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DIGITAL TWIN USAGE FOR SERVICES

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Abstract. *As corporate goal is evolving towards servitization and socialization, service plays a more important role in order to gain competitive advantage. The application of digital twin can be extended from the monitoring and control of product to service and servitization during the product life cycle management point of view. Through services, each area of the digital twin can be used and shared as 'pay-as-you-use' manner. In this paper, the extended domain of digital twin application in service is reviewed and reference model is proposed. Then, a simple use case for service domain is presented. For the application area, the service of blood donation process is adopted and IoT-based device is developed used for the blood collection device.*

Keywords: Digital twin, Digital twin services, Internet of Things (IoT), Blood collection process

1. **Introduction.** Since the idea of digital twin has been proposed as a conceptual model underlying Product Lifecycle Management (PLM) in 2002, companies are applying digital twin in a variety of areas and ways. The application areas are automotive, aircraft, energy sector, health care, and smart-city management to name a few [1].

Digital twin refers to a digital replica of physical assets, processes and systems that can be used for various purposes. The digital twin concept model contains three main parts: a) physical products in real space, b) virtual products in virtual space, and c) the connections of data and information that ties the virtual and real products together [2].

The digital twin may enable companies to solve physical issues faster by detecting them sooner, predict outcomes to a much higher degree of accuracy, design and build better products, and, ultimately, better serve their customers. With this type of smart architecture design, companies may realize value and benefits iteratively and faster than ever before [3].

On the physical side, we now collect more and more data from the machines and processes that perform operations on the physical part to understand exactly what operations, at what speeds and forces are applied. On the virtual side, numerous methodologies have been developed to simulate and visualize the product and processes with the technologies of sensor network, IoT and big data analytics [4].

Even the digital twin has been proposed in the PLM area in the beginning, its applications have focused on the product control and monitoring by matching the physical and cyber world until now. Recently, more companies put emphasis on the product service, its life cycle, and servitization for digital twin application domain.

The digital twin applied in the service domain can provide decision support and technical feedback, integrate various technologies, improve current practice and support optimization along the system's life cycle. The outcome might include multiplied asset's value and automated decision support via feedback of control and optimization.

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The purpose of this research is to propose digital twin model for product service and servitization as-a-service system. For this purpose, the state of the art for this area is reviewed and simple use case in the service area is presented. This paper is composed as follows. Section 2 addresses recent research directions of digital twin and its application in the service area. Section 3 presents the methods and framework for digital twin service model. Section 4 demonstrates the implementation use case in the area of 'blood give' domain. Section 5 summarizes result and conclusions.

2. **Literature Review.** Digital twin was identified as one of the top 10 technology trends of 2017 by Gartner group [5]. The idea of digital twin was that when designing and manufacturing a physical system, a virtual copy should be produced and live alongside it, mirroring the physical system throughout the life-cycle.

Grieves and Vickers further introduced a taxonomy of digital twin, which is paraphrased below [6]:

- Digital Twin Prototype (DTP): Containing the informational sets necessary to describe and produce a physical version.
- Digital Twin Instance (DTI): Linked to a specific physical asset, containing information about that asset and its history, captured from sensors, tests, inspections and so on.
- Digital Twin Aggregate (DTA): A computing construct that has access to all DTIs, i.e., an aggregate of a collection of DTIs.
- Digital Twin Environment (DTE): An integrated, multi-domain physics application space for operating on digital twins., i.e., interrogation of DTIs for current and past states, and prediction of the future behaviour and performance of physical products under various scenarios using their DTI (and possibly DTA).

Cabos and Rostock [7] proposed that a digital twin was constituted by three basic components, which are a digital representation of the object, behavioral models and the configuration or condition of the system.

During the last decade, the digital twin has been adopted in wide areas due to the following reasons [1]:

- Simulation: Simulation tool's capability improves in power and sophistication.
- New sources of data: Data from real-time asset monitoring technologies can be incorporated in the digital twin simulation.
- Interoperability: IoT sensor data and operational technologies can be integrated with diverse platform.
- Visualization: 3D, VR, AR-based, AI-based visualization and real-time streaming is available.
- Instrumentation: Embedded and external IoT sensors are becoming smaller, more accurate, cheaper and more powerful.
- Platform: Global giant SW companies provide cloud-based platforms, IoT, and analytics capabilities.

For the application of digital twin for the product service and servitization, recent review paper has analyzed 59 papers during 2016-2019. In the survey, three types of digital twin in data integration are suggested. They are digital model, digital shadow and digital twin. In the digital model, both data flow from physical object to digital object and data flow from digital object to physical object are manual. In the digital shadow, data flow from physical to digital is automatic, but data flow from digital to physical is manual. In the digital twin, data flow is automatic in both directions [4].

More attention has been paid to the service area of digital twin application. In view of the concept of Everything-as-a-Service (XaaS), services could fully release the potential of digital twin. Through services, each component of the digital twin can be shared and used in a convenient "pay-as-you-go" manner. In order to implement smart manufacturing, three-level digital twin is proposed: unit level, system level and SoS (System of System) level. For the machine tool operation, servitization model is proposed by service encapsulation based on XML [8].

One good IoT application for service domain can be found in Pongswatd et al. [9]. Coffee vending machine should always be in good operating condition, which needs real time monitoring and control for the system. IoT-based technique to enhance the remote monitoring and control capabilities for the franchise coffee vending machine is presented.

3. **Methods.** With the rapid development of ICT, network and sensor technologies, there is high demand in the realization of smart system in the industry and business process. However, the real situation is far behind for the implementation of smart system in the real-life environment because the real system is based on the physical world with many real and physical constraints.

The optimized smart system can increase yield, uptime, quality, as well as reduce costs and waste. A transparent network can enable greater visibility across the facility and ensure that the organization can make more accurate decisions by real-time alerts and notifications, and real-time tracking and monitoring. The proactive features enable advanced identifying and warning of anomalies, quality issues, safety and maintenance concerns. Self-adaptation to schedule and product changes is available by agile features. Figure 1 represents a typical digital twin architecture composed of physical thing, cyber thing and physical instantiation [10].

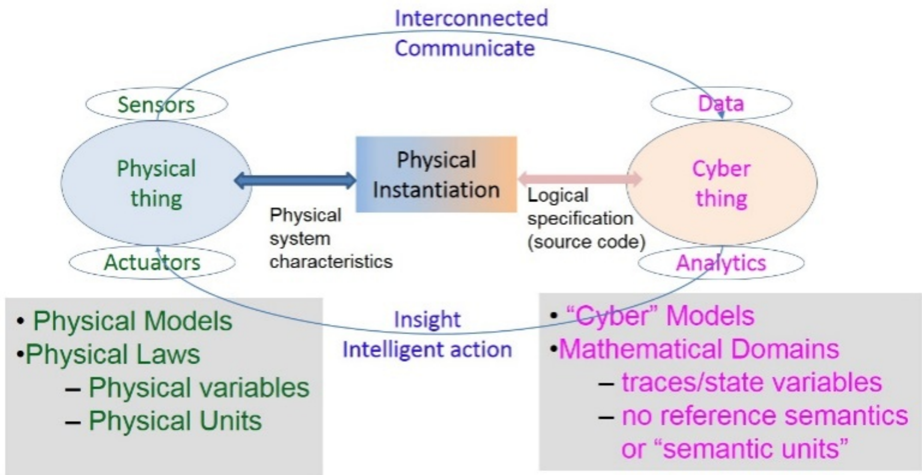


Figure 1. Digital twin architecture

The implementation step of smart factory based on digital twin is sensor data creation, communication between physical process and digital platform, data aggregation, analysis and visualization, insights from analytics, and action back to the physical world. The above steps also can work over different processes or operations.

Digital twin is a dynamic virtual representation of a physical object or system across its life cycle. It connects IoT and IoS (Internet of Service) in the real manufacturing domain or in the real system. IoT consists of various sensors that gather data from the factory shop floor and transfer them through wireless sensor network. IoT corresponds to physical world which is hardware dependent processes with embedded system, sensors, and all-IP factories. IoS consists of ERP (Enterprise Resource Planning), MES (Manufacturing Execution System), SCM (Supply Chain Management), QMS (Quality Management System) and data analytics. This constitutes cyber world, where legacy system works for hardware-independent planning & control of factory and process monitoring [10].

The product-based and service-based system can be compared in many categories. For the product-based and service-based system, they are compared as hard facts vs. soft facts; technologically vs. humanistic; factual design vs. emotional design; tangible goods with minor services vs. service with minor goods; service is a cost vs. service creates value, etc. [11]. The whole contrast of product-based and service-based system is presented in Table 1.

TABLE 1. Contrast of product-based and service-based system

	Product (Technology)-based	Service-based
Facts focus	Hard facts	Soft facts
Main theme	Technologically Supporting product Efficiency based innovation	Humanistic Supporting the customer Client-based innovation
Design goal	Factual	Emotional
Integration	Separate production and delivery	Combine production and delivery
Service mix	Tangible goods with minor services	Service with minor goods
Cost factor	Service is a cost	Service creates value
Structure	Complex structure	Simple structure

Service encapsulation means to transform Physical System Resources (PSR) to Cyber System Services (CSS). Future smart service system in case of manufacturing includes Service-Oriented Manufacturing (SOM), cloud manufacturing and advanced manufacturing. SOM focuses on digital description, perception and access method, quality of service, supply-demand matching, service composition, collaboration and real-time dynamic manufacturing data.

Service Oriented Architecture (SOA) is composed of Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). IaaS provides users access to computing resources such as servers, storage and networking. PaaS provides users with a cloud environment in which they can develop, manage and deliver applications. SaaS provides users with access to a vendor's cloud-based software.

Revised cloud service model is prosed by adding SaaSs (Servitization as a Service system) to the SOA. SaaSs provides users with access to the bundling of goods, services, support and knowledge. The structure of revised cloud service model is shown in Figure 2.

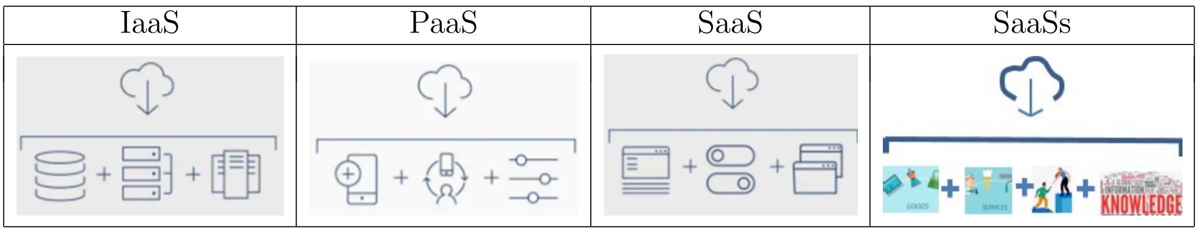


FIGURE 2. The structure of revised cloud service model

4. **Digital Twin Usage in Service Area.** As a use case of digital twin in service area, 'give blood' domain is chosen which is crucial in human health environment. There are two types of 'give blood', which are 'whole blood donation' and 'component blood donation'. The former is to donate all components in the blood including red blood cell, white blood cell, plasma and platelet. The latter is to donate one of the above components and give back the other components to the donor.

As a volunteer, blood donation is a valuable commitment, but the process is very boring. During 30 to 50 minutes of blood donation time, the donor should sit in the chair and monitor when he/she starts hand movement. During blood donation, hand movement is required because of two reasons: first, it improves blood movement; second, it reduces process time.

In order to catch the moment of hand movement, the following methods have been adopted.

1) Monitoring the screen of blood collection equipment.
2) Identify the change of motor's rotation sound.
3) Identify cuff's pressure change in upper arm.

Actually, it is not easy to detect the exact moment for hand motion of blood donor because he/she is in stress or very attentive during the blood donation process. Figure 3 shows blood collection system and the method of detecting knob rotation scheme. For the detecting of knob rotation, there are physical method and digital method. In this research, digital method is adopted which uses magnetic sensor.

Physical method: Attach sensor switch on the rotating knob, and identify rotation change via switch on/off. → Rotation resistance may cause operation error.

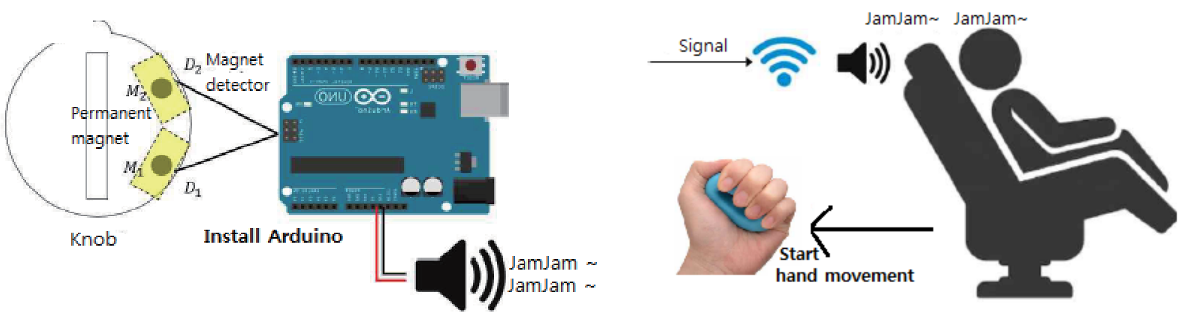
Digital Method: Use magnetic sensor (i.e., door sensor). With permanent magnet and magnet detection sensor, we can identity rotation direction or change of rotation speed. → Simple structure and cheap.

(a) Multicomponent Collection System (MCS)

(b) How to detect knob rotation

Figure 3. Problem domain of give blood: (a) MCS; (b) how to detect knob rotation

In order to recognize the time of hand motion during blood collection, an IoT-based device is devised shown in Figure 4. The device is composed of permanent magnet, magnet detector and Arduino. Arduino is a Single Board Computer (SBC) which can perform computing function in a small scale independently.



(a) IoT-based rotation detection device

(b) Wireless connection with speaker and JamJam

Figure 4. Proposed device concept model (IoT-based device for hand movement time notice)

At the knob of MCS, permanent magnet is attached. At a distance of knob, magnet detector is installed. Arduino can process signal transferred from the magnet detector. When the time for hand motion is detected, it is transferred to the donor wirelessly, and then the donor can start hand motion of fist to improve the blood movement and fast processing.

This device is a simple use case for digital twin applied in the domain of service areas. While the physical process is underway for blood collection, cyber operation for identifying the rotation change in knob is working at the same time.

Generally, for the operation management during system life cycle, a digital twin updates the system status to reflect the current condition of the asset, based on sensor data, test and inspection results, conducted maintenance and modification, etc. [12].

5. Conclusions.

Nowadays, digital is not the asset of an early adopter or a pioneer but a norm. Digital twin could be applied during the whole process of life cycle from product development, production, manufacturing, maintenance to services. Digital twin helps us in the decision making process by formalizing the knowledge that is created over the product life cycle or service. Through this process, the value of a product or service will be increased to a higher level. Thus, it fosters us from 'doing things right' to 'doing the right things'. In this paper, digital twin framework is proposed covering service areas. For the service improvement problem of blood collection system, an IoT device is proposed for digital twin implementation.

The following could be suggested for a further research. As described in earlier section, digital twin can help the whole life cycle of a product or service. Servitization is a new business trend in recent decade. A good use case of digital twin for servitization could be a value enhancement for the service of PLM.

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