

Developing a Customer-Producer-Interaction System for One-of-a-Kind Product

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This paper addresses how to develop a customer-producer-interaction system for a one-of-a-kind product. The proposed system consists of four modules: input, modeling, feedback, and output modules. A web-enabled input module is developed. As manufacturing is transforming toward regionalized and personalized production, this study contributes toward materializing such forefront of manufacturing transformation.

1. Introduction

Manufacturing has been transforming in the following way: craft production, mass production, mass customization, and regionalization and personalized production. This transformation exhibits a U-turn in the plot of production volume per variant versus product variety, as shown in Fig. 1¹. As seen in Fig. 1, the forefront of manufacturing transformation is regionalization and personalized production. This forefront demands new manufacturing enablers (methods, tools, systems, human resources). The enablers result in a highly flexible manufacturing system. In order to achieve such a manufacturing system, appropriate hardware and software are needed. As far as hardware is concerned, a highly versatile machine tool must be developed so that the machine tool can perform different manufacturing processes (milling, drilling, turning, extrusion, casting, and so on) whenever needed. As far as software is concerned, a highly responsive customer needs system must be developed so that the system facilitates two-way communication between a customer and a producer, considering that the customers are unfamiliar with manufacturing technicalities. In order to elucidate the requirements of the abovementioned hardware and software, the authors have been performing a series of studies. In these studies, the authors considered the scenario of one-of-a-kind product. Some of the salient points of these studies are presented in the rest of this article.

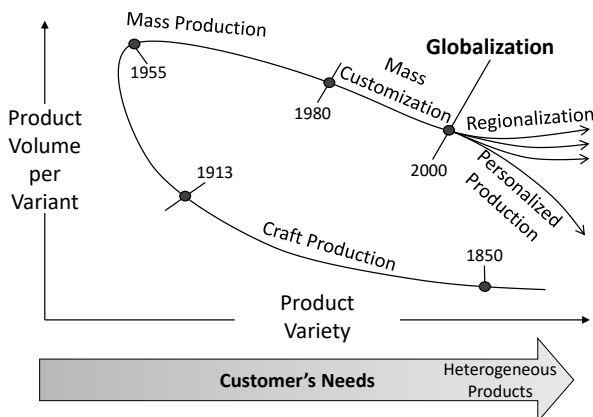


Figure 1. Transformation of manufacturing¹.

2. Additive Manufacturing

Additive manufacturing (popularly known as three-dimensional (3D) printing) can play a vital role as far as a versatile machine tool is concerned². For example, consider the mechanical product called gear-pump, as shown in Fig. 2. The CAD model shows the parts (casing, shaft, gear, screws, and so on) of a gear-pump can be used to manufacture it using different manufacturing processes. As a result, several machine tools are needed to materialize the gear-pump (conventional product shown in Fig. 2). Alternatively, a single machine tool, i.e., a 3D printer, is enough to produce

all parts of gear-pump, as shown in Fig. 2 (right-bottom picture). Thus, the regionalization and personalized production can be founded on the workflow of 3D printing (Fig. 3).

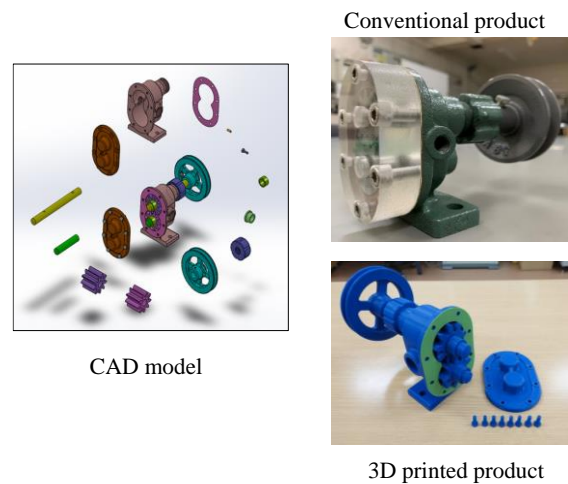


Figure 2. An example product.

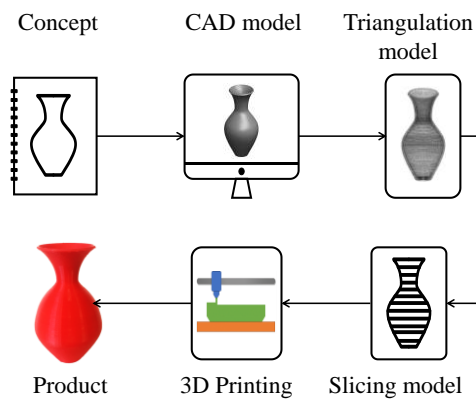


Figure 3. Workflow of 3D printing³.

3. Results

Based on the contemplation described in the previous section, this section presents some of the noteworthy results. First, the system layout is presented as schematically illustrated in Fig. 4. As seen in Fig. 4, a customer-producer-interaction system for developing a one-of-a-kind product consists of five modules: input module, modeling module, feedback module, output module, and delivery module. The interaction occurs in four stages, each corresponding to a unique module. In stage 1, the input module receives the customer's order. This module must support a high-level description of the product, e.g., a sketch and/or linguistic description of the product to be fabricated. In stage 2, the modeling module produces a CAD model based on the output of the input module. Since the product description is

a sketch or some linguistic phrases, the CAD modeling must be performed using sketch-based information. The modeling module also produces some alternative models considering manufacturability. The reason is that 3D printing sometimes needs support. However, the feedback module presents the original and alternative models to the customer at her/his disposal. Finally, the customer's decision is passed to the output module if the customer is satisfied; otherwise, the modeling module is activated again for remodeling. This process continues until the customer approves the model. Once the customer approves the model, the output module then generates the necessary commands for the selected 3D printer. The outcome of the output model is the final product that is made available to the customer and delivered to the customer.

Based on the system layout shown in Fig. 4, the authors are developing the system's modules. Figure 5 shows two of the screen-prints of the input module. The system is developed using Hypertext Preprocessor (PHP) and My Structured Query Language (MySQL) to make the input module a web-enabled system.

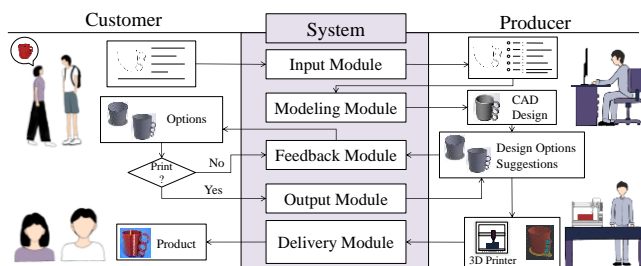


Figure 4. System's layout.

The user (customer) can open an account or work as a guest user. A study by Yamaguchi⁴ shows what form of answers to be expected from the customers related to 3D printing one-of-a-kind product. The result of the study shows that customers tend to give data in form of text, sketch, and both text and sketch. Therefore, the system allows the user to input CAD data, sketch, and/or linguistic description of the product to be fabricated.

The authors are working on the modeling module and feedback module. The modeling module is one of the complex modules because its main function is to convert a sketch into a machine-readable CAD model from which the STL data (the default data format for 3D printing). The main assumption behind materializing the modeling module is that a set of point clouds can represent any sketch, and each point cloud can be geometrically transformed into STL data. This concept is schematically illustrated in Fig. 6. As seen in Fig. 6, a sketch is converted into a triangulation model after performing the following steps in sequential order: sketch, elemental model, elemental point cloud, model point cloud, and triangulation model. The elemental model consists of some features of the shape presented by the sketch. The point clouds representing the elemental models are the elemental point clouds. Analytical equations or parametric curves can be used to do the job. The elemental point clouds are further modified to create a model point cloud. Finally, the model point cloud represents the shape using a set of triangles. While performing the above steps, the producer can use an off-the-shelf CAD package or develop a customized tool. The feedback module will facilitate the interaction based on the CAD model that is created in the modeling module. The producer can provide some design option suggestions to customers regarding one-of-a-kind product to reduce the cost by changing the geometry of the product, providing other options of material, and so on. An architecture of the producer's system interface that can be applied for different cases of product order is designed. The authors are working on developing the tools in this regard.

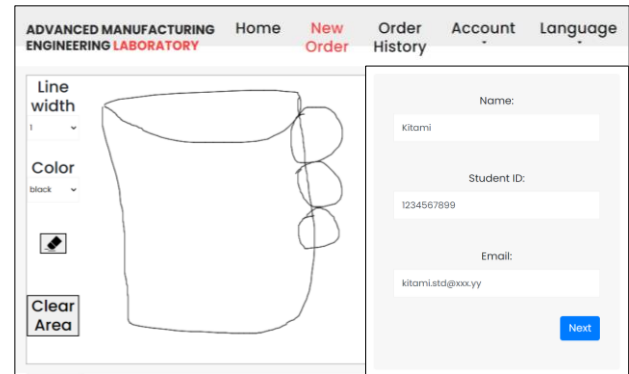
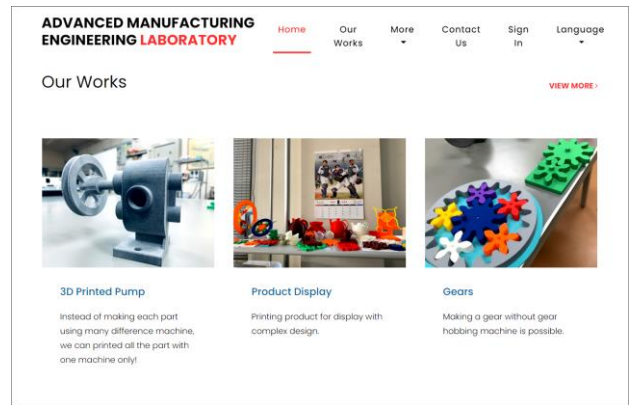


Figure 5. Screen-prints of input model.

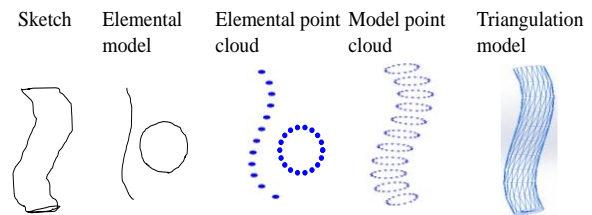


Figure 6. Elements of modeling module.

4. Conclusions

This study shows that a customer-producer-interaction system for developing a one-of-a-kind product consists of four modules: input module, modeling module, feedback module, and output module. These elements support the workflow of 3D printing-based product realization. The functional requirements of the modules are also elucidated. Input module and modeling module relevant system has been developed. Other modules will be developed in the next phase of this study.

References

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