Advanced Materials Research
ISSN: 1662-8985, Vol. 902, pp 351-356
doi:10.4028/www.scientific.net/AMR.902.351

Online: 2014-02-27

Mechanical Product Design Wizard Rapid Development Platform Research based on Axiomatic Design

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Keywords: Design wizard; Development platform; Axiomatic Design; Rapid development

Abstract. In order to reduce time and cost in mechanical product design wizards development work, the Mechanical Product Design Wizard Rapid Development Platform (MPDW-RDP) was established. According to the Independence Axiom, the system architecture of the MPDW-RDP was obtained, then, the MPDW-RDP had been implemented by taking advantage of existing mature software and components in accordance with the Information Axiom, at last, application case indicated that this system can rapidly develop different kinds of mechanical product design wizard.

Introduction

Mechanical product design wizard is a kind of intelligent computer aided design tool which can help designer execute their design work efficiently, and it's normally implemented through integrating the design knowledge into a process guider application [1]. In recent years, mechanical product design wizard researches mostly focus on rapid CAD modeling, and design wizard tools have been applied in all sorts of industries [2-5], such as automobile, agricultural machinery, etc.

Product design wizard development is a complex work, includes knowledge management, product design method, CAD technology, software development, etc. Secondary development based on CAD software now is the main way to build product design wizard, this is always costly and time-consuming, but the design wizard produced by it just can used in a specific product design work and it is hard to update and adjust, so this kind of method features low cost performance, and that is the main reason why design wizard can`t be widespread used.

In order to improve design wizard development efficiency, first of all, shortages of present method have been given according to Axiomatic Design. Secondly, an uncoupling system architecture of the MPDW-RDP system has been established under Independence Axiom. Then, a prototype system has been developed by using existing mature software and components to minimize information content.

Problems Analysis According to Axiomatic Design

The goal of Axiomatic Design (AD) is to establish a scientific basis for design and to improve design activities by providing designer with a theoretical foundation based on logical and rational thought processes and tools [6]. Axiomatic Design includes following two basic axioms.

Axiom1: The Independent Axiom. Maintain the independence of the functional requirements.

Axiom2: The Information Axiom. Minimize the information content of the design.

Plenty of practical cases suggest that products, processes, systems, software or machines conforming to AD have a better performance in function, stability, and reliability [6-11]. On the other hand, if these systems work badly, we can find out the problem according to AD and solve it.

Present design wizard development is a type of customized work. Secondary development toolkit of CAD is the only way to establish knowledge base, build design process and manage product structure information, that means just only one Design-Parameter corresponds to several Function-Requires, it violates the Independent Axiom in Axiomatic Design,. Not only that, but it is a hard and risky work to realize all of the function modules by programming because the present design wizard development is always a customized project. For software system, The easier the system module is developed, the less the information will be inclueded[6], so the information content of present method is high. In a word, present method totally violates principles of the Axiomatic Design, that leads to several critical defects:

- Lack of Professional function. All kinds of work in wizard development need to be done by software developers in present method, however, they barely have any professional background knowledge, so it is always a risky and time-consuming job for them.
- Hard to share and reuse knowledge. Present design wizard is a kind of customized tool for specific product, it is impossible to share knowledge between different tools because their knowledge base are not only stored in mutual independent database but represented in totally different forms.
- Poor flexibility. All different kind of information, such as knowledge, process, product structure, etc., are represented directly in code and coupled with each other, so it always would be a hard work to update anything of the tool when we want to adjust it to adapt to design method improvement.

So we need to establish a new system under Axiomatic Design to overcome the abovementioned problems.

System Architecture Design

The MPDW-RDP is designed for design experts, knowledge management specialists, programmers, to rapidly establish a design wizard. The MPDW-RDP`s user case diagram is as shown in Fig.1

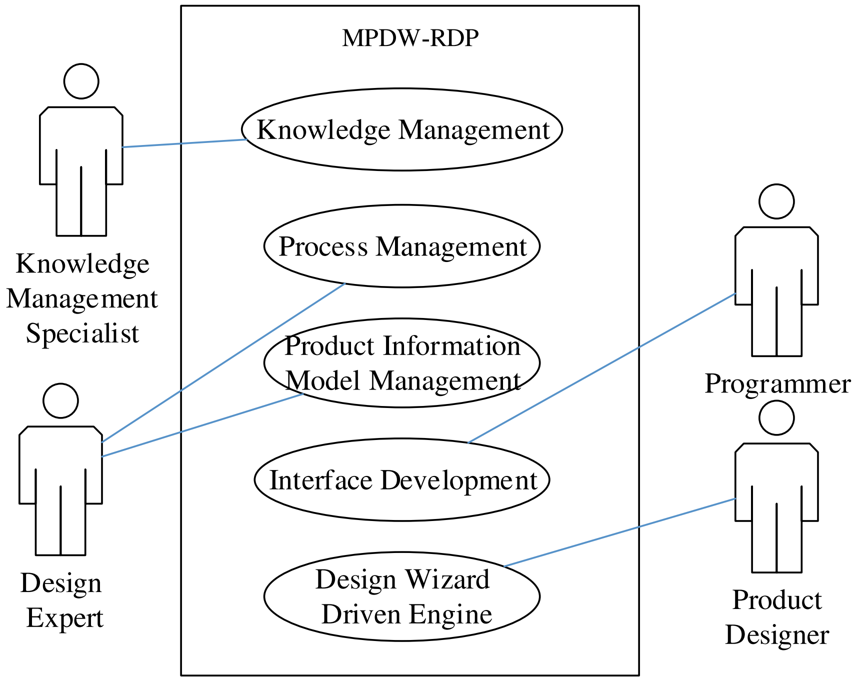


Fig.1 Use case diagram of the MPDW-RDP

The process of the system design based on AD is the same as the ones of other kinds of product or process, the two steps are: determining system function requirements（FRs）and establishing system architecture by domains mapping between FRs and Design Parameters(DPs).

First of all, the FRs of the system is obtained from the user case diagram of the MPDW-RDP, the FRs are as following.

FR_1——knowledge management;
FR_2——process management;
FR_3——product information model management;
FR_4——interface development;
FR_5——design wizard driver engine.

Secondly, system architecture of the MPDW-RDP is gained by mapping FRs to DPs, the FR and DP hierarchies are as shown in Fig.2.

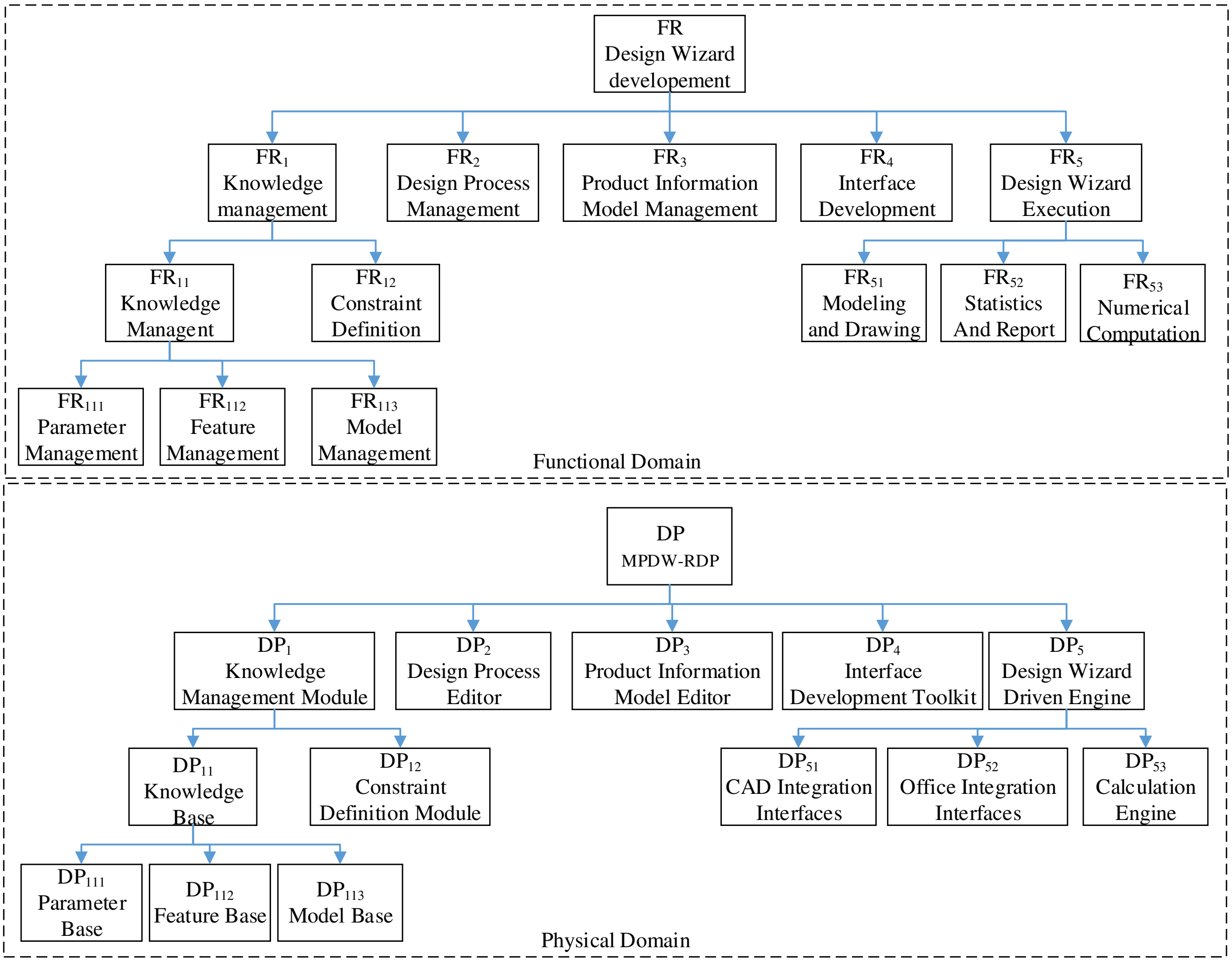


Fig.2 The FR and DP hierarchies

Then, according to the functional logic among system modules, the flow chart of the system architecture is given in Fig.3.

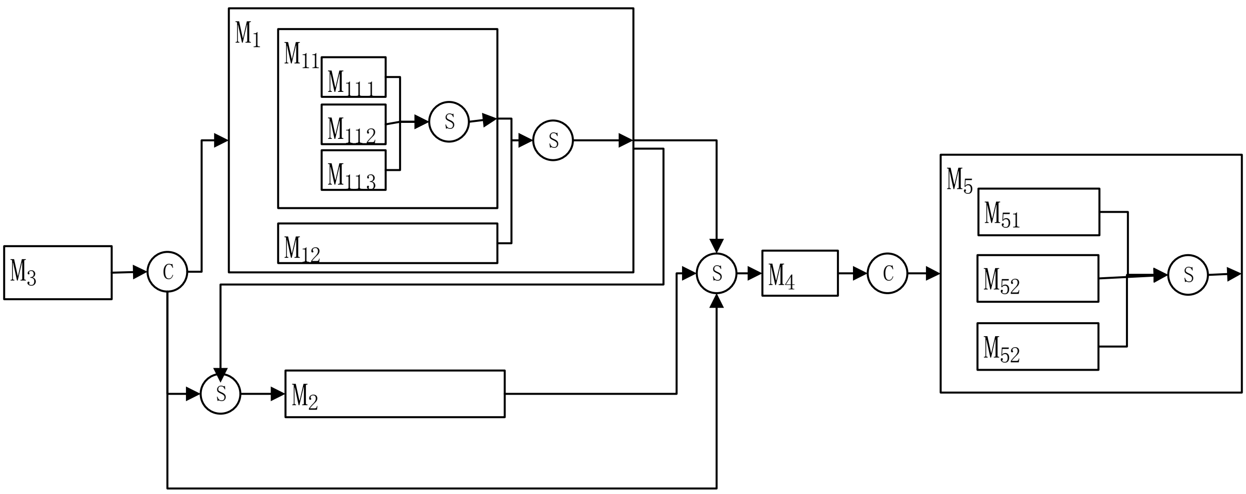


Fig.3 Flow chart of the system architecture

Furthermore, the system design matrix is given according to the flow chart of the system architecture. The flow chart consists of uncoupled nodes and control nodes, so the system design matrix is a lower triangular matrix, that is to say this system meets the Independent Axiom and it is a decoupled system.

			DP_3	**DP_1**				**DP_2**		**DP_4**	**DP_5**		
				DP_{11}			DP_{12}	DP_{22}	DP_{21}		DP_{51}	DP_{53}	DP_{52}
				DP_{111}	DP_{112}	DP_{113}							
FR_3			X										
		FR_{111}	X	X									
	FR_{11}	FR_{112}	X		X								
FR_1		FR_{113}	X			X							
	FR_{12}						X						
FR_2	FR_{22}		X				X	X					
	FR_{21}		X					X	X				
FR_4				X	X	X	X	X	X	X			
	FR_{51}			X	X	X					X		
FR_5	FR_{53}			X								X	
	FR_{52}										X	X	X

Fig.4 The system design matrix

System Implementation and Case Study

In order to reduce the information content in system, the difficulty and risk of system modules development need to be reduced. Therefore, it is wise to adopt mature system platform and existing components to build the MPDW-RDP instead of start from the very beginning.

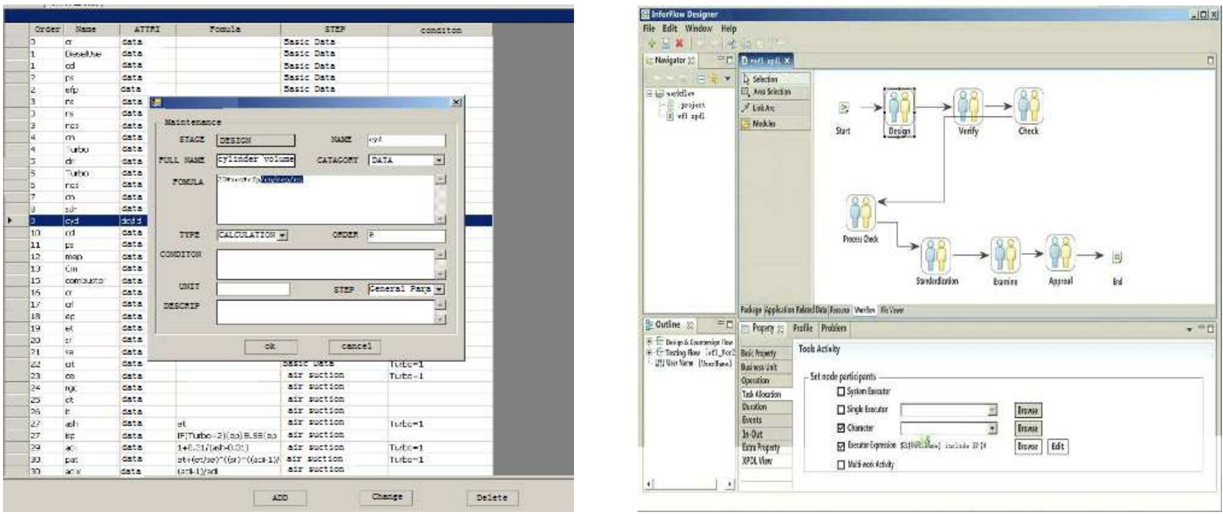
PLM system is the basic product data management system for the company, it provides basic components to construct design wizard, such as document management engine, data management engine, workflow engine, etc., so it is an ideal fundamental platform for design wizard rapid development system.

At last, the MPDW-RDP has been developed on the customizable PLM system- InforCenter and CAD software- SINOVATION by taking advantage of this two existing system`s function,which belong to Hoteamsoft software Co., LTD. Implementation details are as shown in Table1.

Table1 System function module implementation

New System Module	Existing System Module
Knowledge Base	Parameter table management of InforCenter, User Defined Feature Module and Standard Part Management of SINOVATION
Constraint Definition Module	Parameter table management of InforCenter, User Defined Feature Module of SINOVATION
Design Process Editor	Workflow management module of InforCenter
Product Information Model Editor	Product structure management of InforCenter
Interface Development Toolkit	JavaScript language based professional secondary interface development module of SINOVATION software
Design Wizard Driven Engine	SINOVATION integration interface, office integration interface and calculation engine in InforCenter

As shown inTable1, the MPDW-RDP modules are all developed from existing components, it normally just need a certain degree of adjustment to the original software to fulfill the function requirement of the MPDW-RDP. The actual development process indicates it can reduce the difficulty and risk in the MPDW-RDP development, in other words, system information content has been decreased. Fig 5 shows some system interfaces.



(a) Constraint Definition Module (b) Design Process Editor

Fig.5 System interface of the MPDW-RDP

We employ the MPDW-RDP to develop several design wizards of different kinds of mechanical products, such as bearing, electromagnetic valve, Stamping Die, etc. The result shows it is not only the system flexibility has been improved, but the development time of product design wizard has also been reduced. For example, the bearing design wizard development has been reduced form original 14 months to 4 months.

Summary

In this paper, a design wizard rapid development system- the MPDW-RDP has been established in accordance with the Independent Axiom and the Information Axiom of Axiomatic Design. Application case shows it has well flexibility and significantly reduces the design wizard development time.

Acknowledgements

This work was financially supported by the National High Technology Research and Development Program of China (No. 2012AA040910) and the Natural Science Foundation of Shandong province of China (Youth Fund Project) (No.ZR2011EEQ017).

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