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RESEARCH ARTICLE

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Research on integrating customization design for mechanical product

Abstract This paper proposes an integrating rapid customization design system which combines various technologies such as Web, knowledge based engineering (KBE), engineering database and Computer Aided Design (CAD) and has been used in elevator design. The whole system is set up on the base of engineering database technology, integrating Product Data Management (PDM), Enterprise Resource Planning (ERP) etc. It adopts Web technology to enable customers to individually customize products remotely through the internet. The system also adopts KBE to manage and reuse product design knowledge, while combining the technology of product family modeling and technologies of feature modeling and parametric design, based on the assembly of the CAD system of Unigraphics Solutions Inc., to create a product family case library that achieves intelligent, rapid design customization.

Keywords product family, case-based design, knowledge based engineering, Web

1 Introduction

Today, globalization of economy, market, services, free trade and investment has become increasingly strong. Additionally with the arrival of the information era in the 21st century and especially the rapid development of the internet in recent years, electronic commerce is growing and changing the operation mode of enterprises every day. From B to B (Business-to-Business, electronic commerce between enterprises) to B to C or C to B (Business-to-Consumer and vice versa, electronic commerce between enterprises and consumers), the relationship between enterprises and the customer is not exclusively that of business, but more personalized with customers increasingly participating in the whole process of product design. To adapt themselves to strong market competition, manufacturing enterprises have shifted their focus from production to market, the protagonist has changed from the enterprise to the customer, and the goal that enterprises endeavor for is satisfying each customer's individual demand in all aspects of design, production, sale and services. Tsoi et al. presented a knowledge-based customization system of enterprise applications where the users can generically and speedily customize their enterprise applications through intelligent selection and configuration of components required [1]. Jian et al. studied the method of constraint-based product family design. Building blocks are regarded as basic product units which have a certain function and structure. Constraints and configuration rules are retrieved from building blocks. The building blocks and their constraints can be reused for product customization and variations in design [2]. Zhao et al. proposed a methodology for engineering design based on knowledge based engineering (KBE), and the tools and methods for knowledge processing are classified by geometry-relativity with design knowledge [3]. Gzara et al. presented a product information system setting up product models rapidly by reuse of patterns, and two kinds of patterns are distinguished; business patterns and software patterns [4]. Dr. Craig Chapman of Warwick Manufacturing Group pointed out that in 2010, the importance of KBE to enterprises will be the same as that of Computer Aided Design/Computer Aided Engineering/Computer Aided Manufaturing (CAD/CAE/CAM) to manufacturing industry in the 1990's. For the purpose of adapting to volatile market competition, implementing rapid response engineering strategy to develop new products speedily [5], taking full advantage of an enterprise's existing resources, implementing knowledge reuse and intelligent design process, this paper presents an approach on intelligent, rapid product design that integrates KBE and Web technologies, product family modeling, engineering database, feature based parametric design of traditional CAD/CAE/CAM systems, creating a product family case memory series, and realizes an Elevator Integrating Rapid Customization Design System (EIRCDS).

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2 Product modeling design

Functional requirement, technical principle, and physical realization are the main aspects of product design. In this context, product family modeling includes three views; functional view, technical view and structural view [6]. Product family includes a product platform and a set of related products deriving from the platform, which can satisfy different customers' requirements. The product platform that usually has a relatively stable structure is the basis of the product family. It is a set of modules which can be shared and reused by a series of products. An effective product platform is the core of a product family, and it has the common characteristics of all products in a product family. Generalization, modularization, and standardization are the main issues of a product platform. An advanced hierarchy-decomposition tree is used to establish the product family model representing product case and its related knowledge in this paper.

The common model of product family case is shown in Fig. 1. It is expressed by the hierarchy-decomposition tree. In the present case tree, every node that is expressed by object has a common structure, and it stands for elements of products at all levels, such as product, sub-assembly, component and part etc. The AND node that can be divided is called a composition tree. Its child nodes are AND relations. Father node and child nodes are combination (a-part-of) relations; the OR node that can be selected is called an optional tree. Its child nodes are OR relations. Anyone of the child nodes can be substituted by another, but only one node can be selected. Father node and child nodes are an optional (a-kind-of) relation. Moreover, we prescribe that if one optional child node needs to be divided, it still can be re-divided into sub-nodes further as a father node of the lower composition nodes, as shown in the lowest level of Fig. 1.

It can be seen from the product family structure model that the hierarchy-decomposition tree has the following advantages in expressing product family case structure: 1) it can express the product function and structure configuration easily and exactly for design customization; 2) it has characteristics of generalization and modularization; it is especially suitable for realizing general design and modular design of products in mechanical field. For the nodes of different products in the same level, which have the same functions and structures, they may be extracted out and built as common modules; and 3) it can accomplish design standardization and series.

So customers and designers can do customization and variant design through function and structure nodes of different levels in the product family case tree to achieve the design that is characterized by product knowledge re-use and rapid response.

The product family case module can be realized by object-oriented technology. Every node is regarded as an object, and a common element node class is defined to represent product, sub-assembly, component and part in different layers. Relative element function class, element structure class, element parameter class and element knowledge rule class are also defined and embedded in the common element node class. Every specific product case is the instance of the node class. The related data of product cases are stored and managed in the engineering database [7]. Using this method, nodes can be composed or decomposed, appended or deleted at any time and in any location in the tree as you need, which reflects not only the dynamic and process-oriented characteristics of product design, but also the hierarchy and modularization of product information. It is helpful to reuse resources, improves the research retrieval efficiency and enhances the system's maintainability and expandability.

3 Development tools

The development tools should have mature technologies, strong functionality, high performance, and ease of use and ability to integration with other tools. This system adopts Windows 2000 Server operating system, Microsoft Visual

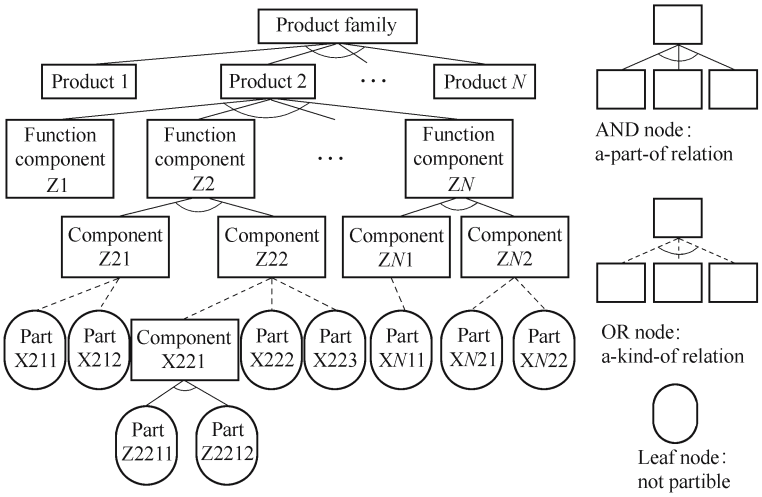

Fig. 1 Common structure model of product family case tree

C++ 6.0 development tool, SQL Server 2000 database management system, Internet Information Server (IIS), Web server software, the Active Server Page (ASP) script, and Java Script as assistant tools to handle Web page and optimize user interface. Meanwhile, it also integrates the related modules of Unigraphics (UG) CAD/CAM software. The related modules of UG are introduced as follows.

The User defined features (UDFs) of UG solid modeling module allows one to create one's own form features module as reused design elements. The UDFs can be stored to construct a library of user defined features tailored to your needs. The expressions, constraints and characteristic parameters of UDFs can be created in the meantime. On the one hand, the UDFs encapsulate the knowledge of topology information and specific characteristic of geometry model, on the other hand, the UDFs enable the expression and operation on objects of product model at a higher level by retrieving characteristic parameters and achieving the variant design.

Knowledge Based Engineering (KBE) technology is fundamentally about reuse of knowledge. It deals with the ability to take advantage of any experience, expertise and other information relevant to each phase of the engineering life cycle of an end user product [8]. Knowledge Fusion (KF) is the kernel module of realizing intelligent design by incorporating knowledge based engineering technology. This module provides an interpreted object-oriented language named Knowledge Fusion language (KFL) that is simple, easy to learn and use. It has been designed to permit an end user to easily add engineering knowledge to the task at hand by creating engineering constraint rules, construct a knowledge library for product design that can express engineering constraints and the corresponding relationship, and can be reused. It breaks through the restriction of representing product design knowledge merely by geometry model, and realizes the intelligent design. The KFL has also the capability to access external knowledge sources, such as databases or spreadsheets, and to interface to other applications such as analysis or optimization packages.

UG/Open C++, UG/Open API, MenuScript and UIStyler are advanced programming tool packages which provide extensive and flexible circumstances for second development in UG to establish special application program inside the platform of UG. Their functions include: the visual editor for constructing menus and dialog forms of UG style and the program interface; it uses many of the current program languages, such as C, C++, and Java, and provides programming interface of calling UG resources directly. This interface is a truly object-oriented interface using C++ language, which has all the object-oriented advantages, for example, inheritance, encapsulation, and Polymorphism.

4 Design and development of mainframe of EIRCDS

For the related knowledge of the node objects in the product family case tree, we classify them as three layers: product geometry layer, product rule layer and product data layer. The product geometry layer is used to express geometry information of 3D solid model and 2D drawings; the product rule layer is used to express engineering rules of design criteria, experience formulae, distinguish conditions; the product data layer is used to express design requirements, part parameters, material specifications PDM data, Bill of Materials (BOM) data and other non-geometry data related to product. Figure 2 is the framework of the intelligent, rapid design customization system.

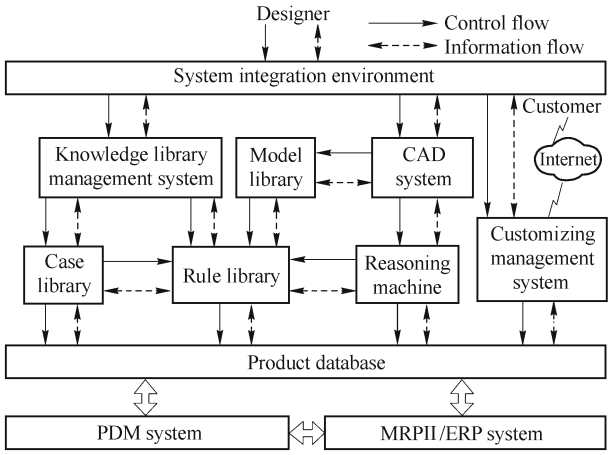

Fig. 2 The framework of the rapid design customization system

Product database is the bottom module and the base of all modules in the system. The product database is to store all kinds of product data used to define, design, manufacture, maintain product and support product data share, transmission for all other sub-systems or function modules. The product database has open interface to other systems such as CAD/CAM, PDM, Manufacturing Resource Planning (MRP II), and ERP, realizing data integration in a logical united database environment.

The product family knowledge library mainly includes product case library and rule library. In the knowledge library, we set up the product design knowledge organization unit according to the product family structure and provide a product knowledge library management tool, combined with Unigraphics CAD/CAM system, complete with the final product design.

The Web customization management system is a web-based order system using browser/server structure. Customers can browse existing products and customize products remotely over the internet.

Meanwhile, traditional CAD/CAE/CAM system (UG) is integrated into this system to perform the subsequent CAD detailed design and other tasks. The whole system is controlled by an integrating environmental interface developed by UG/Open and C++ programming. Other sub-systems have open interfaces to the integrating environment, so they can be seamlessly connected to the system and the system will then be easily extended in the future.

The main developing process is as follows.

Through collecting, analyzing and inducing information of structures and assemblies of existing products in the enterprise according to whole product life cycle, the design knowledge of product parts, components and assemblies are extracted and classified. The model of the product family case design expressed by hierarchy-decomposition tree is created according to the method of product family design. Through the UDF and UG solid modeling module, design parts, components, subassemblies, decide on expression constraints, retrieve feature design parameters, and then create model library supporting parametrical design. Through KF module create the KF rule class package related to the model, including design constraints, assembly relations, experience formulae, selection rules of feature parameters, configuration rules of components and parts, and organize them into the rule library. Extract feature parameters from models, and create respectively case database. According to existing product series in the enterprise, design typical case template and case index mechanism, and create product family case library. Create knowledge library management system. It can modify, add or delete cases and rules. Create Web customization management system, adopting Browser/Server structure [9]. The system mainly includes customer information management, product information management, and order information management. The customer management includes customer register, customer information modification etc. Product information management includes new product definition, product information maintenance etc. Order management include creating new order, order maintenance etc. Figure 3 is the flow chart of design customization.

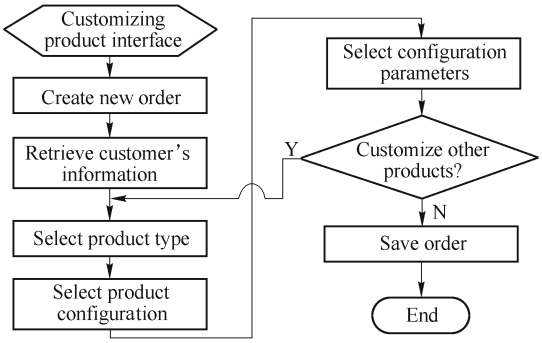

Fig. 3 The flow chart of design customization

In the system developed for this study, the design of an elevator car is divided into design tasks of ceiling, door, wall, platform, railing etc. Customers mainly present the product's contour size, installation structure and decoration configuration as per demand. The main customization demand includes: 1) size customization: the car's contour sizes are decided by the building's well way, resulting in variation of parameters to other relative parts, according to engineering rules and experience. The car's main contour size is: total width A and total depth B; 2) function selection: the different functions of control and operation decide the car's structure, for example, the style of the air draft can be either a side air draft or middle air draft; 3) decoration configuration: customer's configuration for the car's exterior and interior decoration, such as the style of the operation panel, lamp etc.

5 Applicable example

Firstly, the customer browses the typical product series over the internet, selects type number, and specifies the main parameters for customization. Refer to the customization flow chart in Fig. 3, for example. The customizing parameters are as follows: the selected Product Model No. is HSET9703, the car's total width A is 1 500 mm, total depth B is 1 400 mm, the air draft style is middle air draft, the ceiling's cut angle mode adopts right cut angle, the side length of the cut angle R is 150 mm, and the cut angle β is 45°. After the completion of customization, the order list is stored in the database. Next, the designers retrieve this order list through the system. According to the similarity criteria, same or similar cases are searched and retrieved. If matching cases are found, the best cases are selected and modified for detail variant design to conform to the new product's specifications. On the contrary, if no matching case is found, then an entirely new design is made. Finally, after finishing the design, the product's structure and performance should be assessed. According to the assessment, if the design satisfies the design requirements, the design result will be stored in the case library as a new case; otherwise, the system will return to the phase of detail design and start a redesign. Figure 4 shows the assemblies of HSET9703 elevator ceiling generated by the EIRCDS.

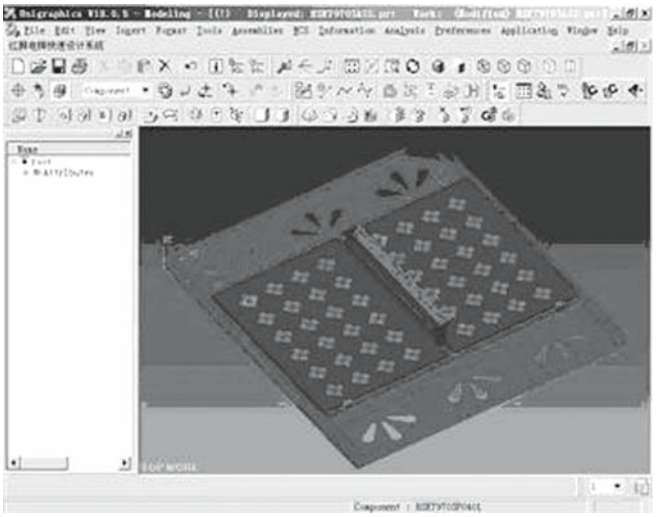

Fig. 4 The assemblies of elevator ceilings generated by system

6 Conclusions

Combining various new technologies and product design approaches into an integrated design system is the successful

guarantee for the speedy and effective development of new products by enterprises. It is also the key point of creative design. This paper realized an integrated intelligent rapid design customization system which takes the product family knowledge base as a center, and effectively integrates various engineering database technologies such as Web, KBE and CAD. It greatly improves the product's design quality and speed in design conception process. It empowers the enterprise to quickly respond to the market demands. This system can be used as a common product design platform. It provides an effective approach of accumulating and reusing engineering knowledge, speedily developing new products, lowering costs, improving quality, and satisfying customer's individual needs for manufacturing enterprises.

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