Digital Twin of Space Environment: Development, Challenges, Applications, and Future Outlook

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This paper explores and discusses the revolutionary applications of digital twin technology in space environments and its profound impact on future space exploration activities. Originating from a proposal by the National Aeronautics and Space Administration (NASA) in 2002, digital twin technology aims to enhance the safety and reliability of space missions by creating precise virtual models. As the technology has evolved, its applications have successfully expanded beyond aerospace to include Industry 4.0, healthcare, and urban management, demonstrating remarkable cross-industry adaptability and broad impact. In space applications, digital twin technology can not only improve spacecraft design and maintenance processes but also enhance the efficiency of mission planning and execution. It plays a crucial role in astronaut training and emergency response as well. Particularly in extreme space conditions, this technology provides real-time monitoring and fault prediction, significantly enhancing mission safety and success rates. However, despite its recognized potential, the implementation of digital twins in space environments faces numerous challenges, including data transmission delays, model accuracy, and the design of user–system interactions. In the future, as artificial intelligence (AI) and machine learning (ML) technologies become mature and integrated, the digital twin will play a more central role in space missions, especially in remote operations, complex system management, and deep space exploration. This article is to overview key technical features, application examples, and challenges of digital twin technology, aiming to provide a comprehensive reference framework for researchers and developers while inspiring further in-depth studies and innovative applications

Biography

Gang Wan is wprking in the department of Surveying and Mapping and Space Environment at the Space Engineering University in China. He has published 25 articles in the reputed journals and has 10 years of experience in the healthcare technology

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