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Product-service systems scenarios simulation based on G-DEVS/HLA: Generalized discrete event specification/high level architecture

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ABSTRACT

In the past decade, personal customers expected manufacturing companies to provide them with a physical product with, nonetheless, some basic additional services. Currently, customers expect a more comprehensive solution, integrating both a physical product and non-physical services, which explains why companies have started to propose Product-Service Systems (PSS). The underlying objective of profitability can be attained if the system is designed, based on system use, to avoid waste, and if services are developed jointly with products. Although all the requisite conditions are well-known, the optimal way to satisfy them is not formalized or even guided by any clear methodology. This paper proposes to create PSS models to be simulated in different service scenarios based on G-DEVS/HLA. The simulation results provide pointers to help decision maker choose between several PSS design scenarios to be manufactured. A case study from the toy industry is used to illustrate the proposed methodology.

1. Introduction

The traditional economy, based on the sale of tangible goods, is challenged by the growing interest of customers in product-use rather than exchange value. Manufacturing companies now propose Product-Service Systems to their customers [1]. This trend corresponds to new customer expectations expressed in terms of results: an attachment to product performances rather than to technical conformities. It can also indicate a preference for breakdown prevention rather than breakdown repair and an evolution from quality/price ratio to quality/cost-of-use ratio.

With national differentiation-inducing factors or international competitiveness-inducing factors the addition, or even the replacement, of a product being sold as a service represents for industrial companies a new source of turnover and a customer loyalty lever. Certainly, at the present time, the income generated by the sale of services and PSS sales is higher than that generated by product sales [2]. Nevertheless, the evolution towards new activities implies managerial and organizational developments that are beyond the reach of most SMEs or even some big industrial companies.

In addition to the product sector, the service sector is also challenged. Service providers must permanently adapt their offers to fluctuations and continually innovate to meet customer requirements. Thus, many different services are proposed, regardless of service design and development, which often lead to a certain number of service management difficulties [3]. The introduction of new service activities is, for instance, not guided by any clear methodology. The definition and practical implementation of services can often penalize the companies, especially because finding defects only at late stage can prove very expensive. Service design and manufacturing are nowadays considered a really vital issue. A methodology to systematize those activities and simulate sustainable development: i.e. the economic, ecological and social viability of the solution for both provider and customer, is required. The aim of this article is to contribute to PSS modelling and simulation by using discrete event models and distributed simulation techniques prior to development. Such modelling and simulation is carried out in order to validate the desired properties and to anticipate potential problems within the system. The simulation results give pointers to help decision maker choose between several PSS design scenarios to be developed. A case study from the toy industry illustrates the proposed methodology. In order to propose a simplified model of client behaviour, we have chosen first to study children's toy interest behaviour that has been abstracted from psychological literature and then give one of the first PSS simulations incorporating customer-usage feedback, even that is, for the moment, in a simplified version.

The article is organized as follows. First, we review the PSS literature to present the PSS concepts and requirements. Second,

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we present a PSS business model which companies can use to create value. Next, a PSS G-DEVS/HLA (Generalized Discrete Event Specification/High-Level Architecture) based modelling and simulation framework is detailed. Scenarios based on this approach are subsequently tested on a case study from the toy industry before presenting our conclusions.

2. PSS variants and concepts

The practice for industrial companies to associate products and services in the same offer is not new. Eiglier and Langeard had already introduced the idea of "extended products": i.e. products integrating services such as payment facilities, after-sales service [4]. Equally called complementary, secondary, additional or combined service in the literature [5–9], the different coupling possibilities have evolved and the PSS concept has started to emerge on the market [10,11]. The currently accepted definition describes PSS as "Product(s) and service(s) combined in a system to deliver required user functionality in a way that reduces the impact on the environment" [12] in [3]. There are several variants of PSS: i.e. product-oriented services, use-oriented services and result-oriented services [13] according to the nature of the object being sold to the customer: i.e. respectively, a product, service (product use) or result (result target). Variants are also linked to the sustainability potential of the system [14].

The first aim of PSS is to satisfy users' functional needs and foster customer loyalty through an eco-friendly, individual and personalized offer, as customers are becoming more and more sensitive to environmental issues and to the sustainable aspect of the performance (economic, environmental and societal). The second aim is to enable providers to differentiate themselves from competitors and to respond to the incentive of reducing the environmental impact of their production.

System optimization leads to challenging the traditional economy to satisfy all stakeholders, and thus combines a sustainable solution offer which can be integrated in the functional economy in which business transactions must:

- Focus on the use of a capital good and not on its sale, and
- Exert positive effects on sustainable development by reducing consumption of material and/or energy [15].

Despite government incentives promoting the functional economy [16], and the interest of a product and service co-design to exploit their synergies, in practice industrial developments are product-centric. Services are subsequently developed according to the options proposed. The resulting product-service system is pushed at the customer who is often unable to grasp its fair value and/or appreciate its use. Innovation aimed at increasing customer satisfaction does not find an echo, and company return on investment is negligible. In addition, each system is unique and consequently does not benefit from the experience of previous systems and, moreover consumes new resources each time. To achieve its goal of sustainability, functional economics requires simultaneous consideration of industrial and service activity. Changes intended to combine these two activities are mandatory, as well as breaking with the traditional economy pattern, which is based on selling a product whose obsolescence is planned.

The strategic role played by services has over the years become a key element for companies to distinguish themselves from their competitors. Services are to be considered as mandatory for their contribution to enhancing incomes and profits, since the sale of services is more profitable than that of products; the latter is punctual whereas the former is generally recurrent and more long lasting. In addition, services can also increase profit margins as they favour the development of customer loyalty and differentiation. Consequently, the competitive set depends less on the price: service is combined in a more complex process and its life cycle is in a less mature phase than that of products. This is a real problem for industrial companies, which encounter difficulties in successfully exploiting the financial potential of the associated service offers.

This disability to create value should incite industrial companies to rethink their business model. This leads on to each company learning from its on-ongoing learning experience. Companies go through or have already gone through several stages, from a product manufacturing centric model to an intermediary additional services salesman-centric model and then to a service centric model. This evolution imposes major organizational challenges: the possession of an efficient network and of a specific structure in profit centres dedicated to the service activity. This last point raises the question of the business model associated with the service activity.

3. PSS business model

The concept of a business model, extensively used in the business area since the development of companies on the Internet, has just began to be precisely defined in management literature. All the various definitions agree on the following constituent elements: the offer and implemented resources architecture, the value proposition for the customer, the position of the company in value creation, and the income model. The pillars of a business model able to handle PSS need to integrate:

- the value proposition which is offered on the market: the product/service combination. The value must be defined, calculated and optimized to obtain a competitive advantage
- management of the customer interface: the market segmentation concerned by the value proposition, as well as communication and distribution channels [17]
- management infrastructure: the competences, resources and activities for business model development
- financial aspects: instruments and mechanisms for the business model control

This view of the pillars of a PSS business model is aligned with the Muller-Stewens and Lechner business model proposition. The authors define a PSS Business Model composed of five sub-models [18] in [3]. However, although the objectives of each sub-model are described, the design and development phase of the PSS life cycle are given less attention. The next sub-section presents a general overview of a PSS life cycle-oriented business model.

3.1. Global overview of the business model

The proposed business model is based on a project process and follows the different phases of a project life cycle. The particularity of the project is to provide customers with a high value solution. As such, the design and development of the PSS are the main concerns. The project process is divided into four main phases (Fig. 1). The article does not specifically focus on the PSS use phase as it is considered as orthogonal to project development. Feedback on customer-product uses are obtained during the definition and closing phases. During each phase, operational and support activities are carried out. Operational activities are activities that enable the PSS to evolve from the status of "idea" to that of a system "delivered" and "evaluated" "by customers. These activities ensure that the functional requirements of the PSS fully satisfy customer needs, the influence of the business environment and company profitability. The support activities ensure business process control and profit management during the whole PSS life cycle. The main aspects of those support activities are indicated in Fig. 1.