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# A Web-Based Fuzzy Mass Customization System

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## Abstract

Mass customization attempts to give customers the product they want, when and where they want it, at a cost comparable to that of mass-produced goods. With the increasing popularity of the Internet and broadband, it is now possible to let mass household consumers be involved in the design of a product that reflects their preferences or personalities. As such an application is targeted at the general public, a descriptive or linguistic input style is preferred. The concept of fuzzy customization is therefore proposed and investigated. A prototype system is implemented on a web client/server architecture, namely CyberFGC, which consists of a fuzzy geometric customization (FGC) program, Virtual Reality Modeling Language (VRML), and common gateway interface (CGI) programs. In this system, household consumers can customize products using their preferred linguistic description such as big, small, normal, etc., over the World Wide Web. Examples of customization of wine glasses and furniture are described in detail.

***Keywords:*** *Mass Customization, Fuzzy Reasoning, VRML, Geometric Modeling*

## Introduction

Due to increasingly demanding customers and market turbulence caused by the globalization of modern economy, the manufacturing industry, and many other industries, has been experiencing a fundamental change—from mass production to mass customization. Mass customization, coined by Davis (1987), aims at developing, producing, marketing, and delivering affordable goods and services with enough variety and customization that nearly everyone finds exactly what he/she wants (Pine 1993). Mass customization challenges traditional manufacturing precepts by using mass production processes to meet the singular needs of individual customers. To achieve the goals of mass customization, manufacturing companies must focus on their competitive advantage (Daflucas 1998).

Mass customization starts with understanding customers' individual requirements (Fulkerson 1997). Effective definition of customer requirements is a prerequisite for realizing mass customization. Companies must initiate a dialogue with individual customers to help them articulate their needs (Proops 1996). A number of techniques have been used to facilitate customer input into the design phase of product development. These include surveys, focus groups, and customer interviews. But these techniques do not capture the complete picture of customer preferences (Brown, Hitchcock, and Willard 1994). Users rather than suppliers are the actual designers of the application-specific portion of a product (Von Hippel 1998).

The Internet has turbocharged companies' abilities to track individual customer preference (Dewan, Jing, and Seidmann 2000). It is unsophisticated to construct a website wherein customers can simply select offered options from lists to generate different product or service combinations. However, in markets like automobiles or consumer goods, which have a crucial emotional connection between customer and product, there is a high emphasis on an appealing and aesthetic exterior of the product. Styling is often the final differentiation criterion among products competing on the market (Dankwort and Podehl 2000). More market share will be captured and higher profits gained if a firm can let mass household consumers customize the style of the products they want.

However, due to the limited network bandwidth and the huge amount of data in the 3D geometry description, it is impossible to implement a full version of a CAD system on today's Internet. On the other hand, most commercial CAD systems currently in use are too sophisticated to beginners. The research work in this paper therefore concentrates on the development of a web-based application that allow both beginners and seasoned users of CAD systems to define and customize certain families of products on the World Wide Web.

With the widespread use of the Internet, web-based design is attracting more and more attention from the CAD/CAM community. The majority of recently reported research focuses on the development of certain methodologies that are applicable to effective communication and cooperation among the working groups that are dispersed all over the world. A substantial American research project—the ARPA Manufacturing Automation and Design Engineering (MADE)—was conducted from 1992 to 1996 (Cutkosky, Tenenbaum, and Glicksman 1996; Petri 1996). The MADE program develops Internet-based tools, services, protocols, and design methodologies for design and manufacturing teams. It is concerned with the comprehensive information modeling and the design tools needed to support rapid design of electromechanical systems.

Gadh and Sonthi (1998) discussed the need of different levels of geometric abstractions to enable design teams collaborating over the Internet at different stages of the product development process. Roy et al. (1997) reported a web-based collaborative product development environment where the Web was used for the sharing of CAD data and product design data. Similar works are also reported by Huang, Huang, and Mak (2000); Kim, Lee, and Han (1999); Summers and Butler (1999); and Wanger, Castenotto, and Goldberg (1995).

In the product development process, various attempts have been made. Huang, Huang, and Mak (1999) and Huang and Mak (1999) developed a generic, web-based Design for X (DFX) shell that can be tailored or extended to develop and apply a variety of DFX tools easily, quickly, and consistently. The CyberCut concept that provides the first design-to-manufacturing rapid prototyping system over the Web was reported recently (Smith and Wright 1996). The CyberCut concept is the synthesis of World Wide Web technology and interconnected CAD/CAPP/CAM components of the Integrated Manufacturing and Design Environment (IMADE) developed at the University of California-Berkeley. CyberCut constrains the user to the design of parts that are manufacturable on a three-axis milling machine.

All of the above researches are mainly focused on conceptual development. Three-dimensional visualization on the Web is not available. In this paper, product families are implemented as parametric models. The solid model of a product is created in such a way that the model creation operation can be re-executed with new values for the defining parameters of the associated geometric features (Cox 2000). Because the system is developed for the public at large, parameters that describe a family of products are defined as fuzzy variables. Fuzzy logic can handle various types of vagueness and uncertainty, particularly the vagueness related to human linguistics and thinking (Tanaka 1997).

In the proposed system, a web server/client architecture, namely CyberFGC (Cyber Fuzzy Geometric Customization) is proposed and implemented. It consists of a fuzzy geometric customization (FGC) program, Virtual Reality Modeling Language (VRML), and common gateway interface (CGI) programs. FGC is used to accept customers' inputs and generate design models. VRML, an ISO standard language for describing 3D models on the Web, is used for 3D model visualization.

## Fuzzy Reasoning

Fuzzy reasoning is performed by inference rules, which are expressed in IF-THEN format. The linguistic rules can simulate human thinking processes to some extent. IF-THEN rules used in fuzzy reasoning are called "fuzzy IF-THEN rules," which represent the relation (or transformation) of input variables to the output and are normally expressed as:

IF $A_1$ and/or $B_1$, THEN $H_{11}$, else

IF $A_2$ and/or $B_1$, THEN $H_{21}$, else

IF $A_1$ and/or $B_2$, THEN $H_{12}$, else

IF $A_2$ and/or $B_2$, THEN $H_{22}$

The defuzzification process is an important step in fuzzy reasoning. In general, defuzzification is the process where the membership functions are sampled to find the grade of membership; then the grade of membership(s) is used in the fuzzy logic equation(s) and an outcome region is defined. From this, the output is deduced. Several techniques have been developed to produce an output. Centroid, which takes the center of gravity of the output fuzzy set as output value (Tanaka 1997), is adopted in this research; that is: