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Author: Mr. Maximilian Mühlbauer
TU Muenchen, Germany

Dr. Florian Leutert
Zentrum für Telematik, Germany
Mr. Christian Plesker
TU Darmstadt, Germany
Mr. Luis Wiedmann
Technical University of Munich, Germany
Mr. Alessandro Massimo Giordano
Technical University of Munich, Germany
Dr. João Silvério
German Aerospace Center (DLR), Germany
Dr. Thomas Hulin
German Aerospace Center (DLR), Germany
Dr. Freek Stulp
DLR (German Aerospace Center), Germany
Mr. Jonas Voges
TU Darmstadt, Germany
Mr. Robert Knobloch
TU Darmstadt, Germany
Prof. Klaus Schilling
Zentrum für Telematik, Germany
Prof.Dr. Benjamin Schleich
TU Darmstadt, Germany
Dr. Alin Albu-Schäffer
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany

AI-BASED ROBUST AND FAILURE-TOLERANT PROCESSES FOR IN-ORBIT MANUFACTURING OF MODULAR SMALL SATELLITES

Abstract

Advances in small satellite architecture and production processes allow for an increasingly robust automated assembly, enabling the vision of an in-orbit factory. The in-orbit production of satellites promises many advantages: For instance, satellites can be commissioned much faster as they are produced directly at their location of deployment. Also, mechanical requirements are lower as the structure does not need to withstand the vibrations of a rocket launch. This opens new business opportunities with the just-in-time production of large fleets of individualised small satellites which are built according to specific customer needs.

As direct human intervention in in-orbit factories is prohibitively expensive, the need for failure tolerant and self-recovering processes arises. The ACOR project leverages AI-based methods for the robust assembly of CubeSats and is built upon three key components: an automated integration and testing

process, a failure-tolerant teleoperation interface and a Digital Process Twin (DPT) orchestrating the whole assembly with fault detection, isolation and recovery (FDIR) capabilities.

The DPT is the high level decision-making authority of the In-Orbit Factory. It orchestrates the individual participants in the manufacturing process and maps the entire process virtually. Standardised interfaces to the digital twins of product and production machines and the virtual representation of the process are used to find alternative solutions in case of errors. Based on this process information the DPT also performs a long-term optimization of the whole process.

The actual assembly of satellites from modular components is performed by a torque-controlled robot arm. Several FDIR approaches are integrated into individual production steps to achieve the required robustness and adaptivity of the process. Automated testing and inspection of satellite modules and subsystems is seamlessly integrated and performed during the production process to ensure a fully functional satellite at the end of the assembly.

A bilateral teleoperation system with force feedback helps to cope with unforseen circumstances. Virtual Fixtures are used to generate guiding forces for the human operator. A probabilistic formulation of these fixtures allows to automatically select the most appropriate fixture and scale the guidance level, balancing human control with automation. This system allows to directly control parts of the assembly, either performing steps that are not automated yet or by completing tasks where the automation has failed.

This paper outlines the concept of our robust and failure-tolerant in-orbit factory and presents results achieved with our approach, combining automated and teleoperated assembly with a Digital Process Twin.