

BLOCKCHAIN AND DIGITAL TWIN FOR INDUSTRY 4.0/5.0

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1. Introduction

Industry 4.0 was introduced in 2011 in German as a government initiative. Industry 4.0 also refers to the smart factories using robotics, autonomous operations, the Internet of Things, big data, analytics, artificial intelligence, and a convergence of IT and OT. The goal is to create efficient, agile and intelligent manufacturing [1-3].

Industry 5.0 has been recently introduced in 2020 to achieve societal goals alongside economic growth and business objectives [4]. Industry 5.0 focuses on the interaction between humans and machines/robots [5]. In the smart factory 4.0, humans work alongside machines/robots and are connected through intelligent devices [6].

Robots become more important, and can be connected to the human mind via the brain-machine interface and advances in artificial intelligence [7]. In the industry 5.0, robots will be intertwined with the human brain and work as a collaborator, not a competitor [8]

Industry 5.0 will focus on more advanced human-machine interfaces using artificial intelligence (AI) algorithms, for a better integration, enabling faster, better automation combined with the power of human brains [9].

In the direction of interaction between humans and robots, we can divide into two groups: humanoid robot and robotic human/digital human. In the case of humanoid robots, although many of them are still in the prototype phase, a few have entered the real world as bartenders, concierges, deep-sea divers and as companions for older adults [10]. In the case of digital humans, they might be photorealistic digitized virtual versions of humans. While they don't necessarily have to be created in the likeness of a specific individual human, they could look and act like humans [10]. Besides, in other directions, current advanced technologies can produce the digital twin human.

This editorial aims to explore how blockchain and digital twin can be used in the industry 4.0/5.0, focusing on smart cities, smart hospitals, smart manufacturing, automotive industry.

2. Blockchain and digital twin for smart cities

The global smart cities market size was valued at USD 1,226.9 billion in 2022 and is expected to register a compound annual growth rate (CAGR) of 25.8% from 2023 to 2030. In smart cities, both information and communication technologies are integrated for exchanging real-time data between their citizens, governments, and organisations. Blockchain has been considered as the key driver for development of smart cities. Blockchain technology can provide high security for large communications

and transactions between many stakeholders in the smart cities. In addition, digital twins are also considered as the starting key for construction of smart cities. Digital twin refers to a simulation of physical products in virtual space. This simulation makes full use of physical models/wireless sensor networks/ historical data of city operation to integrate big information(digital twin cities) under multi-discipline, multi-physical quantities, multi-scale, and multi-probability. In addition, with the support of artificial intelligence (AI) tools (such as fuzzy logic, genetic algorithms, neural networks, ambient-intelligence...), wireless sensor networks nowadays have become smarter [11].

The digital twin and blockchain can be used in smart cities through 3 below sections.

- Digital twin and blockchain for managing the regular operations and services in smart cities (information management, smart grid, transportation system, construction project, roads infrastructure, logistics/supply chain management, water management, waste management, vehicle management, vehicular sensing networks, smart transportation, autonomous vehicular networks for smart cities...)

- Digital twin and blockchain for safe cities (secure air-ground integrated networks, personal security, structural health monitoring, disaster management...)

- Digital twin and blockchain for healthy cities (epidemic services, security and privacy in the smart healthcare, healthcare monitoring, healthcare facilities management...)

3. Blockchain and digital twin for smart hospitals

Nowadays, the latest technologies have been used intensively in the healthcare sector. Among the current high technologies, Blockchain has been considered as the key for the perspective of industry 5.0.

Global revenue in the Health Care segment is projected to reach US\$60.72bn in 2023, with an annual growth rate of 10.95%,

resulting in a projected market volume of US\$92.01bn by 2027. The future of healthcare might be only a few doctors/nurses taking care of a growing number of patients. For smart healthcare applications, blockchain technology can improve the connectivity and secure data sharing to deliver better patient experiences, streamline workflows, and reduce costs. Besides, the digital twin global market size was valued at \$17.5 billion in 2023, with an annual growth rate of 36.3% for reaching \$154 billion by 2031. In addition, intelligent wireless medical sensor networks can provide big information to monitor and manage the patient clinical data in the smart hospitals.

The smart hospital framework involves three main layers: data, insight and access. Medical data is collected realtime from all devices/systems in a smart hospitals. These data should be integrated to the smart insight from the analytics or machine learning software. This smart insight should be accessible to any doctor/nurse/staff via a smartphone or mobile device, for providing the fast decisions with more efficiency. Blockchain technology can improve health services in smart hospitals, especially during COVID-19 pandemic.

In the smart healthcare, digital twin and blockchain can be used widely, such as the electronic health records, real-time storing and updating patient data, healthcare data management, insight healthcare consultant/telehealth-telemedicine, prescription/medicine/drug traceability and safety, clinical trials, medical insurance, healthcare digital twin, healthcare monitoring.

In case of smart hospitals, digital twin and blockchain can be used in prescription process from manufacturing to pharmacy, decentralising patient health, privileges or accessibility of patient health history records, efficient medical data exchange, diagnostic and therapeutic purposes, health apps, patient consultant and insight/telehealth framework, providing and maintaining the financial statements in hospitals, multiple digital patient check-in wireless medical sensor networks.

4. Blockchain and digital twin for space/aircraft industry

Manufacturing can provide a high Return on Investment. It was reported that \$1 of investment in manufacturing can create ~ \$2.5 of economic activity. Current manufacturing involves batch production. However, in the Industry 4.0/5.0, personalized/individualized products with low quantities can be fabricated in the smart factories, which integrates all companies working in the supply chain from manufacturing to marketing/services. In this regard, in Industry 4.0 the products become more personalized, more flexible and smarter [12]. Smart products should be fabricated from smart materials via the intelligent manufacturing system framework. Blockchain can build secure and connected manufacturing infrastructure. In 2017, it was reported that the benefit of the space industry was valued at \$384 million USD, and it is expected to grow to \$1.1 trillion USD by 2040. Space application requires high-performance materials with high strength, high stiffness, high thermal resistance and lightweight. In addition, the electronic devices in space application should be lower power consumption, more accurate, more reliable and in smaller size. Blockchain and digital twin can be used effectively in the aircraft industry - a high technology sector, for certifying and monitoring the whole component production process, especially in the additive manufacturing [13]. The additive manufacturing technology has been considered as the key driver to perform the rapid prototyping of product components, through the supply chain, thus reducing time-to-market, while ensuring quality and containing costs. Blockchain and digital twin can be used in various applications in aircraft [14-17] and UAV (unmanned aerial vehicles) [18], such as for enhancing aircraft maintenance records security [14], the decentralized digital asset management system for commercial aircraft leasing [15], aircraft parts traceability and trackability for inventory management [16], aircraft wing health monitoring [17]...

5. Blockchain and digital twin for smart agriculture

Smart agriculture refers to the application of fourth industrial revolutions in agriculture (Agriculture 4.0). Fully automated and autonomous agriculture can be achieved by using various new technologies, such as the internet of things (IoT), big data, artificial intelligence (AI)... In a smart real-time agriculture, the quality of agrifood products could be fully controlled, from the seed to the harvest/delivery, as well as from the egg to the butcher shop. In this regard, smart sensors and their wireless network are important components of Agriculture 4.0/5.0 [19]. Blockchain and digital twin can be used widely in smart agriculture [20-22], such as pilot study [23], water management system [24], supply chain management [25]... However, agricultural digital twins are challenged to capture the interactions between living systems and their environment [22]

6. Blockchain and digital twin for automotive industry

In the far future, blockchain technology might change our world, from the unity of markets (e.g. financial markets) to the equality among nations (e.g. peer-to-peer cooperation). Recently, blockchain technology has been developed faster, partly due to the evolution of the crypto market. Blockchain technology is the key for the perspective of industry 5.0, smart healthcare/smart hospitals, or space exploration/application. Nowadays, the latest technologies can be found not only in health care and space application but also in hybrid supercars. Supercars/hypercars require high-performance materials with high strength, high stiffness, and lightweight. For higher performance, car engines now become stronger, but smaller and lower fuel consumption (with cleaner exhaust). Currently, the automotive industry involves batch production, but in the near future, personalized/individualized automobiles with low and limited quantities can be fabricated in smart factories, which integrates all companies working in the supply chain from manufacturing to marketing/services. In this regard, the future automobiles in smart cities become more personalized (single user/limited version/personal spare parts), safer and smarter. Blockchain technology is the key to these future perspectives toward

intelligent automobiles without any risk of safety/accident, security/theft, or traffic jam. In the current industry, blockchain technology can explore the interconnection of blockchain with other innovative technologies and trends such as the internet of things (IoT) and artificial intelligence (AI) and analyse the potential to transform business processes and whole industries of these innovations are applied jointly.

For vehicles in the smart city, blockchain-based distributed frameworks can be used. This framework can include a novel miner node selection algorithm for the blockchain-based distributed network architecture.

For automotive manufacturing, blockchain can be used in various stages, such as self-driving car development, car quality assurance, smart vehicular communications, automobile sales and leasing, electricity board (meter readings/payment)...

For future drivers' everyday lives, blockchain can be used in various applications, such as future mobility, digital vehicle passports, backbone of the connected ecosystem of autonomous vehicles, charging stations for e-cars through blockchain, ride and car sharingapps... [25].

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