

Changeable, Agile, Reconfigurable & Virtual Production

Applications for Frugal Product Customization and Design of Manufacturing Networks

D. Mourtzis*, E. Vlachou, C. Giannoulis, E. Siganakis, V. Zogopoulos

Laboratory for Manufacturing Systems and Automation, Dept. of Mechanical Engineering and Aeronautics, University of Patras, Patras, 26500 Greece

* Corresponding author. Tel.: +30-2610-997262; fax: +30-2610-997744. E-mail address: mourtzis@lms.mech.upatras.gr

Abstract

Manufacturing is moving towards a new era of frugal innovation, exploiting customization and regionalization practices, where companies base their business on mobility and on adapting local market requirements, resulting to a new business model through low-cost and high customer value solutions. Mobile applications and advanced decision-making tools are becoming more and more necessary in order to address individual needs and preferences of customers and markets, in general. Towards that end, this paper presents a framework that consists of a mobile application supported by augmented reality technology, and a manufacturing network design tool supported by a smart search algorithm. The proposed framework aims to support the customer integration in the product design phase and, consequently, in the design of the manufacturing network. The proposed work is validated in a white-goods industry.

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1. Introduction

Modern companies, in the context of global competition, in order to maintain their market share rates and also reach new markets, should re-shape their strategy by taking into account the needs of the different regional markets. Customer integration in product design [1], considering multiple regions, is a promising step towards capturing the market's pulse and new ideas on product design provided by the customers themselves. This leads to regional characterization of customer demands and product requirements. In order to address these challenges, Original Equipment Manufacturers (OEMs) are searching for new approaches to create well-structured manufacturing networks with higher efficiency, moving towards a more close-to-customer approach [2]. This combination of global production and distributed customer networks forms the basis of frugal innovation. Frugal innovation exploits the concept of intelligent use of resources, developing products for specific markets with optimal cost and quality [3].

The Information and Communications technology enables the use of mobile devices and the distributed decision-making [4] which can form the basis of the dissemination of the frugal innovation concept. The use of mobile applications is an enabling technology capable of supporting the ubiquitous access to data and integrating the customer and their needs in the product design process. More and more companies are starting to base their business on mobility and on distributed decision making [5, 6] in order to target and reach new markets.

Motivated by the need to support the companies to move towards frugal innovation and design, the proposed work presents a customer-oriented mobile application that provides the ability to configure the customized product using Augmented Reality (AR). In addition to that, the proposed work presents a smart decision-making algorithm for the manufacturing networks design that uses as input the different product configuration provided by potential customers of emerging and developed markets.

2. State of the art

Following the main objectives of the research work, the literature review is clustered into the following topics.

2.1. The frugal innovation concept

The frugal innovation concept aims at introducing new business models in order to reduce the complexity and the total life-cycle costs while providing high value and affordable solutions for customers of emerging and developing markets. [7]. Frugal is defined as: Functional, Robust, User-friendly, Growing, Affordable and Local, and can be found in many industries [8]. There are numerous examples of frugal innovation outcomes in the industrial sector, including cars, refrigerators, as well as power systems [9]. The previously mentioned outcomes are produced by the unique needs of the customers of the different emerging markets. Several research works have already pointed out the importance of frugal innovation and the fact that it can produce sustainable solutions and results [10, 11]. The innovative combination of existing technologies and tools supported by the Information and Communication technology will assist the companies to address the economic, social, and environmental challenges.

2.2. Product Configuration through Web and Mobile applications

Customer integration through mobile applications in the design phase can increase customer satisfaction by considering their needs. Online product configuration has been investigated by Chen in [12], including a web-based software prototype, where household consumers can customize products using linguistic description. A more recent approach for online customization was proposed approximately 8 years later by Chryssolouris [13], presenting a virtual/augmented reality environment for collaborative product review and customization. As a next step, Mourtzis et al. presented an online 3D product personalization, the product being a car [14].

Taking the aforementioned solutions, a step further, customer-oriented apps have been developed and have been reported in literature. The use of the mobile application and the customer integration in the design phase provides the OEMs access to geolocation, user profiles, regional options, and supports them to re-design their products for new markets [15]. In addition to the above, mobile applications supported by AR technology is a novel approach; therefore, only a few consumer-oriented apps supported by AR have been reported in the literature. Common functionalities on this field include visualization of a product from a catalogue in the customer's accommodation (IKEA) [16], fulfilment status and typical visualization of products of a catalogue (Sandvik) [17].

2.3. Manufacturing Networks design and planning

Online product customization and personalization following regional requirements will enable OEMs to easily

and effectively target new markets. OEMs should consider new decision-making and decision support systems for the manufacturing networks design and planning [18] in order to produce new configurations of their product and quickly release them with a low cost to the new markets.

Numerous decision-making systems have been reported in the literature, especially focusing on a mass customization environment. A decision-making method that supported the selection of colour combinations for customized products was proposed in 2007 [19]. Another work conducted in 2005 utilized a Case-based reasoning technique in order to generate an accurate Bill of Material (BoM) that fits in individualized situations [20]. In the field of mass customization, a new approach for decision-making was introduced by Mourtzis [21]. This work introduces an investigation on the performance and viability of centralized and decentralized production networks under heavy product customization. In addition to that, in 2014, an approach for the design of the manufacturing networks for mass customization, using an intelligent search method, was presented [22].

Moving from the era of mass customization to the era of regionalization, a few literature works have been reported. An approach for customer-driven planning and control of global production networks considering regional requirements is presented in [23,24]. Moreover, a decision-making method which utilized a smart search algorithm considering criteria like locality, frugal lead time, as well as production cost and quality was presented in [2]. New criteria that can support the decision-making and can take into account regional requirements were introduced in this work, moving towards frugal innovation.

2.4. Remarks and Contribution

Existing examples of frugal innovation emphasizes the frugalization great potential [25]; nevertheless, industrial applications appear as fragmented and far from being structured. This asks for business approaches, which are able to provide locally adaptable offering, without loses in terms of efficiency, in a systematized manner [26]. To achieve that, new product-services, related advanced ICT and cloud-based tools for supporting frugal innovation should be developed, allowing the co-evolution of products (and services)-processes-production systems, according to localized customers' needs and production sites capabilities [26]. The suggested approach contributes to the research on the field of frugal product customization and design of manufacturing networks. A product configuration application supported by AR technology and capable of capturing the different regional requirements of the different targeted markets is introduced. Following the new product configuration and the possible re-design of the products for a new market, a smart decision-making algorithm is utilized in order to support the design of the new manufacturing networks efficiently and quickly. Addressing the main challenges of designing the appropriate products for each market and selecting the optimum suppliers based on their suitability and availability, the proposed work aims at introducing the smart use of resources in order to move towards frugal innovation.

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