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Procedia CIRP 83 (2019) 8–13

www.elsevier.com/locate/procedia

11th CIRP Conference on Industrial Product-Service Systems, IPS^2 2019, 29-31 May 2019, Zhuhai & Hong Kong, China

Integrating Product-Service Systems into the manufacturing industry: Industry 4.0 perspectives

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Abstract

Industry 4.0 is the current trend in the technologies used in exchange of data in manufacturing. Product-service system is a concept that provides self-aware and self-learning machines, and consequently improve overall performance and maintenance management. Companies continually strive to increase production, but in recent years, the effects of this effort have demonstrated that provision of products alone with less resilient technology-enabled service industry is insufficient to remain competitive. The importance of leveraging flexibility and capabilities offered by cloud computing is inevitable, but adapting prognostics and health management algorithms to efficiently implement current data management technologies was research and develop in this study. In this paper, we present an integrated product-service system as a potential concept from a life-cycle perspective to reduce disruption, costs and associated services such as autonomous maintenance, through exchange of data to understand equipment degradation using sensors application, to aid timely services intervention for manufacturing processes transformation. The results is the knowledge base servitude backed by machine clusters generated data for different working conditions to improve operational efficiency using Cloud IoT to connect, process, store, and analyse data on the dashboard, locally and in the cloud for future health assessment.

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Industrial Product-Service Systems

Keywords: Integrating Product Service Ssytem; Cyber Physical System; Industry 4.0; Internet of Things

1. Introduction

The continued development of infrastructure is critical to ensuring economic growth and jobs creation for many unemployed people. The traditional business model requires obtaining raw material, components, and converting them into a product through a manufacturing processes, and assembly them until the sales stage. The transfer of ownership happens at the sales stage, where the customer takes ownership of the product. The complexity of such a system require that all stakeholders involved in the system collaborate for value creation. Service innovation involves using service information to selling a product, while Product-service systems requires data management and distribution in Big Data environment for achieving self-aware and self-learning machines. The products service system creates relationship amongst valued stakeholders, while the threats to transform the economy and reinvigorate the manufacturing industry due to emerging markets and global manufacturing supply chain has prompted organizations to enhance their product service systems. In the manufacturing, the transformation from today's status into more intelligent machines requires further advancement in the field by tackling several fundamental issues, while manufacturing companies make quality products as well as improve service by utilizing service knowledge from similar products to improve the design and manufacturing of the new products with associated services such as autonomous maintenance. Industry 4.0 involves the

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Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Industrial Product-Service Systems.
10.1016/j.procir.2019.03.147

use of digital transformation in Big Data/Analytics, Internet of Things, and Robotics, to realize connected factories, smart decentralized manufacturing and the digital supply chain.

Cyber-Physical System (CPS) is an open system, which composed of cyber and physical parts [1] and belong to system that fit a wide class of generic systems, with smart products, intelligent systems, complex and adaptive systems. The future industry will be able to achieve a fleet-wide information system that helps machines to be self-aware and actively prevents potential performance issues [2]. CPS services are partly autonomous, multimodal and multifunctional, networked and distributed along the application area, which are adapted to current systems requirements and independent from location [3, 4].

The autonomous computing methodology has be successfully implemented in computer science with the use of self-learning machines, but still far from implementation in the current industries. The emergence of sensing technology in the developments of IOT framework have created a unified information that tightly connects humans and systems together to populates a big data environment with more advanced analytics in the advent of cloud computing [2]. The importance of leveraging flexibility and capabilities offered by cloud computing is inevitable, but adapting prognostics and health management algorithms to efficiently implement current data management technologies prompted this research.

The offering of integrated products and services as an effective strategy for meeting varied and rapidly changing customer needs with more value creation for the customers according to [5] is also a matter of concern for both manufacturers and service providers. The need for companies to offer fuller market packages or bundles of customer-focused combinations of goods, services, support, self-service and knowledge is termed as manufacturing servitization, an innovation of organizational capabilities and processes, from product sales to integrated product services [6]. The work of [7] on Product-Service Systems (PSS) across Life Cycle Novel Tools for PSS reveals that tools to support effective engineering of services around such products are still missing. The speed of computation, ease of deployment and investment cost, on an integrated predictive analytics, and visualization platform [8] can increase the drivers for change within the industry and thereby increase cost efficiency and quality from a life-cycle perspective [9,10]. The transmission elements for Integrating Product-Service Systems process into the manufacturing industry in Figure 1, involve the product life cycle through a service of product embedded sensor elements, through data processing and transmission communicating via IoT for product health assessment, compare, prediction, user relationship mining and clustering, with informed decisions to the manufacturing processes.

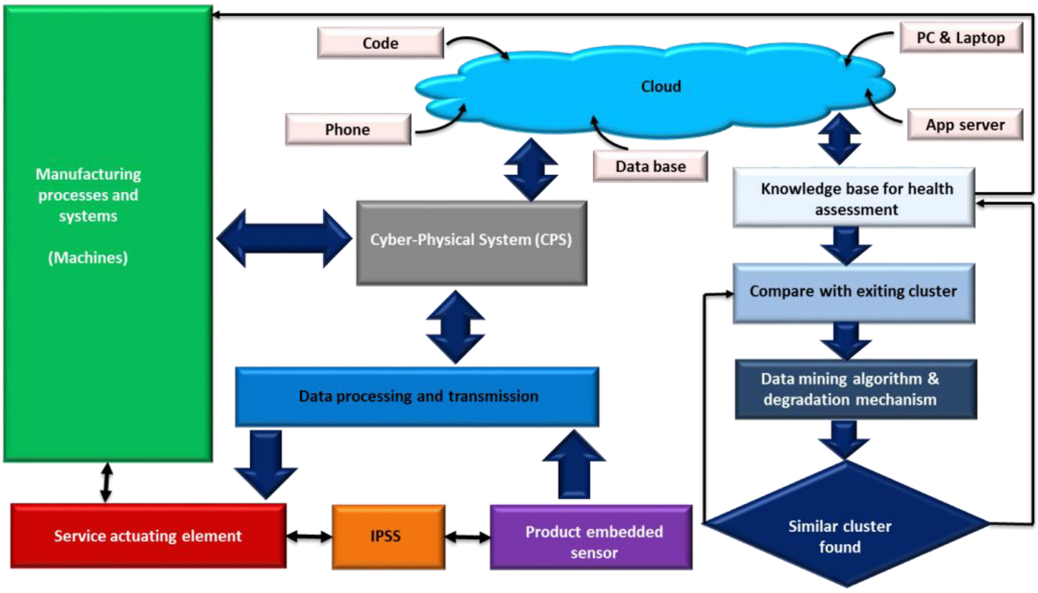

Fig. 1. Transmission elements for Integrating Product-Service Systems process into the manufacturing industry

In this paper, we present an integrated product-service system as a potential concept from a life-cycle perspective to reduce disruption, costs and associated services such as autonomous maintenance, through exchange of data to understand equipment degradation using sensors application, to aid timely services intervention for manufacturing processes transformation. The paper is organize as follows: Section 2 focuses on evaluation of current technology; Section 3 describes the Product Service System transformation. Section 4 presents Integrated Product Service Systems Methodology, Design and Operating mechanism; and Section 5 present the results of the Back end coding and Dashboard for sensor Integrated Product-Service for data analytics and Section 6 is the concludes the paper with some perspectives. The aim of the integrated products service system is to create a manufacturing system that produces quality products, aid by timely services intervention using interconnected systems and intelligent data analysis for factory transformation and production management at the best possible time to predict failure therefore reduce disruption, costs and associated services such as maintenance. The system is customer focus by combining products, services, support and knowledge.

2. Evaluation of current technology

2.1 Dedicated manufacturing systems limitations

Dedicated manufacturing systems are single purpose machines; they focus on producing of a particular product. Their advantage is high production volumes and production cost reduction. This type of applicable machine technologies cannot do a product mix, time consuming, costly and have to change for different products. In the evolving Industry 4.0 era, intelligent analytics and cyber-physical systems are teaming together to realize a new thinking of production management and factory transformation. Companies have realized that dedicated systems use in producing more products are not desire enough to remain competitive.

2.2 Flexible manufacturing system limitations

A flexible manufacturing system consists of computer numerically controlled machine tools, which is a system that provide flexibility to manufacturing so that a variety of parts can be produce when there is a demand in the market. These type of manufacturing systems are very expensive due to extra design flexibility and capacity. They are complex and require skilled workers that were train to operate the system. The software and hardware being use cannot be change when there is a demand and these makes these systems irrelevant [11]. They cannot support the actual processing of big data into useful information, which is key to the sustainable innovation within an Industry 4.0 factory. The product development process interlinked with supporting services through a cyber-physical system, which enables the extraction of useful data for maintenance and related activities.

2.3 Reconfigurable manufacturing systems

The ability of a company to start new product models quickly and the potential for rapid alteration of manufacturing system capacity is becoming important in today's economy. Reconfigurable manufacturing systems (RMS) are widely consider as one of the promising key technologies to enable responsiveness to the new production era, known as mass customization. In order for companies to remain competitive in the unpredictable and changing market conditions, flexibility must be combine with responsiveness, high reliability, scalability, ability for easy software and cost efficiency [12, 13]. The developments of an Internet of Things (IOT) framework and the emergence of sensing technology have created a unified information grid that tightly connects systems and humans together, which further populates a big data environment in the industry. There is more advanced analytics with the advent of cloud computing and a Cyber-Physical Systems (CPS) framework. Future industry will be able to achieve an information system that helps machines to be self-aware and actively prevents potential performance issues.

3. Product Service System transformation

2.1. The Product Service System originated in north of Europe at the end of the 1990s. The number of PSS publications has grown over the years, but many researchers discussed this concept in such a different terms as "servitization", "dematerialization", "service design", and "sustainability", among others. The concept of the PSS as an attempt that has been made to identify all the following terminology such as "service design", "service economy system solution", "remanufacturing", "functional economy" and "product substituting service" [14]. However, the term used most often (in almost half of the searched articles) was "product-service system" obviously, it is important to consider this as the main keyword in this area. Increasingly, companies are displacing solely tangible products with products based on services. The trend intend to add value to a business [15], because services are dominating the market, businesses and researchers must develop tools that consider service operation [16]. The key elements of the PSS are: (i) the product; (ii) the service, in which an activity is perform without the need for a tangible good or without the need for the system; (iii) and the combination of products, services, and their relationships. The prevailing tools used in solving the manufacturing challenges are simulation, modelling and agents. Inferentially, the trend of proffering solutions to complex and most challenging manufacturing problems has been between the uses of multi-agents systems to controls, process plan, enterprise integration and scheduling [17]. Transformation from today's status into more intelligent machines requires further advancement in the science by tackling several fundamental issues, divided into five distinct categories according to [2]:

3.1 Manager and operator interaction

The operator operates the machines within the company while the manager is responsible for designing logistics schedules for operators and machines. The decision on the health condition of the machine components is significantly important factor in communicating the failure on machines by the operators to managers. The product service systems exploits this gap, while the invisible issues in an industrial factory around the information generation algorithm will be design to detect and address machine degradation, component wear on the factory floor.

3.2 Machine fleet

It is extremely important that similar or identical machines are being expose to completely different working conditions for different tasks. Health management methods are not taking advantage of considering these identical machines as a fleet by gathering worthwhile knowledge from different instances. An adaptive but yet powerful methodology is required to manage, categorize and process data for further analysis by prognostic health management algorithms. Machines that have similar operating mechanism can be exposed to different working conditions, data can be extracted from both instances and conclusions can be drawn from the data. The data can be analysed for better understanding of health condition.

3.3 Product and process

Product Quality (PQ) can provide feedback for system management, used to improve production scheduling. The feedback loops used for monitoring quality are unavailable and need further research. The feedback loops are prognostic health management analytical engine that can capture those failure signatures from various assets (machines) to refine its failure detection and estimation capabilities.

3.4 Big data and cloud

The importance of leveraging additional flexibility and capabilities offered by cloud computing is inevitable but adapting prognostics and health management algorithm to efficiently implement current data management technologies requires further research and development. There are various data sources available to provide worthwhile information about different aspects of the factory. In the product development stage, the utilization of data for understanding the current condition and detect faults and failures is an important topic to research.

3.5 Sensor and controller network

Sensor failure and degradation may send an inaccurate reading to decision-making algorithm, which will result in an incorrect outcome. Most prognostic health management methods have access to target only asset data. Asset data might contain hundreds of sensory and system data readings and provide good insight and prognostics results for the current asset. However, there are much more sources of information that are not considered in today's implementation of prognostics management methods. Peer-to-peer evaluation through fleet of assets, life-cycle historical data from identical assets and system configuration are few examples of the huge portion of data that is ignore by now.

4. Integrated Product Service Systems Methodology, Design and Operating mechanism

4.1 Integrated Product Service Systems Methodology

Intelligent analytics and cyber-physical systems are teaming together to realize a new thinking of production management and factory transformation. Industries are generating big data, which require effective processing into useful information for sustainable innovation within an industry 4.0 environment. The cloud technology form the core of the integrated product service system, they are

1. Infrastructure as a service (IaaS), which forms the server storage network consisting of data centers, hardware, virtual server space, bandwidth and cloud hosting.
2. Platform as a service (PaaS), which involves the manufacturing software, network access, database, security, scripting, and hosting, which is the physical environment that involves the end user using a packaged software operating system and application developer.
3. Software as a service (Saas) is the access on the cloud through a packaged software, iOS, mobile computer and cellphone, while the application has a specific kind of coding and server customized to each product manufacturer according to their need. Security access could be through the private cloud, public cloud, and hybrid cloud. Information extract from the production application process to establish a knowledge base and related algorithm to represent machine degradation and performance behaviour in the physical world. Integration of the internet and product users' core will be enhance. Figure 1 illustrates the traditional product development and support services interacts with internet of things (IOTs), and transmission elements.

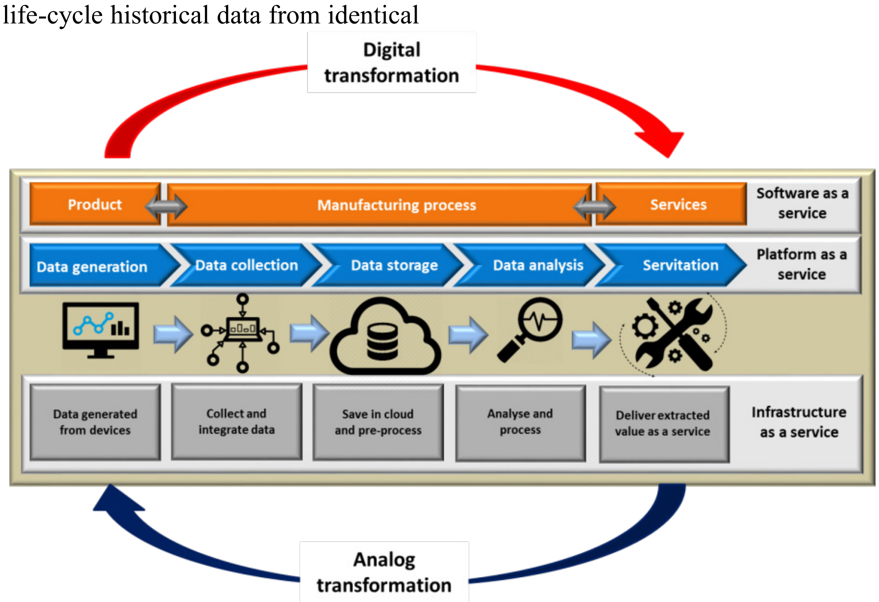

Fig. 2: Integrated Product and service metal model component

4.2 Integrated Product Service Design and Operating mechanism

A self-aware and self-maintained machine that self-assess its own degradation and health, exchange data to understand product degradation through embedded sensor application to aid timely services intervention using interconnected systems and intelligent data analysis for factory transformation and production management. The sensor network pick up the data in form of current, voltage, resistance, temperature, transferred information via wireless or through Internet of Things (IoT) [12] gateway method, it allow communication of various webs application at the best possible time to predict failure therefore reduce disruption, and costs..

The raw data is transform into useful information in cross-platform development that allow Android and iOS (information operation systems), to use the same code across React Native Framework (Real Time Communication for IoT) with Firebase, which is NoSQL (Non Structured Query Language) database to store data in JSON (JavaScript Object Notation) for easy application to access and store data seamlessly. Communication between the Android and IOS is done and implemented by a common communication medium HTTP (Hyper Text Transfer Protocol) and FTP (File Transfer protocol), to communicate between the device with a bit complex software for a simple application. Google firebase, which use NoSQL as an intermediate communication medium between for IoT devices using the powerful real-time database and application programmable interface (API). This application use Visual Code as Code Editor, Android Studio for running the emulator, NodeJs (open-source, cross-platform JavaScript run-time environment) for running the server, with the hardware platform for Arduino IDE (integrated development environment).

Figure 2 is the IPSS metal model component for implementation platform, which uses analogue and digital information transformation from peers for smart maintenance decisions to handle machine health information issues that is required for the knowledge base to provide health assessment; compare information with generated data with its clusters through data mining techniques and prediction algorithm.

5. Results of the Back end coding and Dashboard for sensor Integrated Product-Service for data analytics

The knowledge base servitude backed by machine clusters generated data for different working conditions to improve operational efficiency using Cloud IoT to connect, process, store, and analyse data on the dashboard, locally and in the cloud for future health assessment. The platform pull data from the database for display and push data to the cloud database. The database connect to firebase using Firebase Database Class for information networking to analyse and model Energy Efficiency for manufacturing in the context of industry 4.0 as presented by [18], and described in metal model shown in figure 3 and 4, with servitation components in data analytics in this context. The concretization of the three levels of abstraction in product-services for manufacturing industry communicate the need for established health assessment on products through the embedded sensory devices to the manufacturing processes for adjustment on the products design for market competiveness and inform the service centers of the failure autonomously for relative action. Product-Service components are model separately by function models, and a model of working principles for processes and resources linked by infrastructure in the coupling between the elements. The codes provides out-of-the-box support for devices to trigger automatic changes based on real-time events using Real Time Communication for IoT.

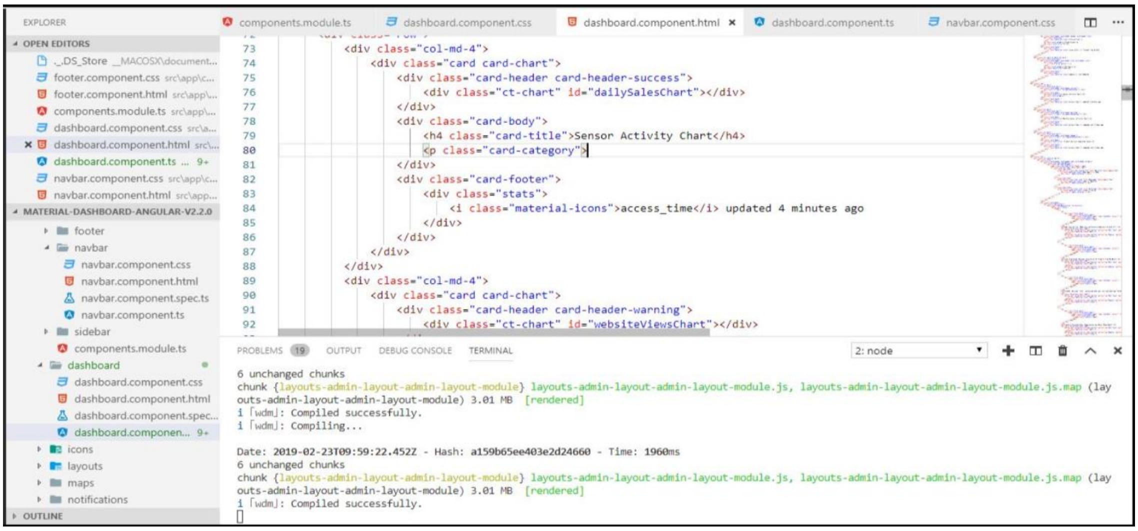

Fig. 3. Back end coding for sensor Integrated Product-Service for data analytics

6. Conclusion

The concept and applications of the IPSS have remained rather fixed, while the business models of the IPSS frequently emphasize its economic aspects, the integration or method of integration is research in this dichotomy. It enables managers to plan an integrated PSS according to their goal and competitive position. In future studies, researchers should delve into the environmental and social aspects of IPSS, because they act as the main barriers to achieving a wholly successful PSS. This research contribute to management practice; as a taxonomy, that allows classification of systematics and engineering. The manufacturing industries is moving towards Industry 4.0 with the notion that it is not enough just to sell products and improve profitability. The real impact on profitability comes from exploiting downstream opportunities by providing the customer with access to newer business models like the product-service system. The paper propose self-aware and self-maintenance for products to offer a better service system, an approach driven by a task model processes for embedded sensor in real-time systems to support reactive control processing. The approach emphasizes the importance of customer's early participation in the design process for increased value creation.

Acknowledgements

The authors sincere acknowledged the support of Tshwane University of Technology (TUT), Gibela Rail Transport Consortium (GTRC) and Innovative Manufacturing Design Solution Group (IMSDG) research team.

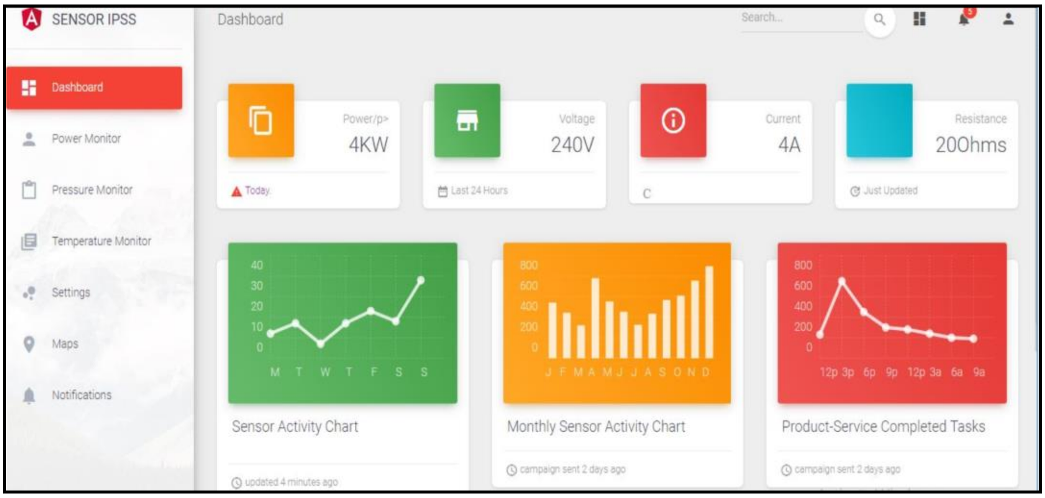

Fig. 4. Dashboard for sensor Integrated Product-Service for data analytic

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