Development of a Web-Based Mass Customization Platform for Bicycle Customization Services

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Abstract: Bicycle manufacturing is a mature industry in Taiwan and several companies already own the world-known brands such as Giant, Merida and KHS. These companies based on not only their core design capabilities but also well established supply chain to delivery high quality products to their customers. However, none of them focus on providing bicycle customization services to a single customer with affordable price. In contrast with these companies, some small workshops provide full customize services, but the price is not suitable for general public. This paper develops a web based mass-customization platform to aid the bicycle customization services through cyberspace. The online platform composes of two major parts, which are the bicycle requirement extraction service and the custom bicycle specification management service. These two modules can assist customers define their needs intuitively (and often at home) while maintain their spending within budgetary constraints. By using these two modules, the bicycle industry can establish an easy customization process for the mass general market. Further, with the mass customization function online, all customer orders and specifications are collected in electronic forms in realtime in order to optimize production planning and execution for quick market response and order fulfillment.

Keywords: Mass customization, information technology, web based product platform, bicycle industry.

1 Introduction

It is only a human nature that people prefers and often is willing to pay extra to be different from others, e.g., one-of-the-find designer outfits and customized home

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decoration. The need for distinction is often used as a product design principle, particularly for the high-end market. From the product design perspectives, the needs for differentiation can be categorized into two folds. One is the appearance and the other is the functionality. The appearance means that the outlook style of a product can be built based on customer's preferences. In functionality aspect, the physiological differences cause a product functioning differently from expected, e.g., a bicycle, used by two people with two different weights and heights, will affect its acceleration rate. Hence, employing human factors into product design becomes a well known approach for mass customization. From the endusers perspectives, customers may very likely to choose the type of product that does not fit their physiological condition due to the lack of human factor knowledge during the product design. In order to close the gap between design and customers needs, this research focuses on developing a system with guidance-based interface to extract customer's preferred functionality and appearances. We use the bicycle customization management service to demonstrate the concept and the IT implementation.

The remaining of this paper is organized as follows. Section 2 is the literature review of mass customization on product design. Section 3 depicts the customization process model and discusses the drawbacks we found in this model. Section 4 describes the web based bicycle mass customization process model and discuss the adventage of the process model. Section 5 presents the system architecture and implementation details. The final section concludes the results and contributions of the research efforts.

2 Literature Review

The definition of mass customization (MC) is to produce a product based on consumers' requirements while the cost is still affordable for general public [1]. The concept of mass customization quickly becomes an emerging research topic. The growing interest in MC led researchers to suggest companies to shift from mass production to mass customization [2]. However, the successful story in real MC adoption is rare. MC itself is viewed being neither a methodology nor as a technology, but a service strategy [3, 7-9]. It involves not only production management but also direct customer requirement response, modular product design, supply chain management and after-service management. The difference between mass production and MC can be easily identified. Mass production is product centre and focuses on controling the cost of product. MC is customer centre and focuses on the customer value creation [7]. The customer-oriented means the product is made based on the requirements set by a customer. In other words, retrieving customer requirements is the crucial first step for customization. Although the traditional face-to-face interview is an effective way to collect customer's first hand requirements, the cost is very high and the efficiency is very low. Further, the requirement extraction process is often an iterative process. Customers may need to review and modify their previous decisions to ensure their needs are recognized and fulfilled. The skill of the interviewer may effects customer's decision and causes unsatisfactory. Thus, using web as an interactive media to collect customer's needs becomes an important option for implementing a system to mass customization [4-6]. Companies can establish an interactive web site to provide the process to customize a product and collect customer's requirements online[11-12]. However, we found most of web sites are designed for people who are familiar with the products at the first place [6]. This situation forms a gap for novice people to participate in the customization process. Thus, this paper presents a process to establish interactive web environment for both novice and experienced customers. No matter the product knowledge level of the customer, a customized bicycle can be configured through the interactive process.

3 Processes of Bicycle Customization

The bicycle manufacturing is a mature industry. Companies in the industry can be divided into two catalogues based on their service attributes. The component provider provides the fundamental parts such as stems, pedal, et al. The finished bicycle companies design their own frame and then assemble the frame and other components. A bicycle construct and its bill of materials (BOM) generally follow a standard design. Thus, it is possible to assemble a bicycle complying with the customer's requirements. If we look closer, a bicycle is composed of 5 sub-systems including frame, transmission, control, wheel and accessories as shown in Figure 1. Each sub-system can be split into further detailed sub-assembly and components, such as fork assembly and head parts assembly. In mass production, the whole assembly process is frame centre. They put the bicycle frame on a stand and mount other parts to the frame. After running through three or four assembly stations, a bicycle is produced completely.

Although the finished bicycle companies already provided four or five different sizes of frames to fit the different heights of bicycle riders, there still are high demands to build customized bicycles. Figure 2 shows the bicycle customized process model. The model is constructed by using petri-net [10]. The model describes not only tasks definition but also the input, output and role in charge the activity in the customize process. As can be seen in Figure 2, the customize process can be split into three phase. The first phase is interview and key dimensions collect. Customer who wants to build a customize bicycle has to interview with bicycle store employee. In the interview, the employee will reveal customer's needs such as riding style and preference, painting style, and some preference regarding to accessories parts selection. Customer's pelvis, thigh, shank will be measure as key dimensions for building the frame. The second phase of the customization process is pre-engineering phase. In this phase, the design employee starts to modify the template frame design with customer's specific dimension that collected from first phase and the purchase engineer starts to send purchase orders to related component vendors by customer's requirements. The third phase is the construction phase. In this phase, the technician employee is responsible to assemble the customized frame and parts into a bicycle. The final adjustment is based on the customer's riding preference.

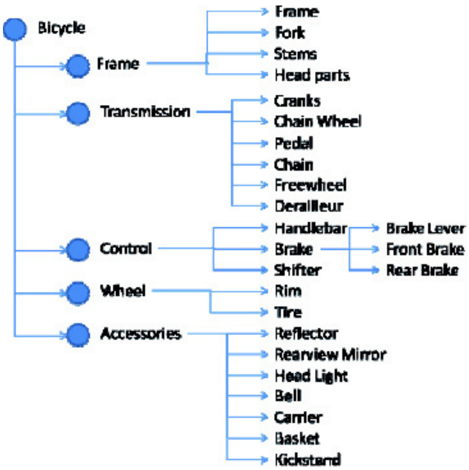

Figure 1. Bicycle bill of material (BOM) structure

Although the customization process model seems be an executable procedure, we found the actual customization is by far a very difficult task to accomplish. Things may go wrong in many stages, e.g., misunderstand customer's riding preference, purchase wrong parts, and assemble the incorrect components. The overall efficiency of MC is too low and the cost of MC is too high. Therefore, the customization is hard to be adopted by general public due to the higher prices comparing to the mass-produced bikes. Hence, we introduce a new process model and information system to improve the MC process.

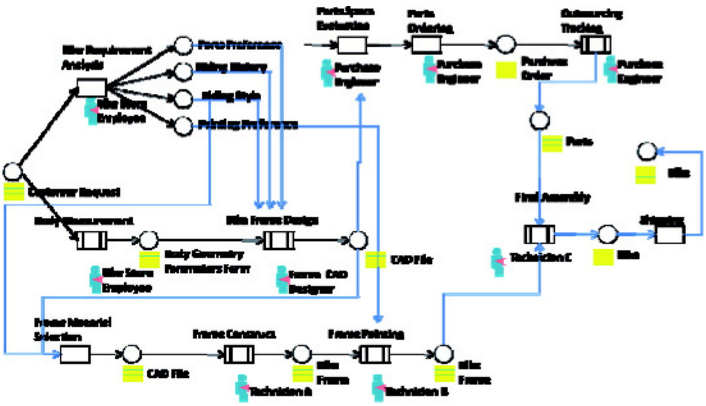

Figure 2. Bicycle customization process model

4 Web-based Bicycle Mass Customization

How to increase the efficiency of the customization process and reach the economic scale is the main consideration of this research. The ideas to improve the overall efficiency of the customization process are in three aspects. First task is introducing a web-based self service system for customers. Second task is establishing a centralized customization order management system to increase the bargaining power to the component vendors and saving the component transporting fee. Third task is establishing a strategic partnership with local bicycle shops for final adjustment and providing after-services for the MC customers. Figure 3 shows the improved bicycle customization process model. The to-be process starts when customer logs onto the site. The self service function collects customer's body geometry, riding style preferences, and key parts preferences step-by-step and interactively. For novice people, the website provides online help video for self education. Besides, customers can review the decision he or she had specified at any time during process. The requirements collection process can be iterated for many times until the customer feels comfortable to submit the final MC design. Once customer submits the customization requirements, the "Bike B2C Service" will be triggered. Customer's requirements will be transformed into a custom bike specification containing the original customer data and some basic parts information, and then be submitted to "Custom-made Bike Engineering." In "Custom-made Bike Engineering," the system will rout the specification to an available engineer. The engineer will analyze the specs and configure the BOM structure regarding to the customer's preference. After the BOM structure is completed, then "Purchase and Build" process starts. In order to reduce the cost, components are not purchase directly. Each part or sub-module has its own minimum purchase quantity limit setting. The purchase order is not released until the minimum purchase quantity is reached. We call this function as the joint purchase approach, which may make a purchase order wait for a period of time before official order being released for final production. Customers may be impatient in waiting if they do not understand the joint purchase policy. Thus, the system provides a progress report to customer as shown in Figure 4. It reveals the status of each part, e.g., "on waiting", "purchased", "checked in", "processing" and "finished." With the status report, customers are able to learn the progress of their MC order in real time. After the assembly process complete, the bicycle will be delivered to the local bicycle shop for final adjustment. Then, the customer will be notified to receive the custom-made bicycle.

There are several advantages of web based bicycle MC. From customer aspect, the web based platform provides an easy to use interface to build a custom bicycle, a transparent progress tracking interface for catching the progress status and cost saving due to the grouping parts purchase mechanism. From engineering and manufacturing aspect, the system provides an integrating environment ensure the original customer requirements can be consistence from the beginning to the final assembly. This can prevent any errors happened during stage transition.

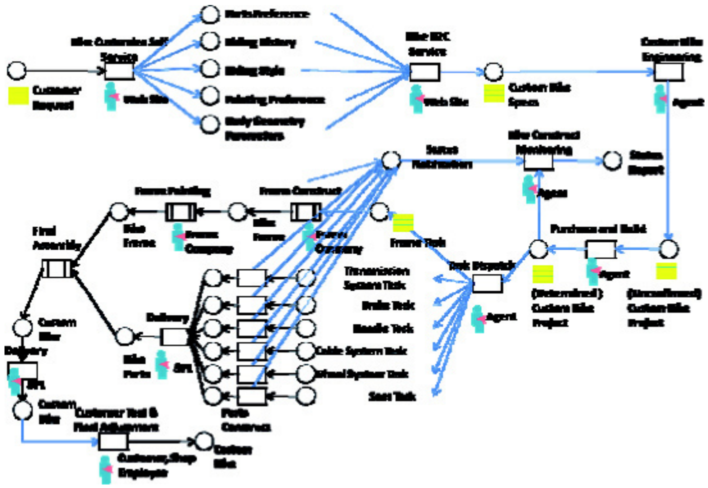

Figure 3. Process model of web-based bicycle mass customization

5 System Architecture and Implementation

The system architecture of this research is shown in Figure 5. The system can be divided into three major modules, i.e., customer requirements collection, order manager, and object persistent module. The customer requirements collection includes customer geometry collection, customer riding preferences, and customer preferred parts selection. The customer preferred parts selection is for professional customers. They can specify their preferred parts or sub-system with specific component or product brands. The order manager module is the core module of the system. For example, the custom specification editing module provides functions to process customer's requirements into production-able specification. The status tracking module collects the information of the actions taken by the engineer for customer to reveal the progress status. Finally, the object persistent module provides a common logic in handling the data storage issues of the entire system.

In addition, the customer preferred parts selection module and the custom specification editing module use the same configuration rule to validate the parts and sub-modules selection. The configuration rule is based on the assembly relationship between parts as shown in Figure 6. For example, a fork is selected only if the fork's head tube outer diameter matches the frame's head tube inner diameter. The part specification data are stored in the database table. Different type of parts has its own table field layout. The information will be loaded into a Java object when a rule is triggered. The rule is expressed as a Java compare clause, e.g., fork.headTube.outterDiameter == frame.headTube.innerDiameter. The rule is stored in a XML file and loaded at run time. The entire system is implemented using Java Enterprise Edition 6 with Apache Tomcat 6 as the web server and MySQL database as the backend data storage.

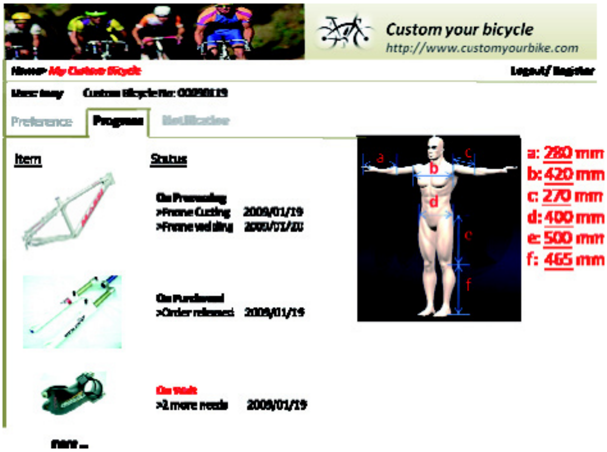

Figure 4. Status report

6 Conclusions

This paper presents a bicycle mass customization system that utilizes process modeling, Internet-enabled and object-orient web technologies. In particular, the improved process model reveals an efficient way of customizing a bicycle from both perspectives of customer order and manufacturing assembly. In addition, two important features are employed in this research, which make the customization more acceptable than the traditional face-to-face approach. They are the joint purchase strategy (for cost control) and constraint based configuration (for manufacturability and assemblability). The former can effectively reduce the overall cost of a customized bicycle, while the later provides an automatic validation of part selections for both customers and engineers. Finally, the web-based system provides a transparent information environment for both customers and manufacturers to track progresses and exchange messages on the fly. The system can keep customers informed in the real-time progress of the MC order and is also the key to keep a good cutomization experiences to the mass market.

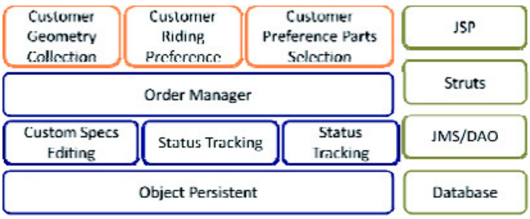

Figure 5. Web based bicycle MC system architecture

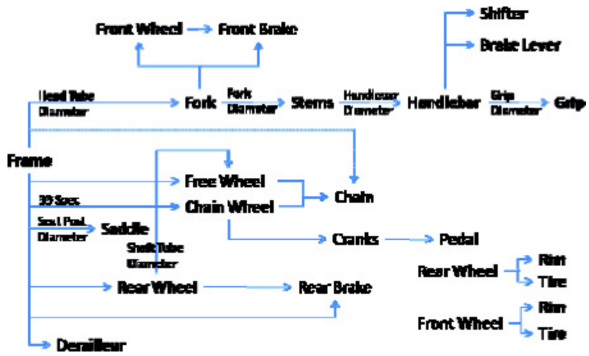

Figure 6. Bicycle parts assemble relationship

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