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AN ADVANCED TOOL FOR INTERACTIVE MISSION MODELING & VISUALIZATION/VALIDATION OF SPACE-BASED SCENARIOS

Abstract

In an era of increasingly complex space missions demanding high safety margins and low risk levels, advanced Simulation, Modeling and Digitalization Tools are becoming imperative to foresee all possible scenarios that could lead to mission failure. In this context, Telespazio Spa is developing an *Interactive Mission Modeling Visualization/Validation* (IMMV^2) tool, aimed at providing both Users and Mission Designers with a cutting-edge platform for Mission Digitalization and End-to-End (E2E) Testing and Validation, known as Mission Digital Twin. The tool harnesses state-of-the-art technologies, utilizing an innovative graphics engine like Unreal Engine for real-time realistic rendering, synthetic data generation within the simulation loop and VR interactivity, in order to provide a complete fault detection-system robustness analysis trough a sensor fusion of multiple virtual environment-based synthetic data. The correlation and extraction of synthetic observables from the scenario exploits a customized module of the tool for the digital environment scenario generation, called *Visual Scenario Generator* (VSG). This module allows to create a realistic/ ultra-wide geospatial virtual worlds by processing billions of points through Unreal Engine v5 (UE5) Nanite technology, thus enabling the import of high-res topographic maps. For example, in case of the Lunar South Pole Environment, starting from the NASA LRO data, it was possible to reconstruct the lunar surface with a resolution up to 5 m/px. Thus, by merging VSG capabilities and a bilateral real-time co-simulation mechanism (Ping-Pong), between the UE5 and a backend simulation environment, it is possible to extract georeferenced Optical/Lidar images and other synthetic observables, essentially enabling the dataset ready for different kinds of mission tests. Another module implemented within the tool, allows to integrate multi-sensor fusion algorithms enhanced by Visual-Based Navigation (VBN) to assess desired navigation performance and guidance Key Performance Indicators (KPIs), in a fully integrated architecture. Representative examples of application of the current tool pipeline and capability will be shown in this paper for the validation of : i) a lunar lander mission scenario in a Lunar environment, ii) an Earth Scenario for an In-Orbit mission between a Target and Chaser with the real-time extraction of optical images and LIDAR point clouds. With regard to the future works the tool aims to potentially develop a Multi-Mission Digital Twin verification, validation fully synthetic dataset

generation framework for different Mixed-Reality Space/Aerial scenarios, integrating different NAV COM technologies Software Hardware-In-the-Loop components and training datasets from existing real assets.