A Knowledge Model for Mechatronic Product Development Based on Ontology

Cheng-long WANG, Qing-liang ZENG, Li Yu-shan, Wan Li-rong
College of Mechanical and Electronics Engineering
Shandong University of Science & Technology
Qingdao, Shandong Province, China, 266510
wcllym@hotmail.com, qlzeng@163.com, skd_lys@163.com, wanlr666@163.com

Abstract—In this paper a knowledge model for Mechatronic Product Development Based on ontology is put forward, which can support the description and reuse of design knowledge in mechatronic product development. Firstly the typical problems of design knowledge reuse in mechatronic product development are analyzed. Secondly a knowledge model for Mechatronic Product Development and its description based on ontology are given. Thirdly a simple example is introduced to illustrate the main ideas. Finally, the conclusions and future research goal are given.

Keywords- mechatronic product, Knowledge model, Unified Product Model, Ontology

I. INTRODUCTION

Due to globalization, Engineering companies involved in product development are under considerable pressure. For them, the design knowledge reuse technology is an effective way in order to reduce product development cost and time.

The development of mechatronic product is a concurrent and collaborative cross-domain process involved with mechanics, electronics, software and other disciplines. There is no ‘single source of truth’ to guide and coordinate the actions among different disciplinary teams. For each of these engineering domains there exist diverse knowledge models, it is difficult to share and reuse the knowledge with the other domains during the development of mechatronic system.

Ontology has proven to be useful in application areas such as intelligent information integration, information brokering, and knowledge-based systems [1]. Using ontology, we can capture domain knowledge in a generic way and provide a common vocabulary for a domain that may be shared and reused among groups and even software agents.

TIAN Yong-li etc [2] established a hybrid knowledge modeling method in the organization knowledge representation, object oriented knowledge modeling method in physical body in conceptual design of mechatronic systems.

Zeng Xiao song [3] developed a multi-view knowledge structural model of Electromechanical Products and given the customization design method based on design knowledge reuse.

Ewald G. Welp [4] introduced a methodical and technological platform in the area of services in the knowledge-based product development.

Yoshioka [5, 6] emphasizes the modeling of mechatronic artifacts and the roles of ontology of engineering artifacts for contributing to such design knowledge modeling from a viewpoint of computer science.

All the research above mainly talked about how to represent and reuse knowledge model. But how to create knowledge model is rarely introduced.

The creation and representation of knowledge model is the basis of reuse of knowledge. The objective of our research is to put forward a knowledge model for Mechatronic Product Development Based on ontology and provide a method of representation and reuse of the knowledge model. It is cross-domain ontology to express the common understanding so as to make the concept and terminology standard.

II. OUR RESEARCH ON KNOWLEDGE MODEL FOR MECHATRONIC PRODUCT DEVELOPMENT BASED ON ONTOLOGY

A. Relationships of Unified Product Model elements

A Unified Product Model (UPM) is given for the cooperative development of mechatronic product [7], which is the Meta-model of system model and provides the ‘single source of truth’ of mechatronic product.

The WSP (Working Surface Pairs) and the CSS (Channel and Support Structures) are the two basic elements of the elementary design model C&CM developed at the Institute of Product Development (IPEK) of Karlsruhe University (TH) [8]. The C&CM is a means to describe the problem on any level of abstraction and it provides a better understanding for the location of functions in a concrete product.

Unified Product Model (UPM) includes the Design knowledge about “Function and Its realization”. UPM is described as following (Fig.1): UPM= {Use-Case, WSP, CSS, Functional Flow}.

Use-Case is used to describe the functionality of the product to be designed. WSP, CSS and Functional flow is used to describe the implementation of function. At the same time WSP and CSS describes the static structure of the
product to be designed. Functional Flow describes the dynamic behavior of the product to be designed.

B. UPM description by means of Ontology

Firstly, the relationships of UPM elements are defined. As showed in Fig.1, UPM include the following four basic elements: Use-Case, WSP, CSS, and Functional Flow.

The relationship between these four elements and UPM is described as “Is-a”. Each element has its own attributes. The relationship between these four elements and their own attributes is described as “Has-a”. The relationships among Use-Case and the other three elements (WSP, CSS, Functional Flow) are described as “is realized by”.

Secondly the classic structure of UPM Ontology is given (Fig.2). The relationships and attributes of all the elements in UPM are described using Ontology modeling software (Fig.3).

Thirdly, instance of UPM ontology is realized and saved in ontology database. The instance of UPM ontology can be used to made inquiry about the knowledge.

For knowledge reuse, the designer can made inquiry about the certain UPM ontology so as to find out the relationship between functionality and function realization of the product. The designer can reuse the knowledge about “where and how function of the product is realized”, which is difficult to be realized by existing approaches.

III. A CASE STUDY

For the arm design of Robot ARMAR III [9], the common results are 2D and 3D models that are submitted as the final results by corresponding engineers. For others and the new engineers, it is hard work to reuse the results when a new functional requirement is provided. The key problem is that it is hard to know where and how certain function is implemented clearly for the existing design.

According to the knowledge model given above, the UPM ontology of Robot ARMAR III can be generated and saved, which provides a basis for knowledge reuse. When engineers inquire the ontology database, they can find the interrelationship of functionality and its detailed realization.

Firstly, the system model of robot arm is depicted as following:

UPM={Use-Case [U001, Robot For-arm, Robot For-arm has two DOF]; (WSP[W001, Computer-UCOM, S, Type (I), In], WSP[W002, UCOM-Drive unit, S, Type (I), In],...}.
WSP[W003, Drive Unit-Arm, S, Type(E), In], WSP[W004, Arm-Sensor, S, Type(E), In, Size(W004-X)], WSP[W005, Sensor-Computer, S, Type(I) ,In], WSP[W006, UCOM-Arm, S, Type(E), In], Size(W006-X)); (CSS[C001, Computer, Type (I), In and Out], CSS[C002, UCOM, Type (I), In and Out], CSS[C003, Drive unit, Type (I,E), In and Out], CSS[C004, Arm, Type (E,E), In and Out], CSS[C005, Sensor, Type(E, I), In and Out]); Functional Flow[F001, Arm acting, Logic diagram (Fig 4)]

According to this way, it can support the knowledge reuse and improve the working efficiency.

![Logic sequence of E/I/M flow in Robot Arm](image1)

Figure 4. Logic sequence of E/I/M flow in Robot Arm

Secondly, the relationships and attributes of all the elements in UPM of Robot Arm are described in Fig.4 using Protégé [10] which is one of the most widely used ontology engineering tools. UPM ontology of Robot arm is realized and saved in OWL database.

Thirdly, the instance of UPM ontology is used to describe the relationship between functionality and function realization of Robot arm. With the inquiry of certain elements, the engineers can not only know “what functions the robot arm has” but also know “why and how the function is implemented”, which means that the designer can reuse the knowledge about where and how function of Robot ARMAR III is realized. Fig.5 shows the inquiry result of all the elements which are used to realize function F001 and Fig.6 shows the inquiry result of all the static structure elements (WSP and CSS) which are used to realize function F001.

![Inquiry of all the elements which realize function F001](image2)

Figure 5. Inquiry of all the elements which realize function F001

IV. CONCLUSION AND OUTLOOK

A knowledge model for Mechatronic Product Development Based on ontology is put forward in this paper. A method of representation and reuse of the knowledge model is given. This knowledge model provides the basis of knowledge sharing in system design stage for Mechatronic Product and ensures the possibility of information acquisition, representation and reuse of design knowledge in late stages. Finally a simple example is introduced to illustrate the main ideas. In the future, our goal is to given the UPM ontology of the whole Robot.

ACKNOWLEDGMENT

The paper is founded by the National Natural Science Foundation of China (No.50875158), the National and Key Technology R&D Program of China (No.2006BAB11B05), Shandong Natural Science Foundation for Distinguished Young scholars of China (No. JQ200816).

REFERENCES


![All WSP and CSS realizing U001](image3)

Figure 6. All WSP and CSS realizing U001


