FROM SMART PRODUCTS TO PRODUCT-SERVICE SYSTEMS: A SERVICE ENGINEERING PERSPECTIVE FROM THE INDUSTRY 4.0

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Abstract— Service Science field presents a paradigm shift that preconize a transition from an economy based on goods exchange to one based on services. Its first impact in production appear in the beginning of this century, pushing organizations toward an innovation through services named as "servitization", followed by a tendency to focus on pure service. However, the influence of this paradigm shift on manufacture industry is studied today by Service Engineering researchers as a hybrid concept of product-service system (PSS), mixing again products and services.
Industry 4.0 have also been a frequently discussed topic among practitioners and academics providing relevant answers to industry new era, called the fourth industrial revolution. They state that systems production and processes are forming a new sophisticated network arrangement supported by internet and combined with intelligent machines. That revolution is guiding manufacturing to reach the concept of smart (virtual) factories producing smart products.
This article briefly reviews and analyzes the emerging coalition between Service Engineering and Industry 4.0 through the relationship between collaborative e-Manufacturing (e-work) and Service Systems co-production model. The aim is to position the Product-Service Architecture proposed by the authors in the context of Internet Factory and Industry 4.0.

Keywords— Service Engineer, Industry 4.0, e-work, digital factory

1 Introduction

During the last decades, practitioners and researchers experienced an evolution on production systems. Driven by new intelligent machines, faster network architectures and multiple ICT devices interconnected through internet can make industry and production to face radical transformations. A substantial increase of operational effectiveness on production value chain is pointing to what some authors call the 4th industrial revolution (Wahlster, 2012; Blanchet et al., 2014; Evans and Annunziata, 2012).

Named by German authors as Industry 4.0 (Blanchet et al., 2014) and, similarly, called Industrial Internet (Evans and Annunziata, 2012) in USA, a next generation of manufacturing systems is envisioned as an infusion of concepts including Internet of Things, Cyber-physical Production Systems, Internet of Services and Smart Factories (Hermann et al., 2015).

Those technologies brings more freedom and flexibility into the production process, growing the focus on innovation to enhance quality and address customer individual needs.

On the other hand, the emergence of Service Science highlight a paradigm shift from the perspective of consumption and value exchange, moving the economy from a good-based exchange to a service based one (Vargo and Lusch, 2006; Lusch et al., 2008).

The impact of service-dominant logic on manufacturing industry lead to the emergence of Service Engineering(Qiu, 2014), focusing on adaptation of traditional engineering approaches to the service sector. That "servitization" process (Schmenner, 2009; Baines, 2015)[1] in manufacture industry calls for more formalized approach in order to offer product-service systems (PSS) that co-create value with customers.

In fact, the combination of Service Engineering and Industry 4.0 can be very fruitful. While Industry 4.0 can propose a flexible and adaptive platform for service manufacturing co-production, the Service Engineering can propose new configurations to transform smart products into product-service offerings, customized and adaptable to a wide range of customers.

To support Industry 4.0 and co-production in manufacturing service we propose the use of Nof's collaborative e-work systems. Based on collaboration between artificial and human agents, and powered by ICT devices, collaborative e-work systems is a framework for design, engineering and control of a network of intelligent and autonomous agents that collaborate together to achieve a goal (Nof et al., 2015; Silva and Nof, 2015a).

On the other hand, to support the transformation of smart products into product-service offers we propose the use of a design discipline using the product-service architecture (PSA) proposed by Silva and Nof (Silva and Silva, 2015). The PSA is an approach that combines several design methods available to information systems

[1] Even if servitization occur in different periods of time with different approach we will refer indistinctly to that based on the common characteristic of mixing product and service approach

with other tools to design plans and schedule. A design discipline using PSA can provide a mix of product-service artifact – that can be composed in a planning/scheduling process to achieve new results and more sophisticated artifacts.

In this paper we propose an analysis of the relationship between Service Engineering and Industry 4.0 through the perspective of collaborative e-work systems and PSA architecture. That relationship analysis can revel new scenarios for service manufacturing and its design principles(Moghaddam et al., 2015).

2 Industry 4.0

The fourth industrial revolution, called industry 4.0, is considered the future paradigm of production. The integration of information network to physical objects, added to the combination of internet with productions systems, have been pointed as evidences of what would be the future scenario of production (Blanchet et al., 2014).

In fact, even if the term is becoming a top priority between researchers and practitioners, its meaning remains blurry (Hermann et al., 2015) as well as several others terms as Cyber-physical Systems, Market-place, smart robots and machines, Big Data, virtual industrialization, and so on (Blanchet et al., 2014).

In his literature review, Hermann (Hermann et al., 2015), points for a definition considering four components: Cyber-physical systems (CPS), Internet of Things (IoT), Internet of Services (IS) and Smart Factories (SF).

Therefore, Hermann defines Industry 4.0 as follows:

> Within the modular structured Smart Factories of Industry 4.0, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and humans in real time. Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain.

In fact, that Industry 4.0 vision is more concerned with how production system will operate than with the solution that it is conceiving for a customer.

3 Service Engineering

Through a Manufacturing Engineering viewpoint, the Service-logic influence started to gain importance since "servitization" term made it incursion in the Manufacturing field at the end of the 80's (Schmenner, 2009). In fact, manufacturing movement to services is "mainly motivated by a continuous strive to create new sources of value for the company" (Cavalieri and Pezzotta, 2012). That approach, seen as an strategic shift, aims a closer relationship between the manufacturer and the customer, pushing the production system to offer better solutions to meet the customer's needs. However, in the mid-1990s, an evident lack of research with more systematic approaches boosted the emergence of Service Engineering field.

In fact, the first research initiatives on Service Engineering started in Germany (Aurich et al., 2010) and Israel (Cavalieri and Pezzotta, 2012). Nevertheless, Japanese manufacturing researchers also followed the incursion of Service Design in manufacturing some years after (Tomiyama, 2001).

Sakao (Sakao et al., 2009), defines Service Engineering as follows:

> In (Service Engineer), however, not only the functions of artifacts but also the meaning of contents must be matched to the specifications given by receivers; only then will the satisfaction level of receivers increase. (...) The critical concept in (Service Engineer) is not the function of a product, but rather the state change of the receiver.

That is, Service Engineering, from a manufacturing viewpoint is more concerned to the engineer solution, and how it satisfies customers needs, than the infrastructure to produce it.

4 Collaborative e-work

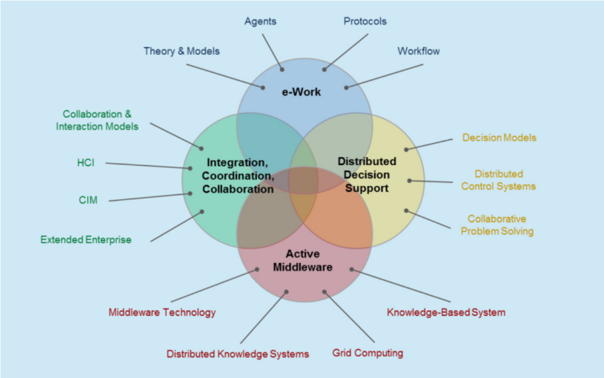
Collaborative e-Work is a framework for design, engineering, and control of next-generation manufacturing systems that has been developed over the past decade. It is based on the idea of collaborative, computer supported and communication-enabled productive activities (Nof et al., 2015).

Nof, proposes e-work framework as the bases of e-production, e-services, e-manufacturing, e-logistics that supports v-(virtual) Factories and v-Enterprises. In fact, the term "e" refers to all activities performed based and executed through ICTs (Information and Communication Technologies).

That framework is formed by four wheels (see Fig. 1) (Nof et al., 2015) that represents knowledge clusters that encompass collaborative ework: (i) ework, (ii) Distributed Decision Support, (iii) Active Middleware and (iv) Integration, Coordination and Collaboration.

In fact, e-Work theory and models provide foundations for augmenting abilities of organizations and all agents (human, computer, robot,

Figure 1: The four wheels of collaborative e-work



etc.) to interact and collaborate through certain protocols, in order to accomplish their goals.

The proposal of collaborative e-work systems appears as as important concept that supports Industry 4.0 and that could form a basic framework to produce product-service systems (PSS), the main design object of Service Engineering.

5 Service Systems

Since IBM's call of action, in 2004, and their investment in the Service Science, Management and Engineer (SSME) initiative, a search for a more formal definition of Service Systems reached new levels between researchers and practitioners. Our proposition is based on the idea that Service Systems are systems that apply for (value) co-creation, co-production and co-design characteristics (Silva, 2014; Dutra et al., 2013; Dutra et al., 2014).

Value co-creation is the main goal of services systems and guide its process to create value for another entity (service consumer). It is a dynamic process that involves perception of value and customer's intention, notions that are difficult to predict and embed on the system. That intensive customer interaction represents the main Service System characteristic (Vargo and Lusch, 2010).

The service providers and service consumers can be people, technology, groups of people or groups of people and technologies. The inputs given by the service customer can be information (language, laws, measures, methods), knowledge or even other service systems (i.e. people, technology, groups of people or groups of people and technologies) (Maglio, 2009).

Service provider internal organization can have other service systems (including also people and organizations external to the service provider control) (Stanicek, 2009). This internal relationship must reach a synchronization of supply and production simultaneously with the service consumer engagement. That characteristic of Service System is what we call co-production.

Lastly, co-design characteristic of Service Systems represents a dynamic process with intense participation of customer and internal entities to create new services or evolve existing ones through service life cycle.

Therefore, basically Industry 4.0 proposes is more related to co-productions process while Service Engineer focus on the value co-creation process. That implies in different focuses and propositions, one connected to manufacturing architectures to support to modularity, flexibility and uncertainty, other connected to architectures and frameworks for conceiving product-service systems that co-create value with customers.

6 PSA: Product-Service Architecture

The role of decentralization has been also studied in Industry 4.0 perspective (Brettel et al., 2014). In a previous work Silva and Nof(Silva and Nof, 2015b) proposed a distributed architecture where manufacturing service is defined an open set of production unities (which could deliver products, services, or even product/services) which could be independent or commercially connected to the same corporation. This production arrangement could provide a product/service once a workflow and a coordination is defined to this set. The workflow defines exchange of information service or components while the coordination is defined as a plan to deliver service, information or components (or a combination of them) in a established sequence and or time. That is the work could be ordered (planned) or follow a time schedule to provide the deliverable product/service.

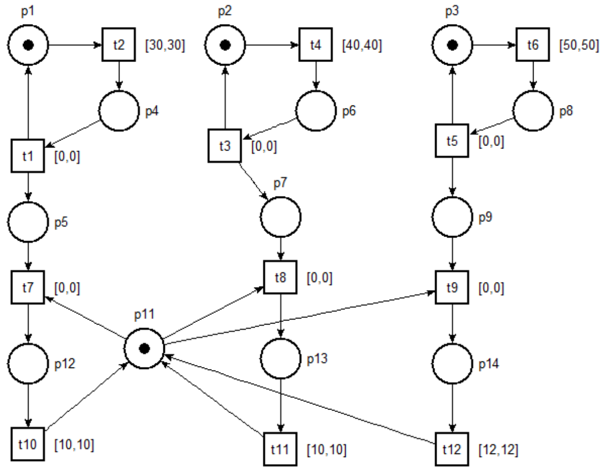
Formally, the production arrangement could be represented by a set of objects $\gamma = \sigma_i$ where each unity σ_i produces an artifact (product, service or both) α_i. The whole arrangement is transition system where each state is defined as a distributed composition of the state of each unit with the amount of final deliverable artifact already produced and delivered. This generic arrangement could be represented by a Petri Net.

Eventually the combination would depend on time and the generic system could temporized - if the production (service) time is fixed and constant - or timed, where the production time is represented by a closed interval $[t_min, t_max]$ where t_min is the minimum time production could be launched and t_max the late time it could be delivered. That would lead to representation using Time Petri Nets. In such a case, model checking could be used to check properties and to model the synchronization of periodic production cycles.

The possibility of using model checking to schedule production process was already explained by del Foyo and Silva (Silva, 2014), and an example with three processes can be seen on Figure 2.

The modeling of the production arrangements described above could be done using a Petri Net environment called GHENeSys (General Hierarchical Enhanced Net System)(Silva and del Foyo, 2009), where model checking verification can also be performed.

Figure 2: Three periodic processes to be synchronized.

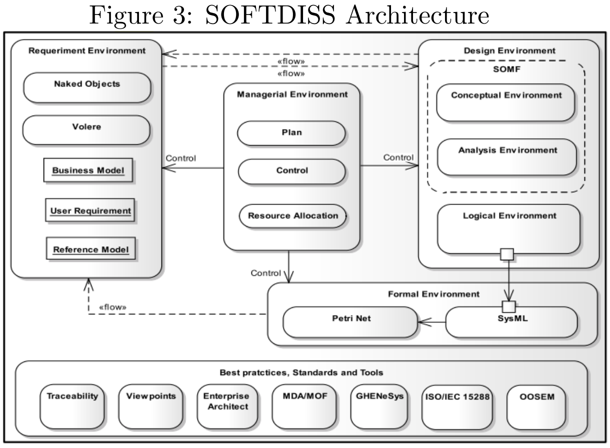


However, a requirement analysis of the manufacturing service could not be performed directly on the net system if the production set is not specified. In order to specify a production set based on the requirements or the product/service delivered to the costumer we should define a design discipline a use other kink of software support.

7 Design discipline using PSA

The architecture PSA (product-service architecture) was proposed by (Silva and Nof, 2015a) as a combination of the collaborative e-work framework and a service framework that congregates available and recent design methods and tools, called SoftDiss System (Fig. 3).

Figure 3: SOFTDISS Architecture

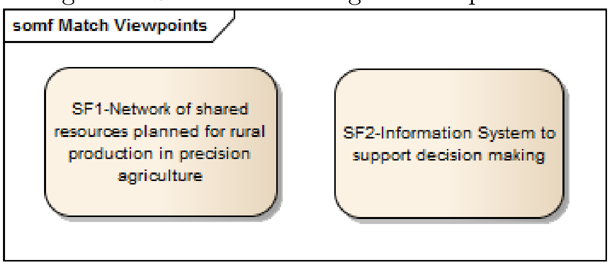


The key point that emerges from several works is that the best way to model process services is using graphs or some derived formal representation of workflow, including Petri Nets.

PSA points for a combination of AI methods (planning and scheduling) with e-work and SoftDISS service architecture to produce a consistent design discipline to not just create the platform for a new modular and flexible manufacturing production but also to support a new designs for product-services systems into manufacturing industry.

Fig 3 shows a framework developed inside the package Enterprise Architect to design services in general(Dutra et al., 2014). Using this system we have a systematic approach to the design of service, or even to evaluate, based on multiple viewpoints, what would be the better service to a specific situation. We will revisit a short application were the situation was exactly the inquire of what would be the best solution to fit the viewpoints of rural producers, a huge corporation that produces agricultural machines and the situation of small partners that today use a franchise to sell machines and give support to producers.

Figure 4: Services matching the viewpoints



Using SoftDISS we found that the best service, the one that better fit the viewpoints was the one represented in Figure 4. Actually, the producer wants to have the service of a machine instead of purchasing it. The manufacturer could have a different job where machines could be produced in the proper amount of demand eliminating stocks. Also the production could be modeled as a real-time system - as describe above - to maximize profit using a distributed manufacturing service. To partners the real business would be to have a network of direct service that intermediate the business between manufacturer and final user, taking care of maintenance.

Therefore, we could revisit the same example proposing now that it could be implemented as a production set composed of two manufacturing facilities and a network of partners strategically planted to serve the rural producer.

The example is quite intuitive and show the potential of the PSA architecture even if not applied to a classic manufacturing problem. A good example - which no fit in a six page papers - is the one of designing a manufacturing service arrangement to produce special notebooks to fit its use in manufacturing processes that demand equipment with capacity of dealing with images, short messages, etc. while submitted to magnetic fields. However we do not have a final result for this problem yet.

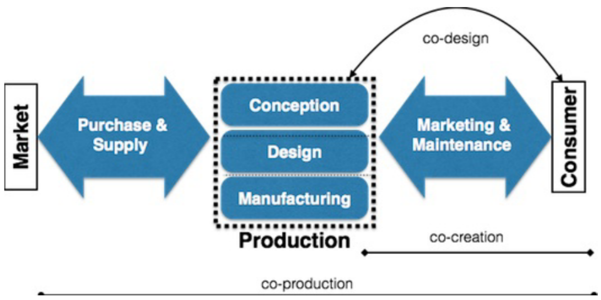
8 Fitting Industry 4.0

Industry 4.0 open the opportunity to compose processes were collaboration is enhanced between man and machine, with the consequence that each human agent is empowered with (machine) resources to improve work. The supervision and general control would now be done by cyber-physical systems. It is also understood that a complete rupture with production line is behind the architectures being considered.

For such a system it is not expected to still cope with waste of material, or to produce goods or services to which there is no costumer. That is, beside being integrated with the supply chain, the production arrangement should also be integrated with costumers. That means to fit a more specific set of requirements extracted from costumer feedback and co-design or mix a set of different viewpoints, as the example shown above.

Anyway we should have a flexible production architecture to fill the gap the appear after a real rupture with the production line that is typically product oriented and dominate the scene during the XXth century.

Figure 5: From production line to a virtual network arrangement



As shown in Figure 5 the new architecture should fit the requirements of the new production strategy: i) which suppose complete integration with suppliers, composing a co-production process (which also involves the user); ii) that work with user viewpoints in co-design, to adjust requirements or to even create new products/services; ii) that fit the need to include the proper issues to enhance value co-creation with the costumer.

Finally all this features should be controlled and supervised using a collaborative e-work system from which depend the proper delivery of new services to the right user.

We claim that so far Industry 4.0 preserves to much a good-oriented flavor even if working in the edge of new technology applied to manufacturing. Inserting a PSA architecture could open a new line of work and also state it clear the need of a general e-work system. Curiously, the example just showed conclude the same thing, based on a new production architecture and a e-system, even if it is not exactly a 4.0 industry. That raises a clue that we are fitting not only a technological enhancement of the manufacturing process but a new conceptual approach.

9 Conclusions

In fact, thinking about just Industry 4.0 leads to an smart product production systems, what means not only intelligent devices that interact and communicate with customers, but new approaches to the production process that leave behind the linear (product-dominant) approach. In this new approach it is necessary to deal with value co-creation, integrated to co-production and co-design, otherwise the new relationship with the costumer will not be reached.

It is also necessary to have a good view and control of this full interactive production environment which lead to e-works proposal of collaboration between customers and systems, as well as with all agents involved in the process. That is why a Service Engineering perspective is required to complement the first production view.

PSA architecture is still in development, specially including more cognitive aspects on its models, however an framework aggregation guided by a design discipline that encompass the whole view can be extremely powerful to support the creation of the next manufacturing revolution.

Acknowledge

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