INTEGRATION OF KNOWLEDGE MANAGEMENT IN PRODUCT DESIGN PROCESS

Yang Xu and Alain Bernard
IRCCyN, Ecole Centrale de Nantes, 1 Rue de la Noë, 44321 Nantes, France

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Abstract: In order to keep up with the high adaptability of the product design requirements, it is essential to integrate knowledge management into product design processes. This paper proposes a model that conjoins the objects, functions, constraints and knowledge, analyzes the task evolution process by means of state characterization. By using the schema based on the model, it is practical and efficient to find appropriate knowledge to a given general object in the context of certain constraints.

1 INTRODUCTION

In this era characterized by worldwide competition, knowledge management is playing a key role in every aspect of our lives, especially in enterprise productions (Bernard and Tichkiewitch, 2008). In order to improve the possibility of success, a variety of knowledge management (KM) and computer integrated manufacturing (CIM) models have emerged in recent years, such as the FBS-PPRE model (Labrouse, 2004), advanced technologies based on CIM (Nagalingam and Lin, 2008), the GRAI integrated method (GIM) (Doumeingts et al., 2000), the object-oriented approach based on the UML (Unified Modelling Language) modelling (Merlo and Girard, 2004), etc. They all have particular contributions to the modelling and analysis of the knowledge management.

Although the notion of knowledge management has different explanations and its research content is fairly abundant, the aim of giving appropriate knowledge to appropriate persons at appropriate times is widely accepted. Therefore, one of the challenges for the knowledge management is to clarify the expectations with constraints in order to propose the corresponding knowledge to satisfy the need.

This paper focuses on the architecture and the process to match the objects, functions, constraints and knowledge, and proposes an OFCK model applied to the product design process.

The paper is organized in four parts. Besides the introduction section, Section 2 proposes a model that conjoins the objects, functions, constraints and knowledge, Section 3 analyzes how knowledge is integrated into the product design process, and Section 4 concludes the paper with several perspectives.

2 THE OFCK MODEL

From the experience in product development process, we know in order to accomplish a complex task, it is appropriate to divide it into sub-tasks and sub-sub-tasks until the objects of the indivisible tasks can be reached easily. The relationship among objects, constraints and knowledge should be well studied in order to find appropriate supports effectively.

Consequently, an Object-Function-Constraint-Knowledge (OFCK) model is proposed to abstract the relationship among these four aspects in knowledge management.

2.1 Objects, Functions and Constraints

In practice, any task is consisted of two parts: the object and constraint, as nothing can be done without any constraint. Thus, a task is divided into two sets: the set of objects and the set of constraints, noted as follow.

- The set of objects $S_o = \{o_1, o_2, ..., o_p\}$, where $o_1, o_2, ..., o_p$ are called atomic objects. Each

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atomic object o_i corresponds to an atomic function f_i, in other words, f_i can achieve o_i and they are one-one corresponding: $o_i \Leftrightarrow f_i$. All these f_i form the set of functions $S_f = \{f_1, f_2, ..., f_p\}$.

- The set of constraints $S_c = \{c_1, c_2, ..., c_q\}$, where $c_1, c_2, ..., c_q$ are called atomic constraints.

According to the idea of divide-and-conquer that partitions the problem into fine scale sub-problems and assembles of the solutions of the partitioned sub-problems to constitute the overall (Gravemeier and Wall, 2008), a task T can be divided into several atomic sub-tasks that can be solved simply, thus, a set of atomic tasks is noted as $S_t = \{t_1, t_2, ..., t_p\}$, where t_i is the atomic sub-task. Each t_i is an ordered pair consisted of an atomic object and a set of constraints, i.e. $t_i = (o_i, \{c_1^i, c_2^i, ..., c_p^i\})$. Due to $o_i \Leftrightarrow f_i$, we have:

$$t_i = (o_i, \{c_1^i, c_2^i, ..., c_p^i\}) \Leftrightarrow t_i^* = (f_i, \{c_1^i, c_2^i, ..., c_p^i\})$$

As a result, the task T is decomposed into a set of ordered pair $(f_i, \{c_1^i, c_2^i, ..., c_p^i\})$.

2.2 The Knowledge

Knowledge should be organized properly in order to be useful in practice, so a knowledge base KB is introduced as the set of the organized knowledge and it is defined as follows.

Definition 1. The knowledge base KB is a group of vectors, noted as:

$$KB = \begin{Bmatrix} K_1, \\ K_2, \\ ... \\ K_n, \end{Bmatrix} \quad where \begin{cases} K_1 = \{k_1^1, k_2^1, ..., k_{m_1}^1\} \\ K_2 = \{k_1^2, k_2^2, ..., k_{m_2}^2\} \\ ... \\ K_n = \{k_1^n, k_2^n, ..., k_{m_n}^n\} \end{cases}$$

In this definition, K_j is the knowledge unit, k_i^j is the atomic knowledge, and $k_i^j \in K_j$.

2.3 The Function-Constraint-Knowledge Map

One of the most important targets in knowledge management is to find required knowledge in the context of the given objects and constraints, in other words, to map the objects, constraints and knowledge in a proper way. As $o_i \Leftrightarrow f_i$, the aim becomes to build a Function-Constraint-Knowledge (FCK) map.

Hypothesis 1. An atomic knowledge k_i^j possesses an atomic function f_y in the context of a certain set of constraints $\{c_1, c_2, ..., c_x\}$, which is noted as:

$$k_i^j \otimes \{c_1, c_2, ..., c_x\} \xrightarrow{\Delta} f_y$$

This hypothesis is based on the facts that the knowledge is regarded as a kind of support in solving practical problems, so it must have a kind of function, otherwise, can it be called "knowledge"?

As a result, in the FCK map, there are groups of "k, f, $\{c_1, c_2, ..., c_x\}$".

2.4 Knowledge Seeking

From the previous analysis, once an atomic task t_i is given with related constraints, required atomic knowledge can be found through the FCK map. Then, an effective method should be referred to in order to seek the knowledge in the KB that can provide the atomic knowledge required. One idea is to apply the inverted list used in the practical information retrieval systems to support text searching (Lester et al., 2006), which is an effective structure that maps from a query term, the atomic knowledge k_1, to a posting list that identifies the knowledge units that contain that term.

3 KNOWLEDGE INTEGRATION IN PRODUCT DESIGN PROCESSE

The process of product design is one of the most complex stages in production which need both explicit and tacit knowledge. For example, as simple as a chair, its design process is not as easy as we thought. Concisely, a designer has to consider about

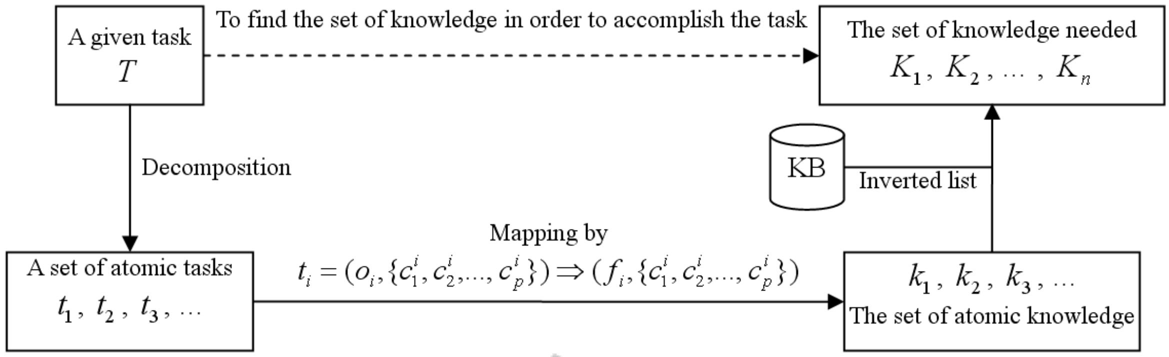

Figure 2: The application process of the OFCK model.

its comfort, mechanical support, recycle possibilities and manufacturing cost. The complicated relationships of function, constraints and knowledge are involved. For example, a designer may use carton as the main material of the chair to satisfy the task of “the chair should be recycled”, but can it meet the requirement of “to support a man of 80kg”? To achieve this object, different chair architectures are possible according to different chair materials, which are related to cost consideration. At the same time, chair architecture should also take the task of aesthetic design into account. In a word, design processes are very complicated, so we need a knowledge management model to simplify and realize them.

One basic idea is to decomposed a whole task as sub-tasks and arrange these sub-tasks. The OFCK model described in the section previously presented is atom-unit oriented, so a general task should be decomposed in order to adapt to the model. To begin with, the product development process is characterized as a basis of task decomposition.

3.1 Characterization of the Product Development Process

In order to characterize the product development process, a finite state machine of product (FSMP) is proposed and defined as follows.

Definition 2. A finite state machine of product (FSMP) is a hextuple $\langle Q, \Sigma, \Pi, \delta, E_0, F \rangle$, where:

Q is a finite and non-empty set of product states;

Σ is a finite and non-empty set of supports (knowledge, manipulations, etc.);

Π is a finite and non-empty set of constraints;

δ is the state transition function: $\delta : Q \times \Sigma \times \Pi \rightarrow Q$;

E_0 is an initial product state and $E_0 \in Q$;

F is the set of final states and $F \subset Q$, and there is at least a state $E_n \in F$.

In fact, the aim of the OFCK model is to find appropriate knowledge to realize the supports according to the given task and constraints.

3.2 Task Decomposition

In order to achieve the main object, the general task is decomposed by splitting the whole project into sub-parts, and the process of achieving the general task is regarded as an evolution process of the product states, shown in Figure 1.

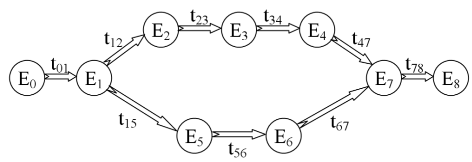

Figure 1: A product development process described by FSMP.

In Figure 1, E_i is the product state and t_i is the atomic task to change the related state. Inferred from the OFCK model, knowledge seeking is processed as:

$$t_i = (o_i, \{c_1^i, c_2^i, \ldots, c_p^i\}) \Rightarrow t_i^* = (f_i, \{c_1^i, c_2^i, \ldots, c_p^i\}) \xrightarrow{\text{the FCK map}} k_i$$

Consequently, the formalized definition the general task T is given as follows.

Definition 3. The general task T is what to be accomplished to realize a product development process, in other words, to evolve the product P from E_0 to E_n. The product P is a finite state

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machine defined on the knowledge set K and $L(P)$ is the language generated by the product, in other words, a sequence of elements in K, noted as:

$$L(P) = \left\{ \begin{matrix} k_1^P k_2^P ... k_n^P \mid (k_i^P \in K) \wedge (E_j^P \in Q); \\ i = 1,2,..,n; j = 0,1,2,..,n \end{matrix} \right\}$$

where E_j^T is the state in the evolution process of the product P.

We have $T \Leftrightarrow P$, that is to say, each general task T links to a product development process of product P. For example, the task of "design a chair", means to realize a product design process, from the initial state "an idea" to the final state "details of the chair".

3.3 The Application Process of the OFCK Model

Thanks to the OFCK model, some issues in knowledge management can be simplified to the problem of seeking solutions from a knowledge base when the general object and constraints are given (shown in Figure 2). For example, in a case of designing a chair, the OFCK model can be applied to seek the knowledge required.

1. Decomposition. The general task of "designing a chair" can be decomposed into sub-tasks such as considering the architecture, considering the cost, considering the recycle possibilities, considering aesthetics, etc.
2. Mapping. Once the atomic tasks are clarified in the design process, the atomic knowledge can be found by the use of the FCK map.
3. Retrieving. The required knowledge can be retrieved through the ILK or imported from the extern.

4 CONCLUSIONS AND PERSPECTIVES

This paper has proposed the OFCK model to describe the relationship of objects, constraints and knowledge, which helps to find the appropriate knowledge to a given general object in the context of certain constraints. The main idea of the paper is to find the appropriate knowledge to a given task.

Further studies may aims at the optimization procedure of the product design process, in other words, how to accomplish the tasks in a more efficient way. Another research opportunity is about the improvement of the characterization of the product design process. When some processes have recursions, the task decomposition process will be much more complicated and the mapping process should be reconsidered.

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