An Approach for Determining the Impact of Digital Content Product Design

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ABSTRACT

Change is inevitable during the digital content product lifecycle. When changes occur, all the affected items must be handled in order to maintain the consistency and integrity of the product content. For this reason, engineering change is a non-negligible issue for enterprises. This paper proposes an object-based and attribute-oriented approach. Specifically, it objectifies the structure of a digital content product design, characterizes the design through items, attributes, and linkages, and further defines the details of the linkages. The paper also proposes an object-oriented and recursive mechanism for proactively determining the impact of changes that occur when designing digital content products. This study presents an example to verify the proposed concept and mechanism of change impact analysis.

Keywords*:* digital content, product design, engineering change, object technology

測定數位內容產品設計衝擊之方法

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摘　要

變更在數位內容產品生產週期內是不可避開。當變更發生時，所有受影響項目必須維持產品內容的一致性與整合性。於是，工程變更對企業而言是一個不可忽視的議題。本研究提出一個以物件基礎及屬性導向概念方法。具體來說，這方法物件化數位內容產品設計的結構，並透過項目、屬性及連結性特徵化產品設計後，進一步定義連結性的細節。本研究還提出一種物件導向並遞歸機制，用於主動測定數位內容產品發生變更之衝擊。本研究以實例驗證變更影響分析的概念和機制。

關鍵詞：數位內容，產品設計，工程變更，物件技術

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I. INTRODUCTION

Nowadays, as competitive markets develop toward globalization and customer satisfaction, responding to customer requirements effectively is an important issue in digital content design [1]. For digital content (DC) product design, two important issues need to be addressed. First, the existing customer demands of the features of the current DC products need to be revised based on the perception they have gained from the digital content they have consumed. Second, customers' expectations of new product features need to be added to the demand list. These demands may cause changes and have a great effect on digital content design. Therefore, engineering changes (ECs) as well as engineering change management cannot be ignored by enterprises.

However, EC is also a risk in product design [2]. Such risk (e.g. bullwhip effect) may arise due to a large number of raw materials or inconsistency in the supply chain. If the risk is not controlled appropriately, it could result in greater costs and would make the DC product design process chaotic. Under the current conditions of manufacturing industries, the EC problem is a noticeable issue that cannot be underestimated in the competitive environment manufacturing industries face; this means that more effort is required to process ECs effectively and efficiently [3].

According to the literature survey, the major concern during product development is the application of data management technologies, including product data management (PDM), engineering data management (EDM), and integrated product data management (IPDM) [4, 5]. Furthermore, concurrent engineering (CE) and EDM have been employed to improve product manufacturability and quality [6, 7, 8]. Hence, the management to DC product data is a big challenge. In addition, in a study [3] about CE, two general findings have been highlighted: that EC is a problem that cannot be ignored, and that the management of ECs was unsatisfactory in the companies surveyed. Both findings indicate that a good engineering change management system is necessary to better deal with ECs in the product development process.

Since product design usually constitutes a major time period of the product development process, shortening the time spent in the design stage has become an important issue for businesses [9]. With more complexity in product content configurations and with more inconsistency in DC product design processes, reacting to changes quickly is vital, and this is an important role that change impact analysis (CIA) plays in digital content design. According to [10], the CIA function mostly handles the product's higher-level contents, i.e., requirements-driven changes. Hence, it is necessary to determine the potential effects of a change across the product's lifecycle.

EC aims to revise the product to meet customer requirements and market demands or to make the resources more efficient [11]. In these regards, the motivations of this paper are as follows:

- To handle DC product data changes throughout a product's lifecycle
- To handle affected items during a product's lifecycle
- To consider type I/II errors while applying CIA
- The need for an automated system that fulfils the above needs and helps relevant stakeholders perform complicated and recursive CIA loops

To address these issues, this paper aims to proactively develop an approach to managing the impact of change on DC product design. Although many methods such as Design Structure Matrix (DSM) or Quality Function Deployment (QFD) are used to determine the relationships between customer requirements and product contents in the DC product design stage, they do not define the relationships further. Therefore, the proposed approach, an object-based, attribute-oriented CIA method, could more effectively and efficiently deal with ECs.

II. LITERATURES REVIEW

2.1. Product Data Management

Product change and product change management are the two major concerns of this paper. Product lifecycle management (PLM) originated from two roots: enterprise management, and the management of product information throughout the lifecycle of the product [12]. PDM is a method to help enterprises to manage product data in digital content design. Management of product information in the product development lifecycle is considered the scope of product data management. PDM, as the name suggests, is the management of product data via information technology to control the product data and related engineering activities [13]. With the PDM system, enterprises are able to handle product changes and product information effectively and efficiently.

2.2. EC & EC Management

EC is a behavior that results in some amendments or changes to the product itself, including process, material, or components [14]. ECs may arise due to 1) new requirements from customers, 2) the availability of new technology, or 3) a change in components or resource. Each change may have an impact and influence the product development lifecycle.

Thus, management of EC is crucial in each stage of the product lifecycle and can be used to improve product quality and customer satisfaction and reduce production costs. Hence, complete engineering data management is necessary to improve the performance and results of the EC process and shorten the product development cycle.

2.3. Methods of handling EC

2.3.1. Design Structure Matrix

DSM, also called Dependency Structure Matrix, is addressed in [15], the authors of which applied DSM to projects, listed project tasks in detail, and then put an X in the matrix to mark the relationship between two project tasks. The advantages of DSM has led to its increasing use in a variety of contexts, including product development, systems engineering, and organization design. Many traditional tools, such as PERT and Gantt, do not address the complexity in the collaboration between persons and tasks. Although these tools allow the modeling of sequential and parallel processes, they fail to address interdependency [16].

According to [17], DSM is able to address symptoms of change in time. In addition, it is also an effective approach to characterizing interdependencies. The management of complicated relationships between product components is important in product design. Although DSM is able to address the interdependencies (i.e. relationships) among items, it does not further describe the details of the interdependencies. Thus, to properly manage change impact in the product lifecycle, comprehensively understanding direct and indirect changes is necessary.

2.3.2. Quality Function Deployment

QFD is a customer-oriented approach to product innovation. QFD aims to design, produce, and provide a high quality product for customers. QFD is well known for its ability to ensure products meet customer expectations during the DC product design or development process [18]. QFD tools such as House of Quality (HoQ) are primarily used in the product planning phase.

In other words, QFD is a method for structured product planning and development that enables a development team to clearly specify the customer's wants and needs and then to evaluate each proposed product or service capability systematically in terms of its impact on meeting those needs. Since customer requirements are the driving force in the first domain, which in turn affects the subsequent domains in the mapping processes, they are a major factor in the processes in DC product design. Therefore, understanding customer needs is vital to a successful design activity. Although QFD offers a systematic method for mapping customer expectations to technical characteristics of the product, the relationships between DRs and CRs are not further defined in detail, that is, QFD is insufficient for handling changes during the product development process.

III. METHODOLOGY

This paper proposes an object-based, attribute-oriented CIA method for digital content design. Our research aims to objectify the structure of the product configuration in terms of items, attributes, and linkages. Specifically, our method hopes to handle DC product data changes throughout the product's lifecycle.

3.1. Terms and Definitions

Items:

In DC product design, a product comprises various items. From the viewpoint of product structure, a product comprises various components. In this paper, product items are regarded as product components.

Attributes:

Attributes are used to describe the feature of the component in our paper, and the attributes in a linkage are defined by two product components that have the same attributes. In other words, a linkage binds the attributes that both items have.

Linkages:

The relationship between two items is called a linkage. Furthermore, a linkage is formed by connecting two items if they have the same attributes. In other words, a change in those attributes for one item will propagate to another item via the linkage.

3.2. Process

The process of this paper can be divided into two phases. Since DC product design usually constitutes a major time period of the product development process [9], and the CE environment is developed, ECs activities can be expected to be frequent. Therefore, this paper focuses on constructing the structure of the product, and then applies changes to product components to simulate conditions during EC. Finally, CIA is performed to identify the affected items. The flowchart of this paper is shown in Figure 1.

Regarding production structure modeling and change impact analysis in Figure 1, they are the processes of production configuration. In this paper, we concerned whether the design process of DC product completed. If yes, went on the next process (i.e. change impact analysis). In CIA phase, we concerned to apply some change factors or methods to analyze whether the designed products were really completed.

Both production structure modeling and change impact analysis, they are iterated and repeated processes.

3.3. Model Framework

In order to handle changes and impacts across the product development lifecycle, this paper proposes an approach that provides maximum quality. Such an approach is an object-based and attribute-oriented method. It characterizes product components and related items via attributes, and builds linkages in the DC product design process. The proposed approach also models dynamic change propagation processes using object technologies.

Structure of the model framework:

In this paper, product items (also called product components) are characterized using attributes. Furthermore, product items have relationships with each other. That is, linkages are defined to represent the relationships between product items. Specifically, a linkage is built by connecting attributes that both items have. In other words, when a change is applied to one item, it will propagate to another item via the linkage.

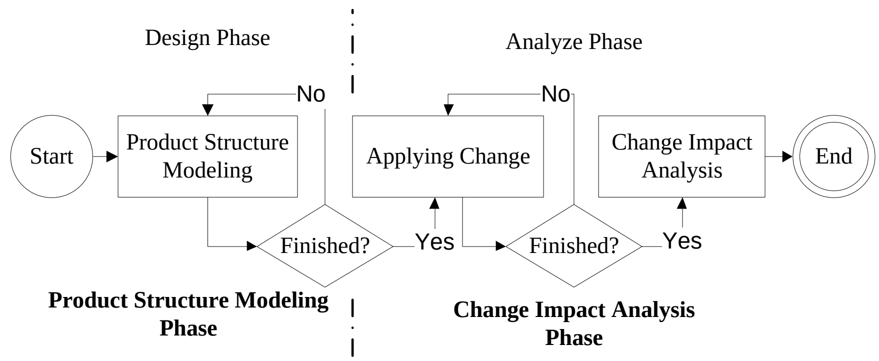

Fig. 1 The flowchart of this paper

Structure of the model framework with change and impact:

Figure 2 shows the relationships among change, impact, and the structure of the model framework. When a product item changes, some of the attributes of the items are influenced due to it. Impacts are then created and propagated to the other items via the linkage. Some of the attributes in those affected items are also influenced by those impacts. The propagation stops when of the impacted items have been identified. This is the key mechanism of the proposed approach.

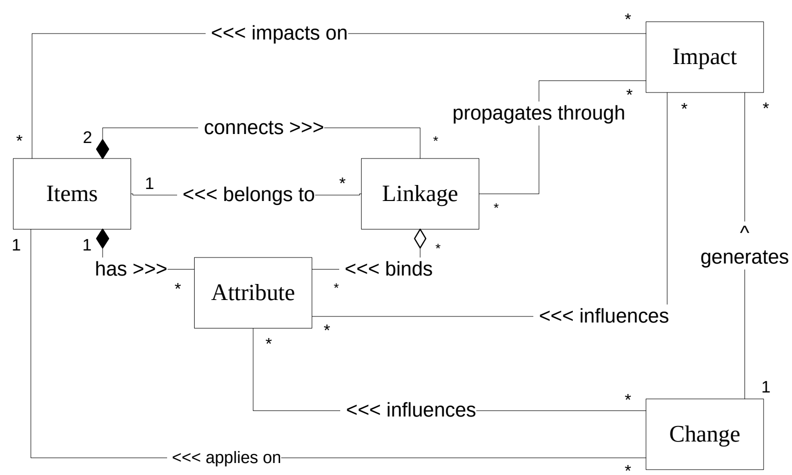

Fig. 2 Model framework with change and impact

IV. RESULT

Based on the proposed approach, the author has developed a system, called Early-Phase Identifier of Change for Engineering Change (EPIC_EC). With the proposed approach, this system is able to find out all the impacted items. The paper can be divided into the design phase and analysis phase. Thus, there are two major parts in the system: 1) Model Builder and 2) Impact Identifier.

Model Builder:

Model Builder provides a graphical user interface (GUI) for users to build the product model effortlessly. There are three main functions in Model Builder: create items, define attributes, and create linkages. Different kinds of items are represented by different colors and images. The user can keep adding items to the model and defining attributes of specific items until all the items as well as attributes have been fully created. Then, the user determines the relationships between two items and connects related items by creating linkages between them. Figure 3 shows the DC product model built using Model Builder.

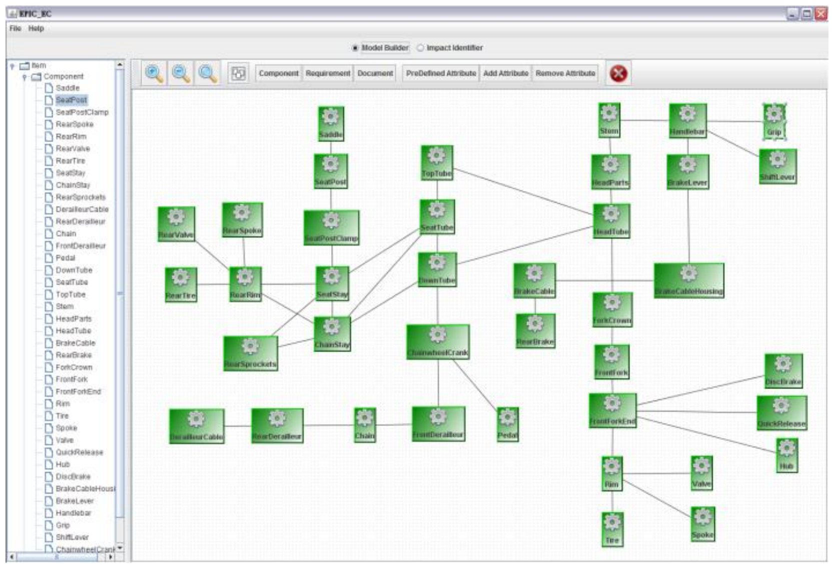

Fig. 3 The DC product model

Impact Identifier:

Impact Identifier is the most important part of this system. It demonstrates the main idea of this paper: CIA using attributes. In the CIA state, users may add changes to specific items in the model by choosing the changed items and attributes. This paper simulates engineering changes in the product development lifecycle by applying changes to those items. Figure 4 shows a screenshot of applying multiple changes to the product model.

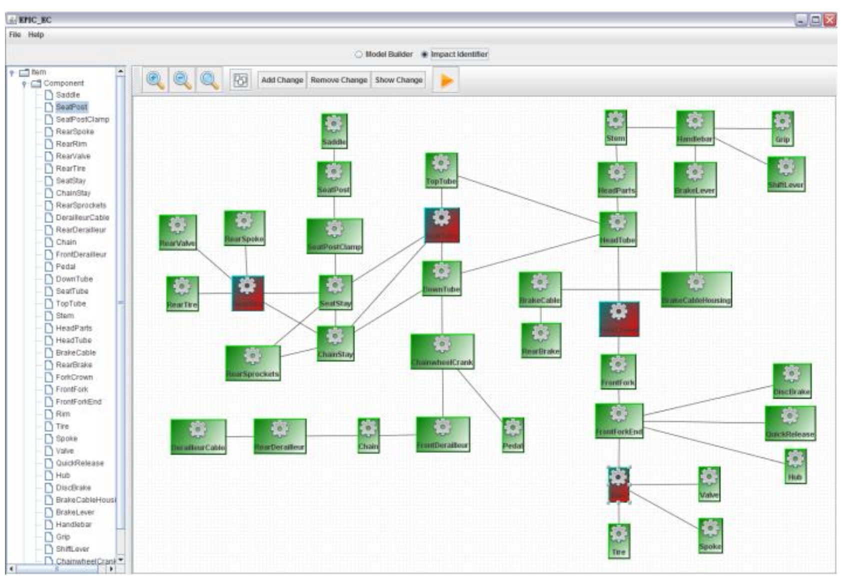

Fig. 4 Applying changes to the DC product model

After the items and attributes to be changed are determined, EPIC_EC labels the changed items in a different color. Impact analysis can be performed by clicking on the Run Analysis button on the toolbar. The report generated by EPIC_EC shows the possible items impacted by the changes.

Moreover, with the help of the proposed object-based, attribute-oriented CIA method, not only impacted items but also impacted attributes can be determined, as Figure 5 shows.

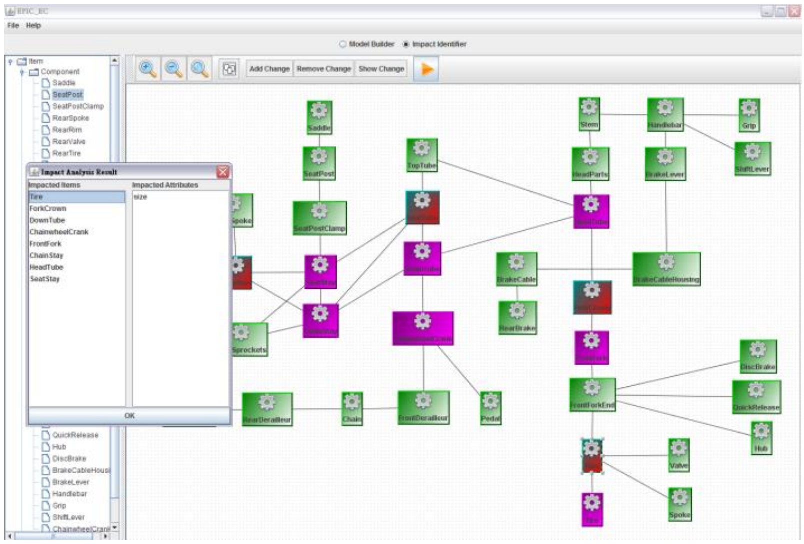

Fig. 5 Applying changes to the DC product mode

V. DISCUSSION

Some comparisons between the proposed approach and other methods (i.e., DSM & QFD) are presented to show the benefits of using EPIC_EC. These comparisons will include dependencies, changes be applied, impact analysis result, suitability for use in DC product design, and precision of the analysis result. On the other hand, under some circumstances, some errors may appear during impact analysis. For instance, an item must be impacted but not appear on the result report. Therefore, data quality (i.e. Type I/II errors) also merits discussion.

VI. CONCLUSION

This paper proposed an impact analysis method named the object-based, attribute-oriented CIA method using object technology. The method was implemented through EPIC_EC. Then, an example was presented to illustrate the use of the proposed method along with some comparisons.

In summary, the goal of this paper was to find a method that could be used to identify early-phase change impacts. This paper proposed an object-based, attribute-oriented change impact analysis method that has achieved this goal. The author also hopes that the proposed approach and system help relevant stakeholders perform CIA as well as DC product design more effectively and efficiently. The expected contributions of this paper are as follows:

1) The proposed CIA could be used in the entire product development lifecycle.
2) Impacts of changes can be identified through the proposed approach.
3) An automated impact analysis system has been implemented that could help relevant stakeholders perform complicated change impact analysis during DC product design.

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