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The Design Process Data Representation Based on Semantic Features Generalization

Denis TSYGANKOV[1], Alexander POKHILKO, Andrei SIDORICHEV, Sergey RYABOV
Ulyanovsk State Technical University, 32 North Venets st., 432027 Ulyanovsk, Russian Federation

Abstract. This article is about the approach to achieve of design decisions modifiability on the level of assembly units. The main feature of this approach is design parameters manipulation as the semantic attributes. This is achieved by the assembly process representation of consistent implementation design procedures. They are treated as basic operations set, united by object orientation with a strictly defined semantic content.

Keywords. automation, 3D-model, assembly, design activity, design solution, process constructing, product, CAD-system, modifiability, solid representation, multibody model, semantic fullness, process, design procedures

Introduction

The current stage of CAD-systems development is the design documentation, presented in the form of three-dimensional model [1] came to the fore. Such documentation is an electronic document in the 3D-model format. Several critical positive aspects (ease of manufacture and convenience of design documentation creating, design solutions visualization) cause other difficulties associated with different CAD-systems operation specificity [2].

Usually a huge number of changes made during of the design documentation production. It occurs for different reasons and requires timely change of the solutions obtained in the corresponding CAx-systems. It is necessary to transform constantly all 3D-models, including on 3D-assembly to account for these changes [3]. The standard approach to modification of assemblies [4] (editing parts in the assembly context) cannot be fully realizable. The reason is that the parts do not correlate with each other and there is no possibility to set associative links between the attributes of 3D-model parts [5]. Thus, the standard approach violates the integrity of the design solution, and therefore requires manual adjustment of it solution. For the designer, who is not the author of the project it will cause additional problems.

Therefore, the actual problem is semantic patterns selection offering the necessary functionality for controlling 3D-image design data, which provides uniquely correct perception of the engineer-constructor.

This article explores the approach to achieve modifiability of design decisions at a level of on 3D-assembly [6], based on its representation as a process consistently

[1] Corresponding Author, E-Mail: d.tsyg@mail.ru

executes basic operations, incorporated in the design for object orientation procedure with a strictly defined semantic content.

1. Procedurally-Semantic 3D-Model Description

The lowest level of product design is designing parts that have one-body corresponding 3D-models within the 3D CAD concepts.

Part 3D-model Det^{3D} can be completely described by a construction tree [7] – streamlined design procedures provided the CAD-systems sequence as follows:

$$Det^{3D} = \sum_{i=0}^{n} des.proc_i \left(\sum_{k=0}^{m} des.par_k, \sum_{j=1}^{(i-1)} int.con_j \right), \quad \textbf{(1)}$$

$des.proc_i$ – design procedure, which has ordinal number of execution with a unique set of design parameters $des.par_i$ and relationships with other procedures $int.con_i$ that exist in the form of mathematical and logical expressions.

Information 3D-image parts Det^{3D} can be viewed as a structured set of project stages – a set of procedures described by the formula (1), combined in a fixed semantic unit [8], which formally as follows:

$$Det^{3D} = \sum_{i=0}^{n} \sum_{j=1}^{m} des.stg_i^{Obj_J}, \quad \textbf{(2)}$$

$des.stg_i$ – the design stage of construction of the j-th object Obj (object is a structural element of the details that has clearly perceived the physical sense).

Design stage notion is fundamental in our research: it is control of 3D-objects construction process in the details allows to parameterize the 3D-image of the product while maintaining the initial set of the discriminant.

Formally the design stage is described as follows:

$$des.stg_i^{Obj_J} = \left\{ \sum_{i=0}^{n} des.proc_i \left(\sum_{k=0}^{m} des.par_k, \sum_{j=1}^{(i-1)} int.con_j \right), M_{des.par}^{Obj_J} \right\}, \quad \textbf{(3)}$$

$M^{Obji}{}_{des.par}$ – is a set of object Obj attributes. Obj – set of design parameters that fully describe its 3D-image information, and perceive semantically clearly. Each attribute of an object from a plurality of $M^{Obji}{}_{des.par}$ has a relationship with the local parameters of design procedures in accordance with a predetermined design algorithm.

The difference between the Formula 3 and Formula 1 in that formula 3 identifies "discriminanst": attributes of the object – the parameters, the source for its construction. Handling these parameters does not require knowledge of algorithm development. Here need only knowledge of the subject area – the structure of the object and the part itself. Moreover, compliance with the design conditions of the system allows us to implement a tree structure form design solutions, allowing to generalize the objects in a single class on the basis of their semantic content.

On the basis of formulas (1) – (3) we can state that the 3D-model of the part may be represented as a set of objects M^{ObjJ}, having clearly perceived within the meaning of the part that can be represented as a formula:

$$Det^{3D} = \sum_{j=0}^{m} M_{Obj_J}^{3D} \left(M_{des.par}^{Obj_J} \right), \quad \textbf{(4)}$$

The basic object is a "Basis" or " Template" for the future design product: its discriminant – design parameters within the domain and technical specifications; He is the source for all other objects, and is associated with the original set of design parameters. Any desining always starts with its definition and formation.

Decomposition of process described by the formula (2), on the basic operations that are part of design stages, allow establishing associations between the attributes of objects, providing a structural and logical integrity of the design solution. This allows to control the assembly 3D-model, using a single set of input parameters.

Procedural representation (2) describes a 3D-model as non a complete solution, but as the process of its formation [9], as it considers consistent contribution of each stage in the final decision. The process of building a 3D-model conveniently considered as part of the IDEF methodologies family for visual display of the interaction design stages. Thus, four types of relationships can fully define the process; These include:

- *Input* – the source data. Technical task can act as an input (set of attributes point to the origin, and others.)
- *Exit* – execution result. It is structurally complete information 3D-image set of intermediate design parameters, 3D-model of the element, and others.
- *Control* – a set of conditions, rules and restrictions. It includes the state and industry standards for designed products, information and technical documentation.
- *Mechanism* – execution tool. As a rule, the mechanism is the user – a design engineer and CAD systems.

Presentation of the process of building a 3D-object within the IDEF methodology allows to clearly establish the types and the associative relationships between the project and the procedures included in their composition design operations, then it is necessary for the program implementation

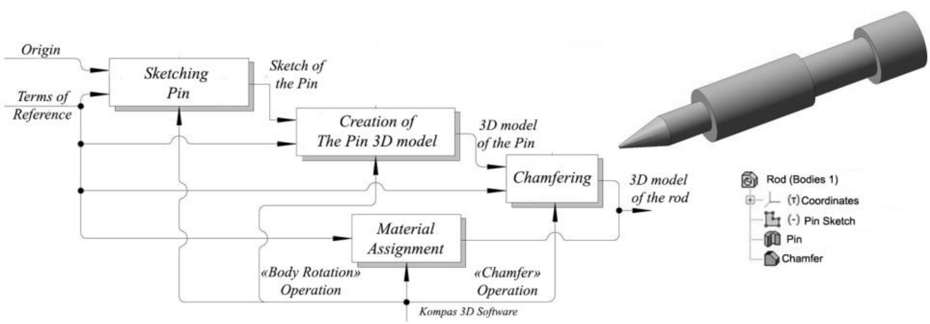

Figure 1. 3D-model of the rod and IDEF0-model of its building process.

As illustrated (in Figure 1) input (source data) – Terms of Reference, the point of origin (for spatial reference) output – the result of the design procedures: Information 3D-image.

Adding a change in one of the stages of design (internal or external) will result in a corresponding change of the output stage, as well as to a change of input data for all subsequent stages. Thus, the design solutions structural and semantic integrity fixing is carried out. Modification of assembly unit 3D-parts is supported at all stages of the its formation process.

2. Assembly 3D-model System Representian

Assembling is a 3D-system parts and subassemblies, which in terms of 3D CAD are complete structural elements. In general, it can be described structurally as follows:

$$Asm^{3D} = \left\{ \sum_{i=0}^{n} Det_i^{3D}, M_{con.}^{Asm}, M_{des.par}^{Asm} \right\}, \quad \textbf{(5)}$$

Asm^{3D} – assembly 3D-model of the product, $M^{Asm}{}_{con.}$ – set of pairings between a set of component parts, Det^{3D}, $M^{Asm}{}_{des.par}$ – set of assembly attributes.

Figure 2 shows: assembly 3D-model of coaxial contact and the model tree. There are only pairing options. This means that the parameterization of assembly is reduced to operating parameters of the interfaces or location of the components in space.

Assembly is controlled by manipulating the values describing its attributes, which can be reduced to two variants of its modification: changing the set of component parts (quantity), and the change in their relative position. In both cases, access is not available for editing the details themselves. This is so both in the assembly their 3D-image is strictly defined.

Mates tie to the structural details of the objects to each other. It determine only the positions of these parts in the space (both static and moving range), making the system components integral in a predetermined structure.

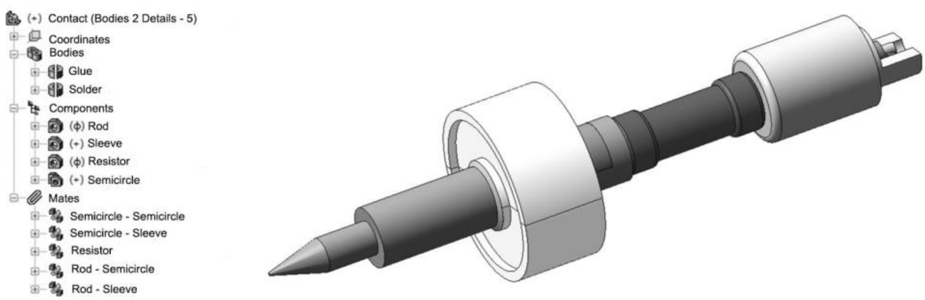

Figure 2. Assembly tree and its 3D-image.

As a result, at the classic sense, the assembly cannot be considered as a process for the following reasons: parts are complete structural elements and the sequence of mates installation has no effect on formed decision. And the processes of creating 3D-model of component changes in will cause a restructuring of the assembly unit, usually accompanied by a number of errors. So, need a different way to describe the assembly.

3. The Approach to 3D-Assembly Model Procedurally-Semantic Description

Presentation of the assembly unit as the process is made possible by shifting the level of model decomposition from the level «3D-Building" to the level of «3D-Detail" which is accompanied by two critical transformation:

- The assembly model is considered as a complex 3D-model of all parts – as a set of objects (separate solids), it allows to keep the processes of construction of each of its components.

- Details – assembly components are treated as objects in the context of a single piece, that allows to establish associations between their attributes, and transfer their design parameters describing the level of the assembly unit.

Thus, a complete set of components, including the process of their construction and ready for detailed analysis and processing is present in a single file. This file allows to fully describe the process of formation of the design solution, while maintaining relevance with decomposition to the lowest levels, and at their change.

Procedural model of on 3D-assembly transformed into a multibody part is a consistent association of constructing processes every part of components:

$$Asm^{3D} = \sum_{i=0}^{n} Det_i^{Obj_i} \left(M_{des.par}^{Obj_J}, M_{des.par}^{Asm^{3D}} \right), \qquad \textbf{(6)}$$

Det^{Obji} – a kit of parts components represented as an object in the context of a multibody part. Each of these parts is a function of parts the attribute values $M^{Obj}{}_{des.par}$ and the assembly itself $M^{Asm}{}_{des.par}$.

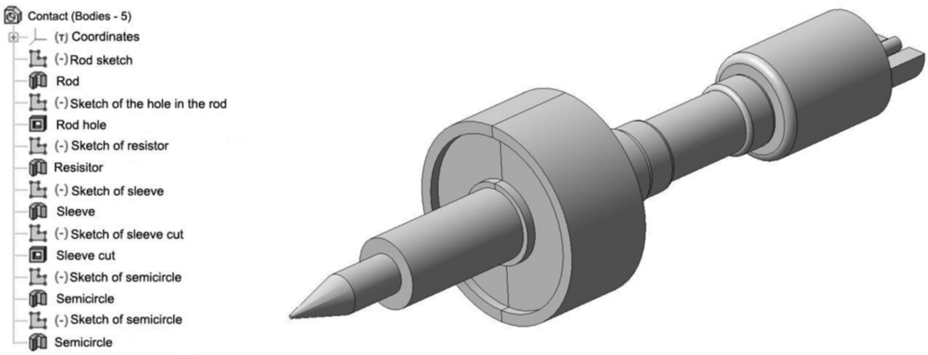

Figure 3. 3D-assembly is converted into 3D multibody-part.

Figure 3 shows the assembly unit of the rod shifted to the level of 3D-part. As can be seen, multibody parts contains 7 solid bodies (5 of them – correspond parts-components). Fixing component (solid bodies) on a single level, allows to select discriminants of projected assembly. Source data are following from them: the type, the length of the rod, type and value of the resistor and the value of the wave resistance; all other design parameters are obtained by calculation.

Thus, it becomes possible to associate the assembly of components that provides its full parameterization and interdependent components. As a result, it provides its modifiability in automatic mode by changing the the describing attributes the assembly itself as well as by changing the the parameters of the local the components.

4. Program Implementation

Program implementation of the proposed approach is based on the use of the Open CASACDE Technology (OCCT) platform as follows: structural analysis of the designed product stands out a set of used design operations from the library OCCT [10], which are encoded in a consistently executing protocol – the object 3D-model creation basic operation. This operation provides its attributes for a complete determination of the designed product.

5. Conclusion

Fixing assembly components based on submission of solid bodies (objects) on a single level, allows to select discriminants projected assembly unit, connect them to define the initial set of data that will be strictly defined semantically and will allow to operate the 3D model of the product, in terms of subject area concepts which applies the product.

Assembly unit description by system patterns allows to select discriminant designed product, link them to determine the source of the data set that will be strictly defined semantic information and enables you to control 3D-imade, in terms of subject area to which the proposed facility.

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