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A Review and Analysis of the Applicants of Digital Twin Technologies

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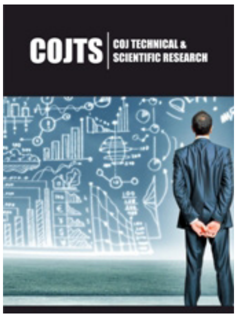

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Introduction

The digital twin concept was first applied to NASA's rescue of the Apollo 13 spacecraft on April 13, 1970, when the service module liquid oxygen tank exploded in space and the rescue plan was simulated in real time by a ground-based simulator [1]. The concept of digital twin was introduced by Professor Michael Grieves of the University of Michigan in 2002, which was defined as an Information Mirroring Model [2]. Digital Twin (DT) was first used in 2010 by NASA in [3], which was defined as an integration of multi-physical field, multi-scale, and probabilistic simulation. [3] also identified four major application scenarios for digital twins, namely pre-launch test flights, in-flight state mirroring, analysis of potential disasters or damage, and analysis of the impact of modifications to mission parameters. The essence of the digital twins is system models and data models based on physical entities. Through real-time interaction with real-world physical entities, the operational state changes of physical entities are monitored, diagnosed and predicted in virtual space to achieve accurate prediction of the real world in the virtual world. Digital twin technologies have been widely used in industrial manufacturing, smart cities, medical and health care, aerospace, and defense industries.

In industrial manufacturing, the application of digital twin technology is mainly focused on two aspects: manufacturing and operation maintenance [4]. The former is mainly used to assist in the full lifecycle management of products, including product design, manufacturing, testing, optimization, production and other aspects, which can analyze a large amount of data generated during the production process to promote the optimization of the entire product; the latter is mainly used to monitor the production process and service quality, helping manufacturers to optimize production resources and processes. Companies such as SIEMENS [5], ANSYS [6], and Lockheed Martin [7] have made extensive use of digital twin technology in the design, manufacturing and inspection of their products. Lockheed Martin has improved production efficiency and product quality significantly by using digital threads. In urban construction, digital twin technology is mainly used in two aspects: urban planning and construction, urban operation and maintenance management [8]. The former mainly uses digital twin to digitally represent urban objects, form Building Information Models (BIM), combine with GIS and big data technologies to assist urban planning [9], and monitor the process of urban construction. Based on the digital twin model, urban operation and maintenance management can monitor the operation of the city in real time, discover abnormalities in time, and propose corresponding countermeasures to assist urban management. Digital twin technology is also applied to the healthcare field. Using the variability of the digital twin model, the resources of different hospitals, regions and countries can be shared and integrated. Digital twin technology integrates the information systems of each medical institution to achieve information resource sharing within medical institutions; on a regional scale, unified management, sharing, exchange and security of healthcare data and information can be realized using digital twin technology [10] at the same time, digital twin technology is used to achieve cross-hospital and cross-region teleconsultation and telemedicine services [11]. In addition, through the analysis of personal health data, we can provide people with health management suggestions and personalized medical services.

At present, digital twin technology has made some progress in the field of health management. In the aerospace field, the digital twin is used for virtual testing, virtual maintenance and virtual simulation to grasp the status changes of aircraft or satellites during air flight, so that they can be monitored and warned in real time, enabling them to take precautions in advance to reduce possible accidents, For instances, NASA is currently trying to use digital twin to ensure the safety of the crew in case of aircraft failure [12]. [13] introduces digital twin technology into satellite engineering and proposes the concept of digital twin satellite engineering, which designs the application scenarios of digital twin technology from both time and space dimensions. In addition, digital twins can also be used to simulate and accurately analyze various physical effects in the space environment, such as space radiation effects, space electromagnetic interference effects, space debris effects, etc., and accordingly formulate countermeasures. In the defense field, digital twin technology is also widely used. The US Deputy Secretary of Defense for Research and Engineering Michael Griffin issued the Department of Defense Digital Engineering Strategy in 2018, which was aimed at guiding the planning, development, and implementation of digital engineering transformation across the Department of Defense [14]. The U.S. Navy announced the completion of the first digital twin model Digital Lincoln in 2019 [15].

Conclusion

The digital twin technology realizes two-direction mapping and state interaction between physical objects and twins through virtual-real mapping; based on real-time sensing and other multi-data acquisition, the twin can reflect the state changes of physical objects comprehensively, accurately, and dynamically; in an ideal state, the twin evolves and updates with the life cycle process of physical objects. By describing the intrinsic mechanism of physical entities, twins can be used to analyze the laws and trends, form optimization instructions or strategies, and realize the closed-loop of the decision optimization function of the physical entity.

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