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Space Structures III Design, Development and Verification (Orbital infrastructure for in orbit service & manufacturing, Robotic and Mechatronic systems, including their Mechanical/Thermal/ Fluidic Systems) (3)

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ENHANCING ORBITAL INFRASTRUCTURE THROUGH AI-DRIVEN DESIGN AND ROBOTIC AUTOMATION: A METHODOLOGICAL APPROACH TO DEVELOPMENT AND VERIFICATION

Abstract

The expansion of space exploration and operational capabilities critically depends on advancements in orbital infrastructure. "IntelliStruct" introduces a groundbreaking methodology that harnesses artificial intelligence (AI) and robotics to enhance the design, development, and verification of space structures. By merging AI-driven design principles with a comprehensive framework that includes advanced robotic and mechatronic systems, IntelliStruct aims to streamline the assembly, maintenance, and management of intricate orbital infrastructures such as satellites, space stations, and other spacefaring vehicles.

At the heart of IntelliStruct is the application of AI algorithms tailored for optimizing structural designs to improve compatibility with robotic assembly processes. These algorithms leverage machine learning to predict and simulate the structural behaviors under various space conditions, enabling early identification and mitigation of potential design and operational flaws. In parallel, the initiative explores the creation of autonomous robotic systems designed for complex assembly tasks and ongoing maintenance in space, significantly reducing the need for human intervention and thus, minimizing associated risks and expenses.

The methodology employs a combination of computational simulations for continuous design improvement and empirical testing of robotic systems in conditions that simulate the space environment. This ensures the structural integrity of the designs and the operational efficiency of the robotic systems before their space deployment. Considerations include the robots' versatility in performing diverse tasks, the endurance of structures against space's harsh conditions, and the effective integration of thermal, fluidic, and mechanical systems within the orbital infrastructures.

Initial findings demonstrate the considerable advantages of integrating AI and robotics into the construction and operational phases of space infrastructure development via the IntelliStruct framework. This synergy of AI-driven design optimization with robotic autonomy signifies a shift towards more durable and sustainable space infrastructures.

The study comprehensively covers the design, development, and verification of orbital infrastructures, addressing mechanical, robotic, thermal, and fluidic systems and subsystems. It includes analysis for both manned and unmanned spacecraft, space stations, re-entry vehicles, and small satellites, focusing on advanced subsystems and designs for future missions. Challenges in material selection, cost-efficiency, reliability, and advancements in engineering analysis, manufacturing, and test verification are examined.

Moreover, the research delves into the design and testing of robotic and mechatronics systems for exploration, in-orbit servicing, and manufacturing, highlighting the experimental and computational simulation of full-scale tests and the lifecycle verification of mathematical models.

Keywords: Orbital Infrastructure, IntelliStruct, Artificial Intelligence, Robotics, Design Optimization, Autonomous Maintenance, Space Operations, Mechatronic Systems, Thermal Systems, Fluidic Systems.