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Modeling of Product Functional Model in Conceptual Design based on Case-based Reasoning

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Abstract: The modeling of the functional model has been researched by using case-based reasoning (CBR) in conceptual design. On the basis of the describing of the functional model and the coding of the product functionthe functional nodes and the edge have been matched. The functional model which has the most high similarity has been searchedthen the nodes and edges have been modified to meet the design require. Based on the above two kinds of technology and follow the design principle of multi-agent cooperation solving system and CBR working procedure, a multi-agent system architecture which adopt a strategy of task harmonize and based on hybrid structure is put forward. The functional model can be established to meet the companys ability in the conceptual design stage by using the methods in this paper.

Keywords: Functional model, Conceptual design, Case-Based Reasoning (CBR)

1 Introduction

The design process of new product is ”function-structure” mapping process. Establishing of the right product functional model in conceptual design is the key problem. The task of conceptual design is to meet the demand of the market. Among them, function model derives from the understanding of the market demand from the designer of [1,2,3,4,5]. For new task, experienced designers get new scheme through the imagination about past design. The process of conception is the process which is based on their experience [6,7]. Function model in conceptual is the initial results from the designers conception. Due to the limitation of the designers experience, it is difficult to get function model which is suitable for the design and the manufacturing capacity for enterprises [8,9,10]. As a result, we need to resort to previous design case to make decisions. The existing design case contains a lot of design experience knowledge. It is the optimization results or satisfied result of the design problem [11,12,13,14]. It is also accord with the design and the manufacturing capacity of enterprises. Combining with computer aided technology and using the function model based on case-based reasoning to complete to determination the function model overcomes the limitations of the experience of the designer, which helps designers quickly set up perfect function model in conceptual design to lay the foundation for the detailed design.

2 The Function Model of the Description

The function model of the products reflects the needs of the user. It is plane figure structure and related information structure which is made up of sub-function and function-unit .It is first to describe the function when establishing of function model .Method to describe the function is classified into two kinds: one kind is to standardize the message content of the function, All functions are expressed by function-unit, practically the abstract modeling. Another kind is to standardize the representation method of the function and to definite language format and establish unification in form. For example, it describes function by verb object which consists of a verb and a noun .But the different industry can lists function-unit according to the characteristic of oneself to classify and number the function-unit. For a

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profession or enterprise, its function-unit numbers is the only.

The basic unit of the function model is function-unit. Function-unit composes sub-function according to the rules. Total-function is composed with sub-function. So the function model can be describes with levels of tree structure[2]. It expresses function model FT=(F,FE) with the binary, F is the node set the of function model, namely the function sets; FE is the combination of edges in function model to express relations between subsidiary and constraint. The root node of the function model is on behalf of the function of the whole machine or parts. Leaf nodes represent the function of the son component or the part. If leaf nodes function model have no bifurcate, the leaf node is the function-unit which can be not decomposed. The description of the function model can be seen in Fig. 1.

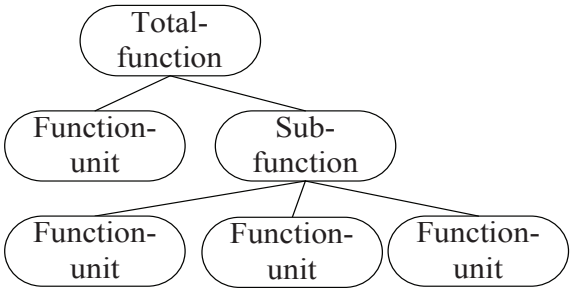

Fig. 1: The description of the function model

3 Establishing of Product Function Model based on CBR

Case-Based Reasoning process is: search the biggest similarity case-cases modify-case storage. Function model which is made up of function-unit according to certain rules is a tree structure. The basic nodes of function model are composed with function-unit. Edges of function model are composed with constraint relationship between nodes. So, case matching is divided into matching of basic nodes and the matching of the edges.

3.1 Searching of the Most High Similarity Node

For a profession or enterprise, its function-unit numbers is the only. So the matching of function-unit can be transformed into the matching of function numbers. The node similarity calculation in function model is as follows:

Similarity calculation of character type is: $S(A,B)=\begin{cases}1, & A=B\\ 0, & A\neq B\end{cases}$ where A,B are characters.

The numeric similarity is more complex. It is divided similarity between node and node, similarity between node and edge, similarity between edge and edge [4,5]. In the function matching, dealing with function-unit numbers only is similarity between node and node. The similarity calculation model is as follows:

Suppose $S(x,y)=1-\frac{|x-y|}{\beta-\alpha}$ node $a,b\in[\alpha,\beta]$,the similarity between a and b:$S(a,b)$.

3.2 Searching of the Most High Similarity Edges

Edge is connecting the two nodes. So the edge is expressed by relationship between the two nodes and other nodes, and has a direction. The edge numbers of function model are expressed with eight digit number. The first six digit number is function number. The other two is constraint relationship numbers. Searching of the biggest similarity edges is also dealing with the number. Likewise, using the calculation model of similarity between node and node can get the similarity of edge.

Through the traverse all the nodes and edges of function model can get the similarities of function model. Comparing with other on the size of similarity may search the largest similarity function model. The similarity of the function model: S=$\sum^{n}SJ_i\omega j_i$+$\sum^{n}SE_i\omega e_i$, SJ_i is the similarity of the i node,ωj_i is the weight of the i node,SE_i is the similarity of the i edge,ωe_i is the weight of the i edge.

3.3 Modification of the Function Model

After searching the most high similarity function model, in most cases, the model should be modified so as to meet the functional requirement of the design. Modification of function model is an operation on a tree. The operation on tree structure can be divided into node/edge delete, node/edge add, node/edge merger, node/edge decompose, ode/edge replace. A concrete operation process can be seen Fig. 2.

4 Establishing Process of Function Model

Establishing of function mode in conceptual design process is the CBR process. Interaction with the designers quickly determines function model so as to improve the efficiency of the function decision-making. Establishing of function model is shown in Fig. 3:

(1) Market research can extract the function which the product required. According to the requirements of the

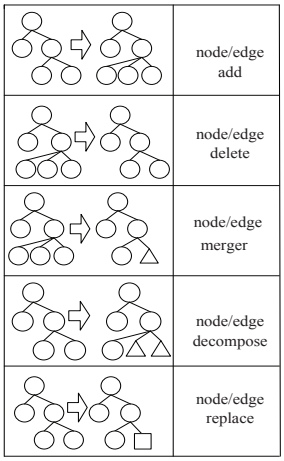

Fig. 2: The operation process of the function model

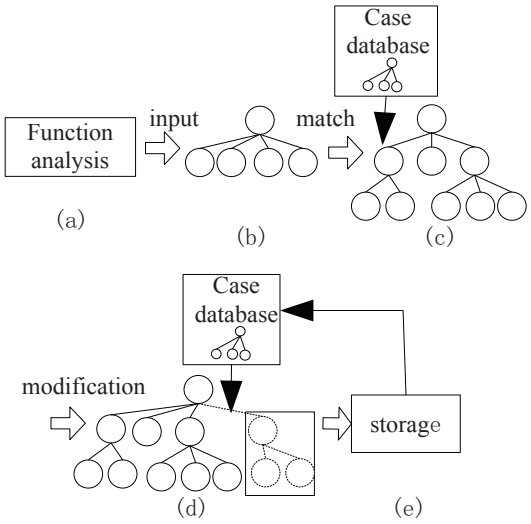

Fig. 3: Establishing of function model flow chart

customers to get rough function model after the analysis of function. Fig. 3 (a) get a rough model shown in Fig. 3 (b).

(2) Input function model in the form of coding. The system matches the most high similarity function model case automatically. Fig. 3 (c) the similarity of function model is the most high, the second nodes need to add new functions, comply with the design requirements.

(3) Ask the function model to add, delete operation so as to meet the requirements of the customers. When add or replace a certain function of function model, search the function with the most high similarity search to add or replace to function model. Search in case database and added to the model with the most high similarity sub-function with the design intent. Box in the Fig. 3 (d) is new sub-function added.

(4) Matching, modify repeatedly until obtain satisfactory function model. Fig. 3 (e) is storage new function model.

5 Product Functional Design Model based on CBR and MAS

Based on the above two kinds of technology and follow the design principle of multi-agent cooperation solving system and CBR working procedure, we put forward a multi-agent system architecture which adopt a strategy of task harmonize and based on hybrid structure. When there are consultation demands, make the negotiation module and other Agent to coordinate based on practical case. The negotiation module take the charge of its Agent send consultation request to the other Agent, and receive feedback information for reorganization module. Based on CBR and MAS Product functional design model is as shown in fig.4.

Through the task Agent finish the problem description, then retrieval by CBR Agent ,when the CBR

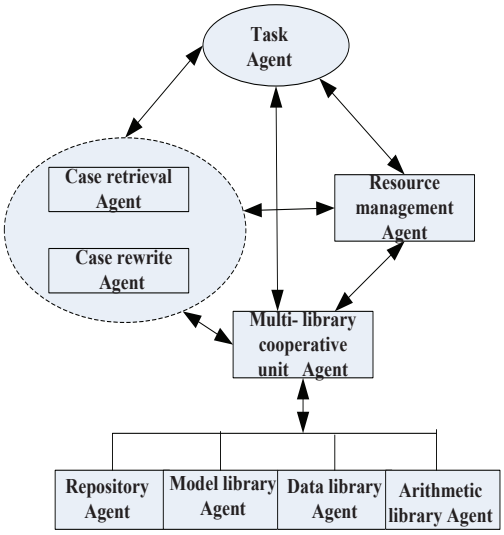

Fig. 4: Product design model based on CBR and MAS

Agent finish the similar case retrieval, put the similar case match into the current problem, then form to the solution suggestions for current problem, at the same time, send the solution suggestion resource management Agent. In this process, multi-library cooperative unit schedule all the libraries resource Agent, complete the knowledge, information, algorithm, model and so on calls which are need in the restructuring process. Resource management Agent collects all information and responses for modify.

5.1 Case-based Reasoning Process

During the process of product design based on case reasoning, knowledge is showed by case, its reasoning process is retrieving case which similar to current solving problem and adjusting it properly to solving problem forward in the search to the current similar case and appropriately adjusted make it adapt to solving problem. Once the match or adjusted matching success, the cases measures to solve the problems can be used to reconfigure reasoning, its main purpose is to search the best case from the case library as the basis of product design, which is according to various constraints of the solving problems. The process of case-based reasoning is as shown in Fig. 5.

When the new design task comes, the first is to process audit by the task Agent, judge system resources whether can meet the new design task or not, if not satisfied, then giving prompt information, the resource management Agent responsible for negotiate solve; if satisfied, then decompose the mission. The assembly product design process which is based on the CBR as follows:

Step 1:

Input the process information of following design task, and make it as the target case;

Step 2:

According to the target case and by a retrieving strategy, retrieve the best similar case as a suggest solution for product design;

Step 3:

If higher similarity judgment, then use the similar case solutions and confirm

Step 4:

If judge the similarity is not high, then correct it. In addition, when happen conflict because of resources limit, we must use Agent technology to coordinate resources.

Step 5:

Evaluate the result of the revised result, if doesnt satisfy the requirements, then return to Step 2 or end;

Step 6:

Generate the design scheme after the evaluation, and make the solution scheme as example save to case-based library reserve for next time to use.

Through reusing and correcting case, get the assembly product design solution scheme.

Through the example save to case-based database, system incremental learning, and constantly improve performance.

Case representation and retrieval is very important, rewrite similar examples dont have fixed model, so it need to according to the domain knowledge and experience to explore type.

5.2 Description of the Problem

Consider for the task G, according to the process will be divided into one subtask is the task $G = (g_1, g_2, ..., g_i)$; for any $g_i \in G$, $g_i = (f_{i1}, f_{i2}, ..., f_{in})$; f_{in} is a feature of g_i representative, such as equipment resources, assemble resources, task completion time, etc which are needed.Design resource $M = \{m_1, m_2, ..., m_k\}$ represent there are k kinds design resources, a kind resource packaged to a Agent;to any $m_i \in M$, $m_i = (p_{i1}, p_{i2}, ..., p_{in})$, p_{in} is a feature of m_i representative, such as basic information, ability information, state information, etc from the resource. Restructuring problem can be converted into the process of matching the design task to design resource matching process, namely, in meet the constraint conditions A to solve X.

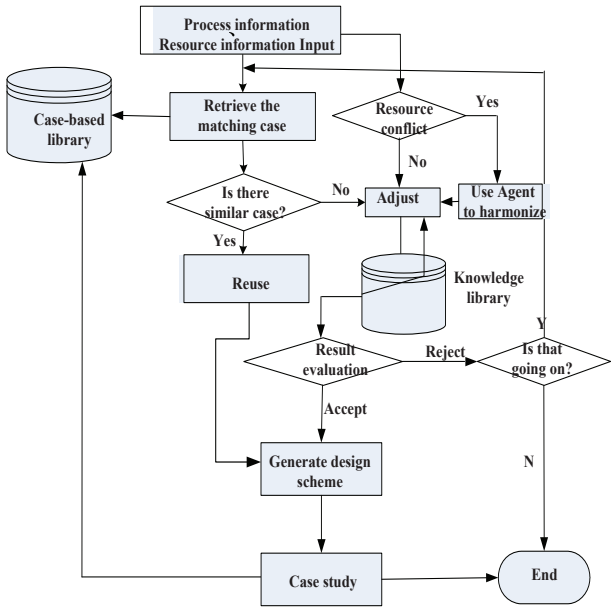

Fig. 5: Product design process based on CBR

According to the characteristics of assembly product design, with three group gives theres giving a restructuring examples expression method by triple set:$C(G,A,X) = C((g_1, g_2, ..., g_i), A, X)$,Where G is design task and composed by subtasks of workmanship, for a specific subtask g_i represent by a set of task characteristics; A represent constraint condition that is project and planned timing of resource using; X is the design proposal which is decided by G.

5.3 Case Retrieval

Case retrieval is the key of CBR system, and related to the efficiency of case retrieval and the quality of retrieve similar examples. To solve the product design problem, product design examples can be expressed into two groups of vector: resource and process feature vector (design task process requirement)$(P_1, P_2, ..., P_m)$ and settlement vector (design proposal) reasoning proceed in two similar examples, one is known examples, it is the

past completed and similar with one of the current problems, recorded as O; the other is a current problem to be solved, recorded as G. If its similarity is $S = f(P_g, P_o) \geq \delta$,then it can be said example G similar to example O. Then we can infer that the solution vector of the restructuring example G similar to the solution vector of the known restructuring example, recorded as $R_g = R_o.f$ is similarity calculation strategy, the typical algorithm has the adjacent strategy inductive reasoning strategy and control matching strategy; δ is similarity criterion and often defined by experts in the field.

In case retrieval process, it may be caused many similar examples, and there is a problem of extracting the best example, adopt a method of example characteristics fuzzy comprehensive evaluation can solve this problem well.

6 Conclusion

Due to lack of design information, in the conceptual design, the establishing process of function model can get a satisfactory result through interaction between the designers and computer only. So, the establishing of function model based on CBR is semi-automatic system. In market research, extraction of the function and the establishing of rough functionality model are realized by the designer's experience. CBR helps designer to search function model for the enterprise practically. In addition, it quickly perfects function model so as to get the most satisfactory design results and improve the efficiency and practicality of the function model design.

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