Development of Concurrent Engineering Tool for Early Design of Mechatronics Product

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Abstract: This paper introduces a model-driven product development for complexity management. Today, the complexity of the mechatronics products makes it more difficult that the engineers collaborate with each other. The causes of the complexity can be categorized into three: (1) the requirement for complex function is increasing, (2) the scope of the design is becoming more widely, and (3) the combination of the line-up product is exploding because of the widely-covered product family. In order to manage and control such complexity of product and product development, this paper introduces a model-driven approach based on a product model. The product model describes three dimensions: (1) the structure of the product, (2) the function requested by the customer, and (3) the product behavior of the software.
Key words: Model-driven; Product development; Product model; Design rationale; Design process

1 Introduction

Authors address the development of the management and synthesis method of development processes for collaborative product design. In multi-domain and functional standpoint, this paper proposes a modeling method which can grasp the entire complex mechatronics system.

In recent years, because required functions of artifacts are getting more and more sophisticated, design information is rapidly becoming complicated. Artifact such as car, aircraft and electronics which is composed of mechanics, circuit and software are called mechatronics products[1]. Today, the 'synthetic development' which means that the designers themselves have to find and exclude the problem, is the mainstream way for mechatronics design[2]. At the scene of the product design, risk of over-dependent on the conventional 'synthetic development' is becoming critical problem.

Because of this motivation, the authors proposed an efficient model-driven management of product development based on the mechatronics model[3]. Figure 1 shows an overview of the model-based concurrent development of mechatronics product. The proposed method enables the designer to share the design rationale and support for synthetic development by describing function, behavior and structure of complex mechatronics products on the computer as the system model. At first, this paper briefly introduces the situation of the complicated artifacts. Secondly, a structural definition of system model which integrates and synthesizes various aspects is described.

1.1 Cause of complication: Increase in functions which require integrated control of the entire system

In design of mechatronics products in these years, the realization of complicated and advanced functions is required. By software, complicated and sensitive functions are easily realized. Therefore many functions such as clash avoidance and the optimum energy control are required with integrated control of the entire system.

As a result, for example the number of ECU (Electric Control Unit) loaded by car was from 1 to several pieces 20 years ago, at present it is increasing rapidly, the number is from 50 to 100 approximately. Therefore, artifacts getting more and more sophisticated. And on both sides of the hardware and software are complicated. Design of both hardware and software is required, cooperative manufacture of mechanics, circuit and software is important.

In car industry, the applicable scope has expanded. For example, mechatronics product activity starts from an important part of engine control, it transfers important safety part such as brake and steering, technique which lines up safety aspect such as air bag and stability control is established, and then satisfaction of charm quality such as vehicle communication and the support for car into the garage, and lane maintenance assistance is addressed.

1.2 Cause of complication: Expansion of scope according to cooperation of artifacts, human and society

The value of the artifacts is not evaluated only by the hardware. However in the connection like

software such as humans and the societies, it has come to appear for the first time. As a result, such as consideration of eco-corresponding, networking and life cycle, in development of artifacts, scope of demand that should be considered is expanding[4].

1.3 Cause of complication: An explosive increase in variety in product development

By acceleration of global development in recent years, each procurement, design, production and the input market is done worldwide. Procurement is diversified and the input market becomes complex, therefore the number of combinations of product specifications is enormous. In the market deployment of products, it is in the situation that if system engineering approach is not applied, the control is difficult[5][6].

For example, in an automobile company, the kind of product in which lineup is possible is over 15 billion by simple combination, furthermore considering combination of procurement and the destination, variety which should control is enormous. If the variety increases explosively, responsible system is obscure, correspondence as company gets stiff and bad effect which can't correspond promptly at the time of recall arises. This situation is heard.

1.4 The huge recall concentrated on mechatronics products

In 2009, it was the year that the safety problem and quality trouble in product development quickly surfaced. For example massive recall was arisen in the automobile company. The example of the recall which is antilock brake system (ABS) of Toyota Prius, in the function that frequency in use is low, bug arose in the boundary portion to which control transfers[7]. The design information was sophisticated and complicated rapidly, so that it is thinkable that not removing problems completely in conventional adjustment between designers contributes to the defects.
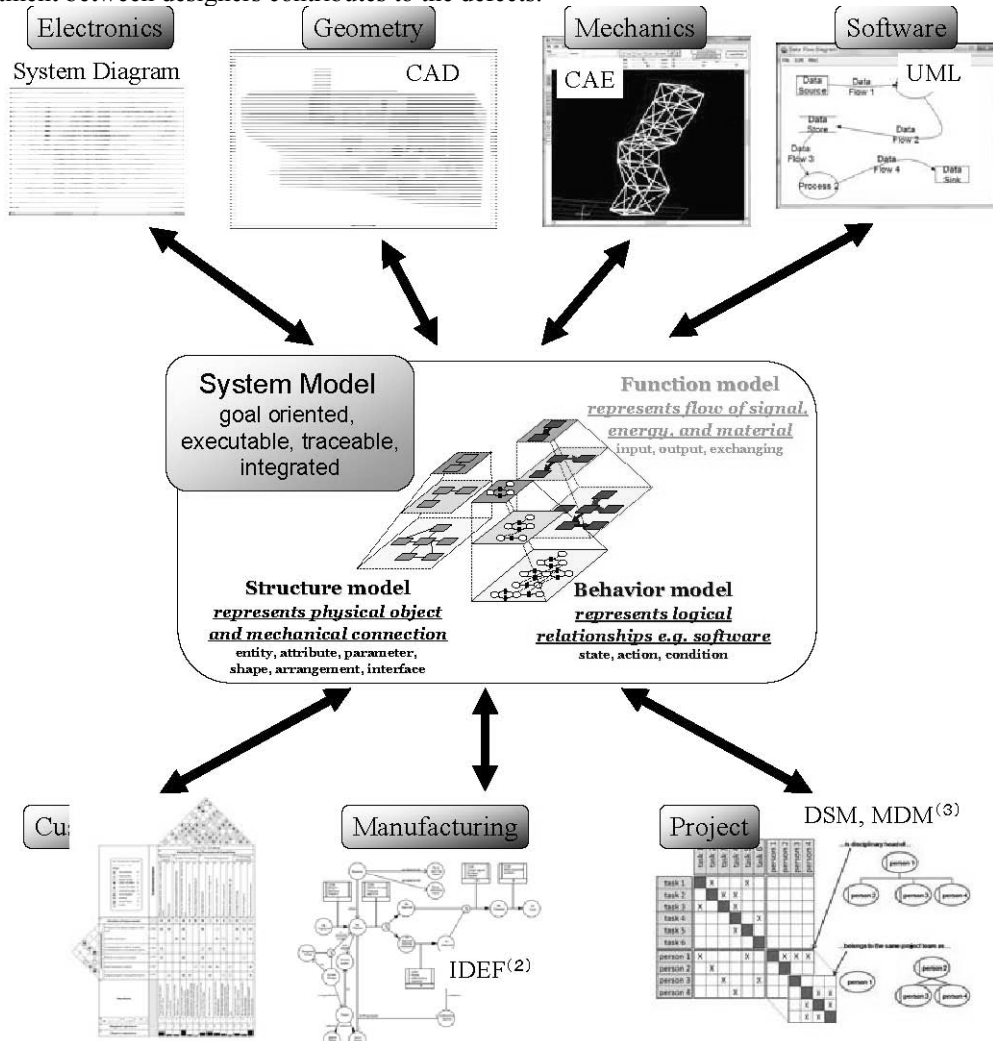

Figure 1 System Model for Model-based Concurrent Development of Mechatronics Product Development

1.5 The limit of synthetic development between designers

Conventional development of artifacts has mainly done by the method of synthesis between designers. That is to say it is the method that advancing the development by dividing responsibility system into every structure and domain, attempting consistency by humanly synthesis in the part across structure or domain, finding the problem and resolving it. In recent years however, complication of artifacts advanced rapidly, so it is likely to exceed considerably the level of possible management by hand. As the idea that 'Synthesis is active and it is likely to inflame' is heard from the scene of product design, it is said that the limit of the development which excessively depends on synthesis is being approached.

2 Model-driven Development Management

From the problem discussed above, model-driven development management is received attention[1][2][8][9]. Model-driven development management is development methodology to create a system-level design blueprint (figure 1) with modeling techniques and languages for functional mutual understanding from the initial stage of a design. It also contributes to transfer the sufficient design quality in the initial stage to a detailed design stage. In the paradigm of the model-driven development management, designers are not recommended to start from specific description (e.g. three-dimensional modeling using CAD or program coding, etc.) of each domain, because their visibility and reusability are very low in the initial stage. The paradigm forces the designer firstly to create system models which express system function and testing from a broad viewpoint such as reliability, manufacturability and a life cycle cost.

Then, model-driven development management is the method that the technique of streamlining development process with model which is system level of created mechatronics products from beginning to end. Three advantages shown below are expected by model-driven development management. The advantages are; (1) constructing the entire model expressing mechatronics products and defining requested specifications and design rationale specifically with model, (2) seeing the entire system of mechatronics products by integration with model, and (3) supporting for the logical synthesis based on the common understanding with models.

Figure 2 shows the structure of the cooperation with system level and domain level. By the model expressing mechatronics products, it is possible to describe not only concrete parameter resulting or information of state from design but also information of design rationale such as "Why did you choose that parameter?", or "Why that state is required?". By explicit description of design rationale, it is expected the designers to grasp extent of the impact of a design change and to reduce design as much as possible whenever changes design and to reuse design property[10].
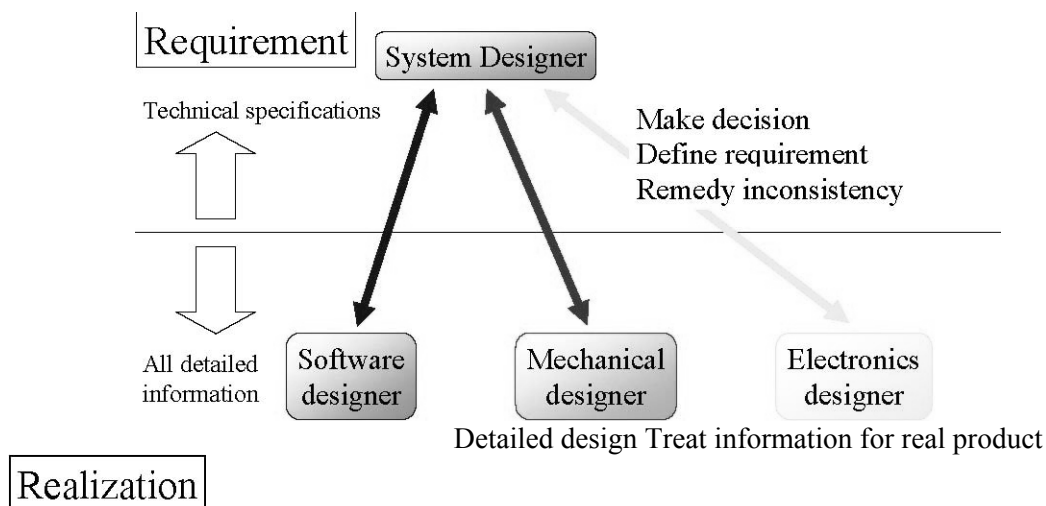

Figure 2   How to Collaborate the Engineer of Each Specific Domains:
to Assist System Engineer who Makes Decisions, Defines Requirements and Remedy Inconsistencies

3 The Proposal of the Design Information Model of Composite Products

It is in the situation that information model which is possible to describe mechatronics products

synthetically doesn't exist at present. The case of mechanics is CAD(Computer Aided Design), the case of circuit is system statistical diagram(System Diagram or Modelica, etc.), the case of software is UML(Unified Modeling Language), and so on individual design information model is in present, but it is in the situation that they don't work together. Therefore, each model is discrete, there is a problem that can't grasp the whole and it is in the situation that bug arise in these boundary portion.

So the authors propose (Figure 1) system model (called design information model of mechatronics products) which describes the design information of machine, circuit and software especially in the integrated form and they implement and test the system which is possible to modeling actually. This system model means the model described and integrated three kinds of design information shown below.

(1) Constructive model (Figure 3) (It takes charge of mechanical composition.) ・・・describing dependency of entity, connecting composition and property parameter.
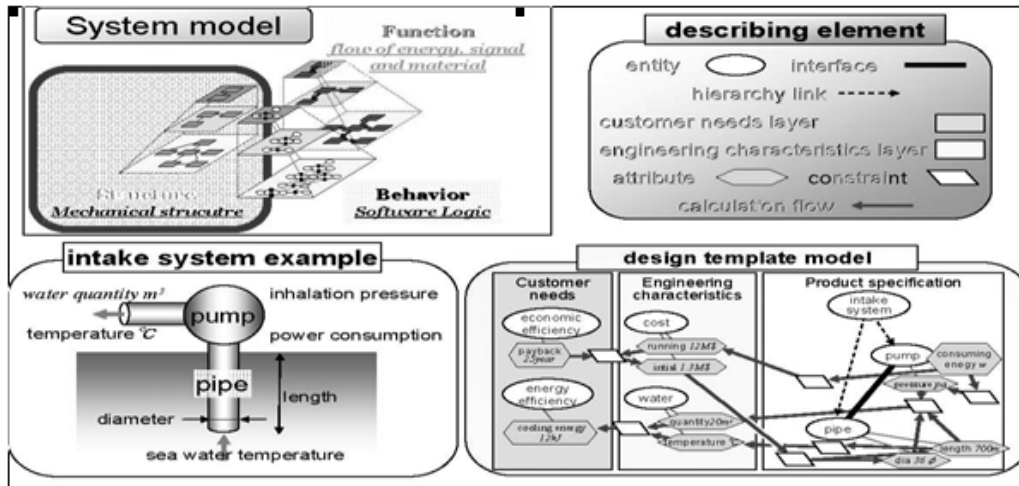

Figure 3　Model of Structure

(2) Flow model (Figure 4) (It takes charge of circuit or ancestry.) ・・・describing the flow of objects by input-and-output relation and conversion function.
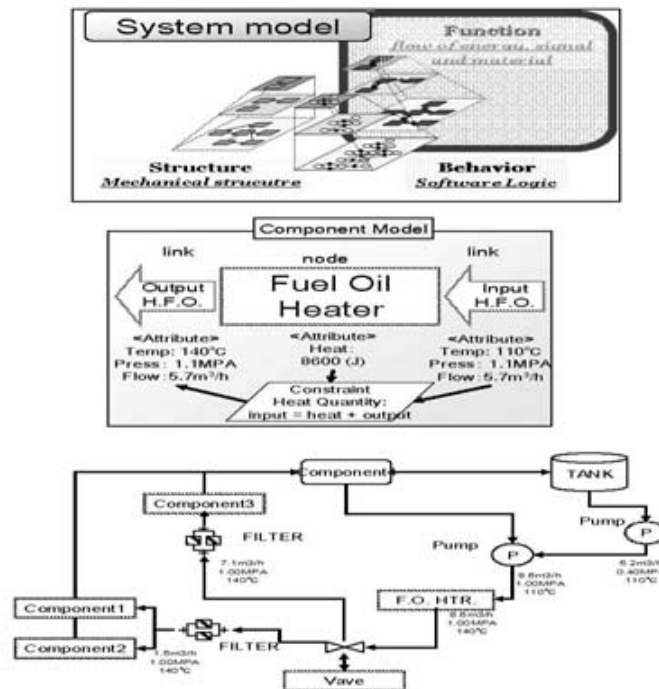

Figure 4　Mode of Function

(3) The model of system behavior (Figure 5) (It takes charge of software.) ・・・describing dynamic phenomenon composed of state and transition.
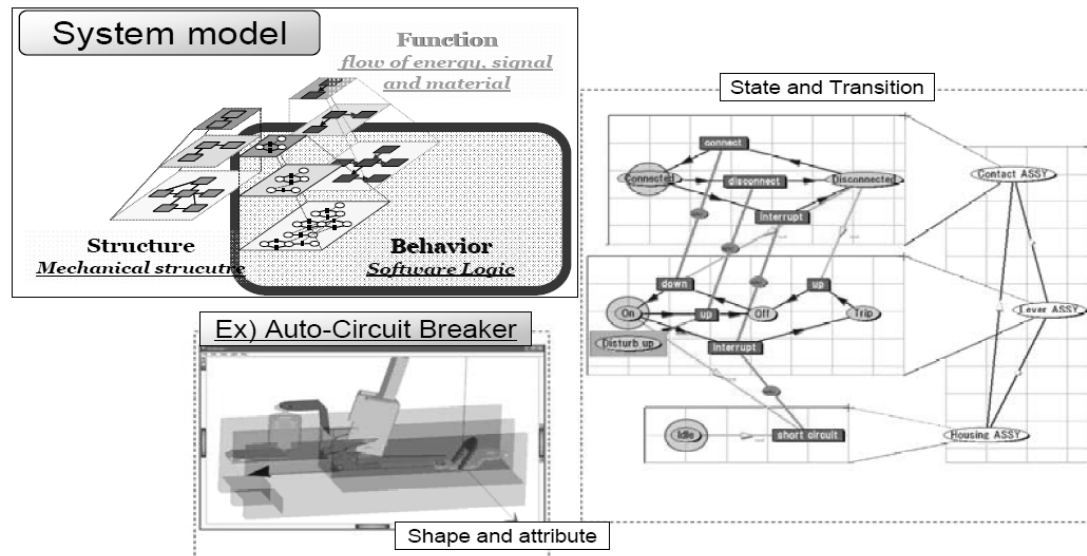

Figure 5   Mode of Behavior

4 Model-driven Development Management Using System Model

If product development is classified into the process which determines information which means "What should we to make?", and the process which means "Whether products is worked properly as expected?", it can be said that the former is the process which advances design to foundations and details from concept and leads to a trial and the latter is the process which leads to evaluation, integration, test, validation and factory trial after trial production. If the integrated model of design information is used, the support for synthesis can be done at the above each design phase by design rationale and intention with integrated model. Since models are described in the form which adjusts many domains and various viewpoints, the support for synthesis which raises and lowers the view or across the domains can be done.

5 Conclusions

The authors introduced outline of cooperative design approach with system model as the attempt to complication of artifacts development in recent years. If proposed design information model is used, design specification and rationale of products defined specially. As a result, it can be supported that developers of mechanics, circuit and software cooperate in a flat position and do synthesis across the domains. Moreover it can be supported for the develop management that Front Loading Type or V&V(Validation & Verification) process which detects the problem across the different domains and resolves from an early stage by describing the design information from the upper phase of development and constructing sharing understanding. Since models are described in the form which adjusts many domains and various viewpoints, the support for synthesis which raises and lowers the view or across the domains can be done.

Further, such as product family development which inputs product group into market and design in consideration of manufacturability and DfX (Design for X) strategy of the design, etc. in consideration of reuse, and life cycle strategy, it is possible to support for examination and the management where strategy expanding scope.

Acknowledgement

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