see WASS1 and WASS3 as does the architect. He may modify some of the properties of this wall, e.g. the thickness and material. This must then be reflected back in the architect's model. Links must be made to the fact that WASS1 and WASS3 are related to SW1, so that any modification to one or other causes a modification to the properties of the others. This relation is represented as an instance of part-of relationship, a subtype of PROD-PROD RELATIONSHIP entity defined in our meta-model. The floor slab SLAB2 defined by structural engineer for a stability point of view is synonymous to FLOOR1 as an element. This relationship is represented by a SAME-AS1 relationship which is a subtype of PROD-PROD RELATIONSHIP.

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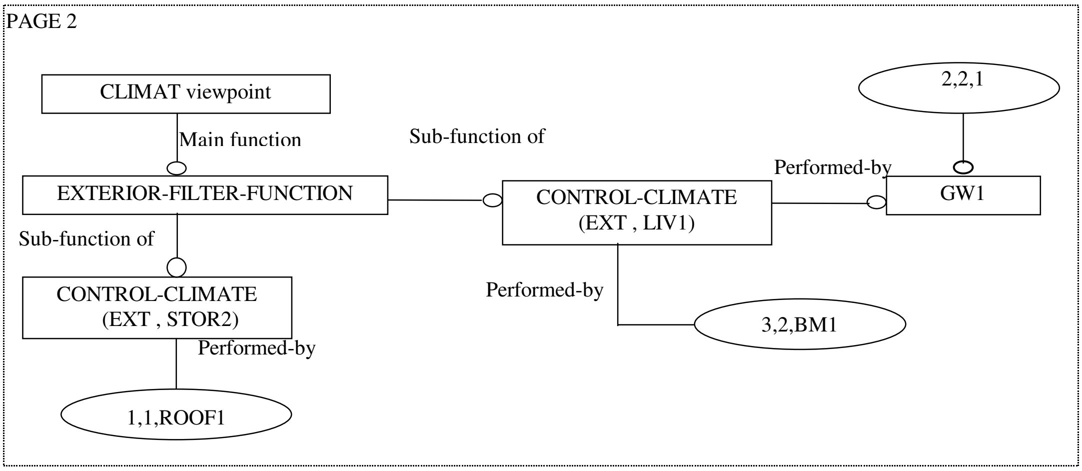

Figure 6(b). Instance of meta-model for the climate view.

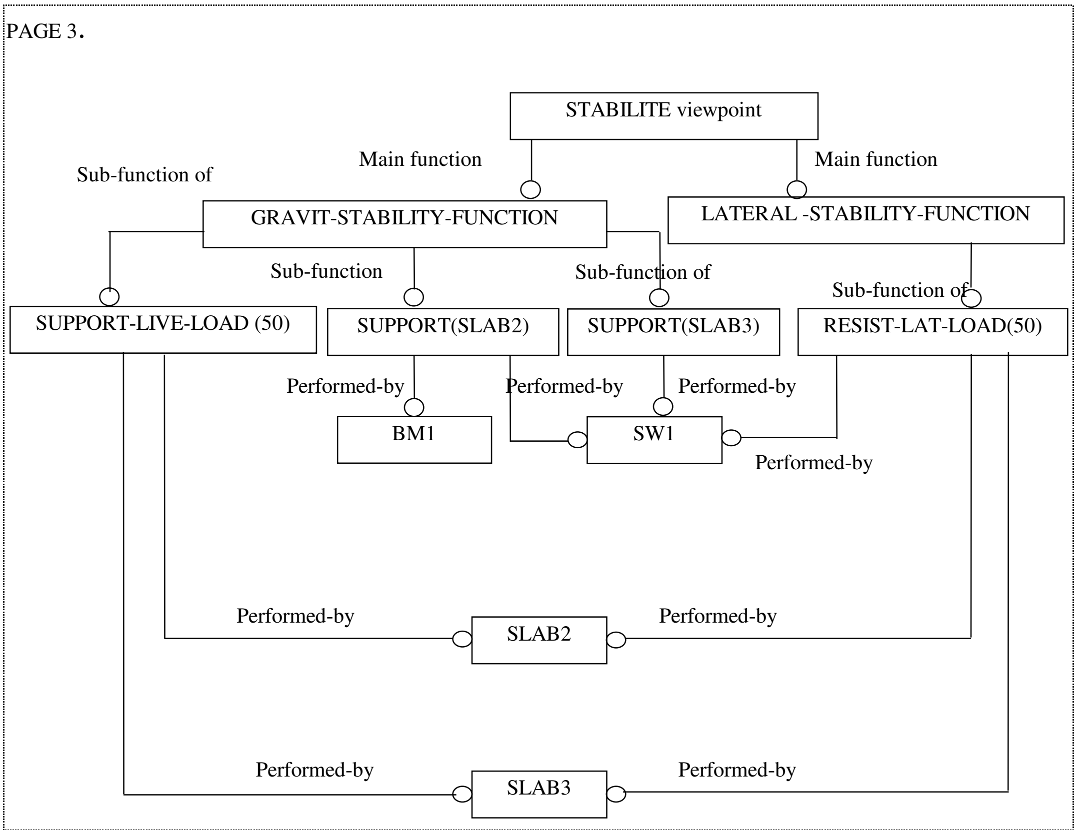

Figure 6(c) . Instance of meta-model for the stability view.

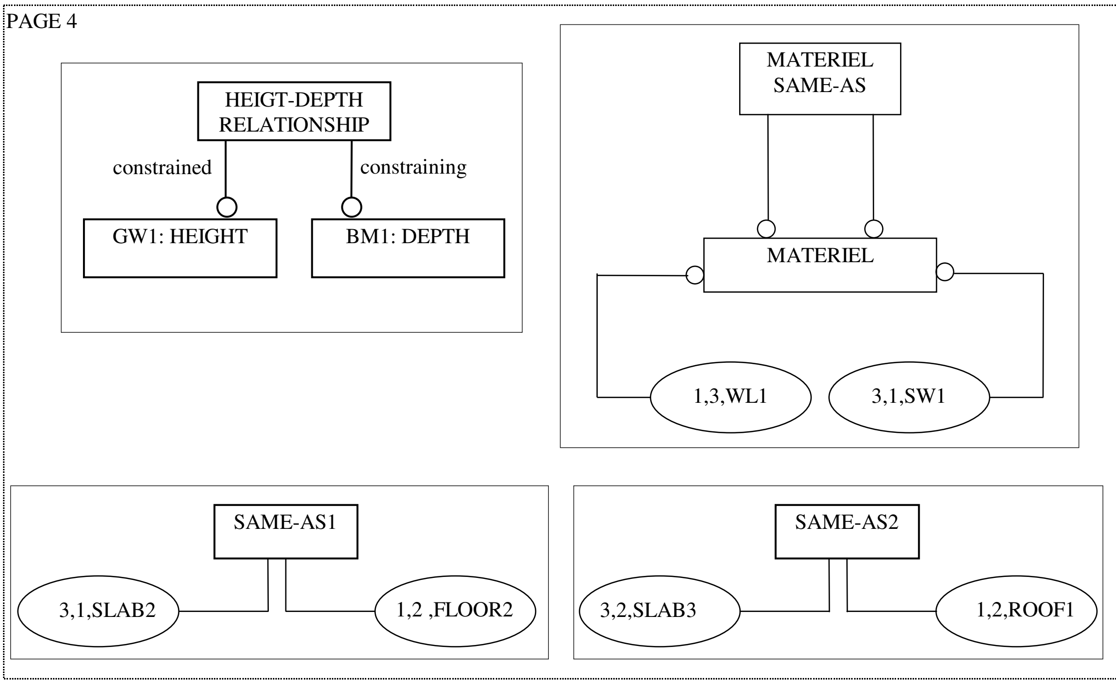

Figure 6(d). The relations between models of the views of figures 6(a),6(b), and 6(c).

5 Conclusion and perspectives

We have described the problem of multiple-view modeling in a collaborative environment. Current CAD systems and the current works on standards such as STEP use single model approach to represent the product. On the other hand, multiple model approach considers the dynamic representation of multiple views of a product based on a functional context.
Regarding all of these considerations we have proposed an approach respecting, at the same time, multiple and single model approach. We have developed a meta-model based on this approach and we have validated this meta-model by a case study.
Actually, we are developing a computer tool to allow multiple modeling of a product applying the approach proposed in this paper. This tool will be able to communicate via Internet network. It helps designers to make their own viewpoint models, manipulate them and to be informed of inconsistencies resulted from the view relations. The output will be an integrated model of all view models and their relationships in a STEP standard framework.

In the future, we contemplate to introduce the concept of behavior, which permits us to relate the functional and structural part of a product in a more logical manner. We will also focus our works on formalizing the views relations to complete our meta-model.

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