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DEEP LEARNING ARCHITECTURES FOR GLOBAL OPERATION AND CONTROL OF MINIATURIZED SATELLITE CONSTELLATIONS

Abstract

While the Space Industry is currently undergoing profound paradigm changes in the current times, both from a technological but also commercial, business perspective, satellite operations have note evolved much since the very early years of human space activities in space, at least from the very base concept. Given the recent NewSpace and mega-constellations trends, these traditional operations concepts and technologies may not be effective and feasible in the following years and missions to come. Automated operation of distributed systems is nothing but a key development still to be achieved to maintain the current momentum of the Space Industry.

One of the most promising technologies to enable automated activities is Artificial Intelligence. AI architectures fundamentally extract patterns from data to succeed at a certain objective goal defined by design: from model identification to simulation, uncertainty classification and propagation, system diagnosis, task allocation and execution, orbital manoeuvring or re-configuration are some of the topics in which AI may overperform humans when operating spacecraft, with special regards to distributed systems, in which a global handling of the different constitutive elements is needed to ensure long-term mission success.

In this work, several Deep Learning and Artificial Intelligence architectures are explored, constructed and validated for the end-to-end operation of a picosatellite constellation, applying such technologies for both Ground and Flight Segment activities throughout the whole mission lifetime. Deep Model Predictive Control, Genetic Algorithms and Reinforcement Learning are first applied and compared for rapid constellation design, deployment and re-configuration under spacecraft faults. Traditional Neural Networks schemes are chained and employed for task assignment and individual spacecraft control based on a global constellation telemetry and control policy Agent, maximizing resources allocation. Additionally, several Flight Segment AI applications are presented: transformers-like nets are used for onboard stochastic orbit determination, propagation and control under atmospheric conditions uncertainties, while Reinforcement Learning, combined with autoencoders, is used to design and implement an autonomous, online FDIR and hardware allocation Agent.

Finally, several mission case scenarios are used to validate such technologies against human performance, with particular emphasis on the assessment of the global system's FDIR capabilities.