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Self-Aware Smart Products: Systematic Literature Review, Conceptual Design and Prototype Implementation

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Abstract

The fourth industrial revolution makes more effective use of data generated during manufacturing processes and creates a more interconnected manufacturing network. The data stored inside a product can be updated, analyzed and protected throughout its life cycle. It is currently becoming a reality to speed up the modern mass-customization. The aim of this paper is firstly to explore the state of art about smart products through a systematic literature review. Second, to design a self-aware smart product in a smart factory production environment based on the review findings. Finally, to turn the conceptual design into a prototype implementation.

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Keywords: Smart Products; Intelligent Products; Smart Factory; Industrie 4.0; Systematic Literature Review; CPS; IoT; RFID

1. Introduction

The fourth industrial revolution, namely industry 4.0, is commonly recognized as the technical integration of Cyber-Physical System (CPS) [1] into manufacturing and logistics and the use of Internet of Things (IoT) [2] in industrial processes [3]. It is the key to make an interconnected manufacturing industries scenario all around the

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world. More specifically, in which, machines can communicate not only with each other (Machine to Machine or M2M), but also with products [4]. This scenario demands smart products to know themselves [5], namely, self-awareness.

During a product's life cycle, so much data are generated, which, usually, only a small part of them are used for the manual or semi-automatic decision making [6]. However, once certain data could be stored inside the product, which carries them throughout its lifecycle, those decision making processes would be realized, with the support of those data, automatically and also in real-time [7]. With that, machines and products can then really communicate with each other. Meanwhile, customers can also participate in the design, manufacturing or maintenance of their own products by embedding their specific needs, for speeding up the mass-customization.

The main objectives of this paper are (1) to explore the state of the art about smart products and (2) to realize the discovered results as a smart factory prototype. The present paper shows on Section 2 the applied systematic literature review method and its main findings. Based on them, Section 3 firstly provides the conceptual design of a self-aware smart product together with its production environment, and then demonstrates the current results of the prototype implementation. Finally, Section 4 concludes this paper and points out future works.

2. Methods and Findings

2.1. Systematic Literature Review (SLR)

The main research question that the paper intents to address is: *What is a Smart Product?* More specifically, it is subdivided into the following three sub-research questions: (1) *Q1: What is the Evolution of Smart Product Definitions?* (2) *Q2: Which are the Enabling Features of a Smart Product?* (3) *Q3: What are the Existing Smart Product Applications?* In order to more neutrally collect and analyze data in an outcome unpredictable situation [8], this research applied the Systematic Literature Review (SLR) method [9,10] and also followed the principles that outlined in the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) Statement [11].

Firstly, to collect a comprehensive set of papers from the existing literature, the search string was constructed by combining the operator "or" between "*Smart Product*" and its synonym, "*Intelligent Product*". The reference database *Science Direct* was used during the systematic search. All collected papers should satisfy the following four conditions: (1) they were published online before the February of 2017; (2) they contain at least one of the two search terms in their titles, abstracts, or keywords; (3) they were published in journals, conference proceedings or book series; and (4) they were written in the English language.

Second, to ensure that all collected papers could be objectively assessed, Table 1 explicitly lists five main inclusion and exclusion criteria together with their subsets. Based on them, the initial review process was carried out to briefly review the paragraphs where "*Smart Product*" or "*Intelligent Product*" appeared. Besides those papers without full-text to be accessed (*WF* in Table 1), this process aims to exclude those that (1) are not academic (*NA* in Table 1) and (2) are not focusing on the smart or intelligent product research (*LR-1* and *2* in Table 1). After that, all the eligible papers were studied in detail, and organized into the corresponding inclusion categories (*PR* and *CR* in Table 1).

Table 1. Inclusion and exclusion criteria.

I/E	Criteria	Criteria Explanation
Inclusion	Closely Related (**CR**)	It is focusing explicitly and specifically on the research of smart or intelligent products.
	Partially Related (**PR**)	Its focus is not about smart or intelligent products, only part of its contents is related.
Exclusion	Without Full-text (**WF**)	We do not have access to its full text.
	Non-Academic (**NA**)	It is not an academic paper, such as, editorial materials or company profile.
	Loosely Related (**LR**)	It is not focusing on the research of smart or intelligent products and also without definitions. LR-1: Smart or intelligent product are only appeared once, twice or thrice as a cited expression; LR-2: Smart or intelligent product are only used as a part of another noun phase;