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A descriptive semantics of modelling process catering for whole product parametric

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A B S T R A C T

To date, the entire product parametric technology has made great progress to significantly improve product design efficiency. However, the technology uses an established modelling process, which makes it very difficult to adapt to changing product requirements. A method that can be customised for the whole machine is discussed in this paper; this method is intended to increase the adaptability of the entire product parametric technology. First, a frame model concept is proposed based on an analysis of a large number of product modelling processes. Second, a semantic model for describing the modelling process is proposed, and its instantiation is studied. Next, according to the semantics of the modelling process, a product parametric modelling system is established. Finally, based on an examination of the electronic module modelling, it was found that modelling efficiency increased significantly.

1. Introduction

Nowadays, many companies have to speed up their new product development to meet the challenge of keen market competition. Parametric technology is the most effective way to achieve rapid geometry modelling that has thus far been found [1]. However, current parametric technology is only applied to the creation and modification of models of parts, which makes it difficult to fully meet the demands of rapid modelling [2]. When creating a whole product model with traditional parametric technology, designers must still perform many cumbersome operations primarily with respect to the three following points: first, a designer must fix the types, number, and assembly relationships of the product components; second, a designer must define the topology of components and features, such as joints, plug devices, and the lockers for each avionics crate module; lastly, a designer must verify the design parameters. In a digital modelling process, there are a large number of parts, features, and parameters with complicated interrelationships. Because these parts, features, and parameters must be maintained, modified, and adjusted constantly, a designer's modelling workload is large. According to statistics, product modelling time makes up 40% of the total working time for designers using the current parametric technology.

For a particular product, the above modelling process has certain rules that must always be followed these are referred to as 'modelling processes'. Whole product parametric technology can be described as follows [3]: in view of the characteristics of a certain type of whole product model, designers summarize modelling rules in order to help them write a model's programs. These programs can automatically finish a series of whole product modelling tasks in order to greatly improve modelling efficiency. According to Boeing's forecasts, introducing whole product parametric technology into the Boeing 777 design process will save 50% of the time spent on repetitive work and revising mistakes. Additionally, the time spent developing subsequent models will be reduced by at least 50% [4]. Parametric technology is believed to be useful to increase the efficiency of tedious design cycles, and effective to facilitate the exploration of different ideas and innovations by reducing and simplifying the updating tasks.

Currently, a major challenge for engineering informatics research is to develop a new modelling approach that can be used to describe modelling process top-down, and significantly to improve the expression efficiency of the whole modelling processes, which has several merits of better description of the whole product modelling processes, concise description semantic, high adaptability, clear and accurate modelling description.

The paper further develops knowledge-based engineering technology. First, given the poor capability of existing KBE scripts for describing whole product modelling processes, a frame model concept is proposed, which effectively defines a product's hierarchical description using virtual components (VC), virtual features (VF), component instantiations and feature instantiations, etc. With the whole product modelling processes described, tedious mod-

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elling details can be ignored. The associations and constraints of components, features, and parameters must be described emphatically, and then product model details are constructed by final users through configuration. Second, based on the frame model, the whole product descriptive semantics are constructed. Then, combined with the KBE technology, a descriptive method for the whole product modelling process is established, and a corresponding whole parametric technology is constructed.

2. Literature view

In the engineering field, the application of parametric technology was traditionally limited to geometry construction. More recently, broader definitions and applications of advanced parametric are developed. It is expected that future comprehensive product models, which include semantic, analytical and geometrical details with computer interpretable accuracy, will provide the scalability support of modern engineering informatic technology. Parametric technology is one of the key enabling technologies. Research on parametric technology has been greatly expanded due to many recent efforts and achievements around the world, which makes parametric technology more applicable and mature. Currently, parametric technology is under rapid development to meet the demands of product innovation, collaboration, time-to-market competition and managing complexity [31–33].

At present, domestic and overseas research on whole product parametric technology focuses primarily on three points: first, whole product parametric technology is based on instantiation programming, which can build a knowledge database by refining the modelling experience of a product [5–10], and then rapidly create a whole product model. These modelling rules are often treated as fixed codes [11–13] in a system, which can only run according to its pre-programmed rules. If the product is changed slightly, the system will no longer work effectively. In real engineering, many factors can affect the geometric shape of a product. Modelling rules are trivial and changeable, so the whole product parametric modelling technology has poor adaptability to actual engineering requirements. Second, whole product parametric technology is based on geometry constraints, which define the basic product geometry information of the model using referenced elements (points, lines, and areas) at an early modelling stage, and then construct part details (features and size) based on referenced elements during the detailed design stage. Product geometry models can be controlled by modifying the position, shape, and parameters of referenced elements. Typical projects using this technology include WAVE (What-if Alternative Value Engineering) [14], Skeleton Models [15], and Assembly Layout Sketches [16]. This technique's good flexibility allows it to be used for top-down modelling [17,18], but because whole product modelling is a complex process, some associated problems still cannot be solved. The modelling process and its rules cannot be described comprehensively by geometry constraints. modelling efficiency and operating complexity have a big gap with real one. Lastly, whole product parametric technology is based on knowledge description, of which kind is Knowledge Fusion (KF) [19], by which the product modelling process can be described, the process having been introduced the scripts. Dassault Systemes develops this knowledge expert technology and provides compound modelling technology using knowledge-based engineering [20]. GM considers knowledge-based engineering (KBE) technology as the key to improving the development capability of products, and develops several design-advisory systems [24,25]. The Air force Research laboratory proposes self-adaptive knowledge modelling language (AML) based on KBE, which has already been used in UVA wing design [21–23]. One main advantage of this method is that parametric scripts are automatically saved, and users can modify scripts to control product modelling processes. On the other hand, scripts built using traditional parametric technology can only be used to describe the modelling process for fundamental modelling operation functions. Scripting is too cumbersome to satisfy the configurable demands of whole product parametric systems.

In engineering informatics field, research on knowledge modelling has been developing rapidly. The commonly used methods of knowledge representation are first-order predicate logic, production rule and semantic network and framework [26]. To enable storage and accessibility by the inference mechanism, the domain knowledge needs to be structured and formalized by means of some symbolic representation [27]. Rules and frames are the two most common forms of knowledge representation [28,29]. The first is based on the well-known IF-THEN construct. The second is a concept, proposed in 1970 by Minsky [30], based on the use of a collection of slots to describe attributes and/or operations featured by a given object. Each slot may contain a default value, a pointer to another frame, or a set of rules (including IF-THEN rules) and procedures by which the slot value is obtained.

However, the modelling process applications for parametric design are not well studied because no mature mechanism is available to manage design evolution of changes explicitly and systematically. In the scope of specific views of the product description with respect to the classes of characteristic properties and computing, this paper proposes a method of formalizing semantics.

To prove the applicability for typical modular products, a electronic equipment module is used in our case study. The proposed frame model and descriptive semantics method allows explicit change propagation.

3. Frame model and descriptive semantics

3.1. Frame model definition

The modelling process is represented by the transition of modelling states, each of which is defined as a set of valid modelling concepts and their related knowledge and information at a certain moment. The frame model is the synthesis of the semantic representation and geometric representation of the modelling process. According to different expression levels, the frame model is divided into a product frame, an assembly frame, and a parts frame. The following is a list of definitions of frame-model-related concepts,

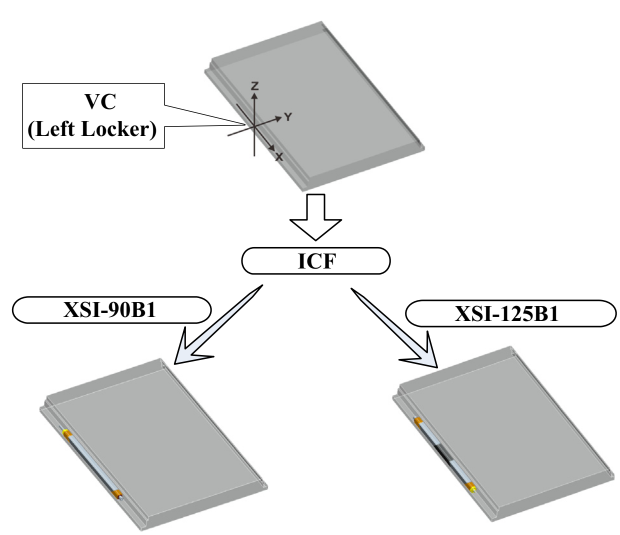

Fig. 1. Component frame and virtual component.