Smart Livestock Farms Using Digital Twin: Feasibility Study

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***Abstract*—While the convergence of ICT in various industries is actively under progress, there is still the nontrivial matter of the livestock industry being smarter and safer. This problem can cause unnecessary expenses in the case of various diseases due to the contamination of livestock farms. In this paper, we propose a design concept of a smart pig farm using digital twin for improving animal welfare as a feasibility study. Digital twin is the digital replica of the real world and is becoming more attractive with the realization of the industry 4.0. Due to the deployment of digital twin, livestock farming has been replicated and simulated to be more vigorous against livestock disorders in the virtual world and applies outcomes to livestock farms in the real world.**

***Index Terms*—** Digital twin, smart livestock farms, digital world, livestock disease

I. Introduction

Agriculture has a special meaning and significance in the history of humans because humans cannot survive without food. According to [1], the worlds population grows by nearly three people per second and the global population will reach 8 billion people by 2025 and 9.6 billion by 2050. To provide all the people with enough food, agriculture is the most crucial industry and accordingly, agricultural technology is evolving rapidly. The author of [2] described a technological revolution in agriculture led by advances in robotics and sensing technologies, to improve production as well as maximize efficiency. The authors of [3], [4] also discussed future agriculture with information technologies and proposed blueprints for farmers. Unlike the overall improvement of agriculture converged with information and telecommunication technology (ICT), however, livestock farming is still having difficulty. A Foot and Mouse Disease (referred as to FMD) in the livestock farming industry is a perfect instance to explain the reason, because the global impact of FMD is colossal due to the enormous number of animals affected.

Even though the US is one of the leading countries in the farming industry, [5] estimated that the annual impact of FMD including direct and indirect losses reach between $6.5 and $21 billion per year in the US. Thus, it is necessary to solve the fundamental problem of livestock farms with the support of ICT.

Digital twin [6], [7], [8] is a bridge between the physical and digital world and enables active interactions between two worlds. It originated from the full automation in factories, which configures virtual factories in the digital world, and it manages, operates to estimate the amount of production, the lifetime of components, expected errors during operation, etc. Now the realization of digital twin is extensively used in various industries. As a perspective candidate where it can maximize the benefit by deploying digital twin, we focus on livestock farming in the agriculture industry. By building virtual livestock farms in a digital world, it is possible to discover out the best environmental conditions for growth including temperature, humidity, CO_2, etc. for livestock during simulations using real datasets given by farms in the physical world. In addition, the unnecessary cost due to disease can be minimized.

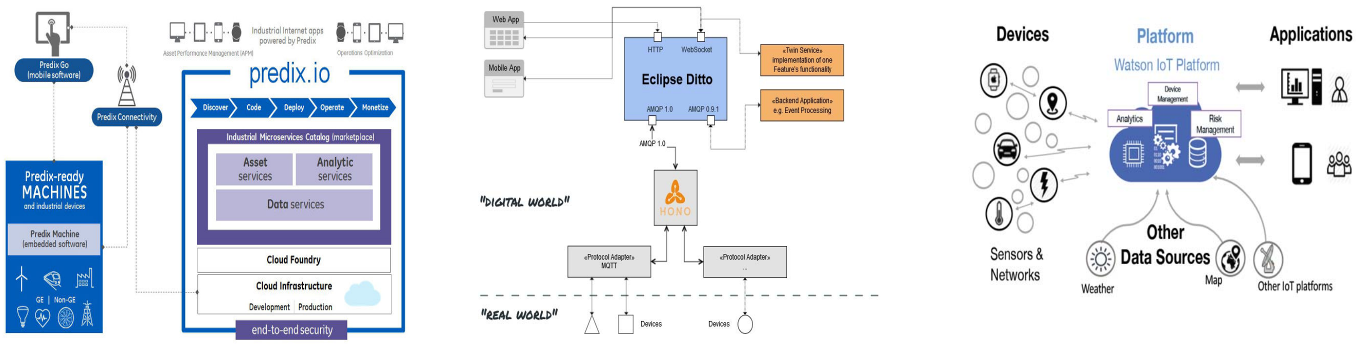
With the catchphrase "one welfare" which tries to improve animal welfare and human wellbeing, we propose a design concept of smart livestock farming based on the digital twin platform as a feasibility study. The rest of the paper is organized as follows. Section II presents industrial activities regarding digital twin platforms. Section III gives the design of smart livestock farms using digital twin platform and Section IV describes further study of smart livestock farms.

II. Digital Twin Platforms

Currently, there are several commercialized digital twin platforms that are widely used in various industries. In this section, we briefly introduce Prefix, Ditto and Watson IoT.

Predix [9], [10], [11] is General Electrics software platform for digital twin and it collects and analyzes data from industrial machines. It provides a cloud-based PaaS (platform as a service), which enables industrial-grade analytics for operation optimization and performance management. It connects data, individuals, and equipment in a standard way. Predix was initially designed to target factories, and gave their ecosystems the same simple function as operating systems that transformed mobile phones. It is now extending its deployment as the dramatic rise of IoT applications. Figure 1a illustrates the overview of Predix using GE digital twin framework.

Ditto [12] is an open source IoT platform for digital twin under progress by Eclipse Foundation. It enables a digital twin to be a cloud based representation of real world counterpart (real world things, e.g. devices like sensors, smart heating, connected cars, smart grids, EV charging stations, etc.) by simplifying developing IoT solutions for software developers



(a) GE Predix (b) Eclipse Ditto (c) IBM Watson IoT

Fig. 1: Digital twin platforms

TABLE I: Comparison of digital twin platforms

	GE Predix	Eclipse Ditto	IBM Watson IoT
Definition of digital twin	Software representation of physical assets	The way to simplify IoT solution deployments	Virtual representation of physical assets
Strength	Comprehensive software platform for digital twin	Open-source(free) & easy to extend	Comprehensive management platform for IoT solution
Focus	To provide overall solutions for IoT service (Operational technology)	Define basic protocol (minimum requirements)	To provide overall solutions for IoT service (Operational technology)

as they do not need to know how or where exactly the physical things are connected. With Ditto, information can be used as like any other web service via its digital twin. Figure 1b shows the implementation of digital twin using Eclipse HONO [13] for the connectivity of IoT devices.

Watson IoT [14] commercialized by IBM had started as IoT management platform in the early days and is now launching new capabilities to implement digital twin and manage physical things in a digital world. It creates multiple views of products by bringing together various digital threads and data streams that can be tailored to the needs of a particular user. Digital thread capabilities, combined with IBM engineering capabilities help individuals or teams understand the impact of engineering decisions on a products performance. Figure 1c describes the conceptual architecture of Watson IoT for digital twin.

Table I summarizes the comparison of digital twin platforms.

III. Design of Smart Livestock Farm

A. Framework

The framework of smart livestock farms consists of 2 layers: digital farm engine layer and digital farm framework layer as shown in Fig. 2.

The digital farm engine layer is to analyze livestock farms according to given conditions and it includes 4 components: *modeling & analysis, simulation, big data* and *visualization*. *Digital thread* [15], [16] was initially designed to manage data processes in industry 4.0 and smart factories. It also has the same role in managing data in livestock farms. A short description of each component is below:

Modeling & Analysis: this component provides the base units for simulation. Various kinds of modeling and analysis including machine/deep learning methods can be applied.

Simulation: this component runs simulations using given conditions and data, produces results in order to control livestock farm.

Big data: this component gathers data generated by various sensors and devices installed in livestock farms. According to the characteristics of type of data and modeling method, not all data needs to be stored in the database as either real time or non-real-time. This component then decides not only what kind of data to be stored but also the way to store. It also provides simulation component with data.

Visualization: this component provides information including data and analysis results in a more user-friendly way using 2D/3D.

The digital farms framework layer purpose is to manage connectivity between sensors and devices equipped in physical livestock farms. It also virtually installs, configures and manages sensors in digital livestock farms to run simulation.

B. Service Scenario

To describe how physical livestock farm interworks with digital livestock farms, this section gives a service scenario of autonomous control in livestock farms which can be easily deployable as illustrated in Fig. 3.

1) Sensors for measuring environmental factors (i.e., temperature, NH_3, CO_2, humidity, wind speed, dust, etc.), which can affect the growth of livestock, were installed

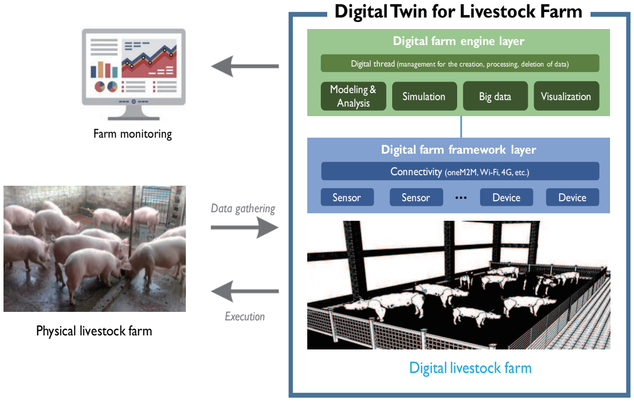


Fig. 2: Framework of smart livestock farm

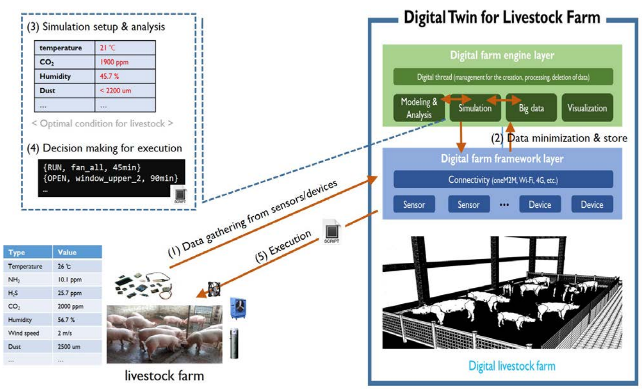


Fig. 3: Service scenario in livestock farm

in the livestock farm and reports raw data to the digital farm framework layer.

2) Gathered data was sent to *big data* component.
3) *Big data* component decides which data is necessary for autonomous control analysis and how to store in either real-time or non-real-time according to policy. In this scenario, temperature, CO_2, humidity and dust are in consideration to be used for simulation.
4) *Simulation* component is initialized and queries stored data in *big data* component. It also refers modeling information in advance in *modeling & analysis* component as well. The simulation is then executed.
5) After the simulation, the outcome of the simulation is followed and the decision making to control devices in livestock farm is executed. In this scenario, simulation results suggest optimal temperature and CO_2 for livestock farms. To achieve this condition, they operate fans and open windows during specific periods as an execution. This execution can be written in script file to be read in tje system in livestock farms.
6) Finally, the control system in livestock farms gets script file to control devices and execute script file.

IV. Further Study

As a feasibility study, our preliminary design of smart livestock farms provides a guideline how to converge ICT with livestock to make it smarter and safer. In addition, it is the first trial to apply digital twin into the livestock industry. In future research, we will implement components designed in both layers and equip several sensors in the real livestock farms. Afterwords, we will operate and investigate the the realization of smart livestock farming using digital twin.

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References

[1] "2017 World Population Data Sheet," tech. rep., Population Reference Bureau, 2017.
[2] A. King *et al.*, "The future of agriculture," *Nature*, vol. 544, no. 7651, pp. S21–S23, 2017.
[3] J. C. Aker, I. Ghosh, and J. Burrell, "The promise (and pitfalls) of ict for agriculture initiatives," *Agricultural Economics*, vol. 47, no. S1, pp. 35–48, 2016.
[4] G. Betti, E. Amaldi, A. Capone, and G. Ercolani, "Cost-aware optimization models for communication networks with renewable energy sources," in *INFOCOM, 2013 Proceedings IEEE*, pp. 3231–3236, IEEE, 2013.
[5] T. Knight-Jones and J. Rushton, "The economic impacts of foot and mouth disease–what are they, how big are they and where do they occur?," *Preventive veterinary medicine*, vol. 112, no. 3-4, pp. 161–173, 2013.
[6] S. Haag and R. Anderl, "Digital twin–proof of concept," *Manufacturing Letters*, vol. 15, pp. 64–66, 2018.
[7] F. Tao, J. Cheng, Q. Qi, M. Zhang, H. Zhang, and F. Sui, "Digital twin-driven product design, manufacturing and service with big data," *The International Journal of Advanced Manufacturing Technology*, vol. 94, no. 9-12, pp. 3563–3576, 2018.
[8] B. Schleich, N. Anwer, L. Mathieu, and S. Wartzack, "Shaping the digital twin for design and production engineering," *CIRP Annals*, vol. 66, no. 1, pp. 141–144, 2017.
[9] Predix Architecture. https://www.predix.com/sites/default/files/ge-predix-architecture-r092615.pdf. Accessed: 2018-07-24.
[10] GE Predix. https://www.ge.com/digital/predix-platform-foundation-digital-industrial-applications. Accessed: 2018-07-24.
[11] H. D. Morris, S. Ellis, J. Feblowitz, K. Knickle, and M. Torchia, "A software platform for operational technology innovation," *International Data Corporation*, pp. 1–17, 2014.
[12] Eclipse Ditto. http://eclipse.org/ditto. Accessed: 2018-07-24.
[13] Eclipse HONO. https://www.eclipse.org/hono/. Accessed: 2018-07-24.
[14] IBM Watson IoT. https://developer.ibm.com/iotplatform/. Accessed: 2018-07-24.
[15] E. M. Kraft, "The air force digital thread/digital twin-life cycle integration and use of computational and experimental knowledge," in *54th AIAA Aerospace Sciences Meeting*, p. 0897, 2016.
[16] D. Mies, W. Marsden, and S. Warde, "Overview of additive manufacturing informatics:a digital thread," *Integrating Materials and Manufacturing Innovation*, vol. 5, no. 1, p. 6, 2016.