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A GAME ENGINE-DRIVEN APPROACH FOR CONSTRUCTION OF MANNED LUNAR RESEARCH STATION DIGITAL TWINS

Abstract

The manned lunar research station stands out as the most viable starting point for extraterrestrial space exploration and space habitation. To its sustainable operation, advanced dynamic assessment and simulation are necessary, with digital twin technology being a promising approach. However, traditional GIS-driven digital twins face challenges in the extreme lunar environment, including the long length of the day/night cycle, wild temperatures fluctuations, high levels of radiation and microgravity, leading to issues with fidelity, data visualization, and interaction between data and algorithms. Given the above problems, this research proposes an approach using a game engine to drive the construction of digital twins for the manned lunar research station, in order to improve the capabilities of digital twins in phygital interaction for manned lunar research stations. The study firstly screened and demonstrated constraints affecting the modelling. Then, the appropriateness of applying game engines is demonstrated based on feature comparison of typical game engines. A dynamic data integration mechanism is designed to establish a theoretical framework that encompasses the organisational structure of physical space, virtual space, and the interaction between the two. With respect to the assembly, deployment, operation and maintenance process of the digital twin of manned lunar research stations, the mapping method of virtual-physical entities, the fusion method of twin data, and the construction method of high-confidence information model with full attributes are proposed, and the proof of concept of the model is conducted based on an intelligent algorithm. The study found that extreme terrain conditions, complex thermal conditions and mechanical conditions are the main constraints affecting digital twin modelling at manned lunar research stations. Game engines have the capability advantage of mapping complex terrain conditions with 3D rendering capability, mapping special gravity environment with real physics engine, and mapping anomalous climate effects with real-time interactive algorithms in the digital twin modelling of the manned lunar research station. By applying game engine, effective enhancements can be generated in terms of enhancing the fidelity of digital twins for lunar applications, and potentially improving the interactive experience between data and algorithms. The results of this research can help to enhance the on-ground interaction of manned lunar research stations and provide effective dynamic monitoring and simulation prediction support for all aspects of their lifecycle, such as in-situ construction and maintenance.