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PROTOTYPING OPERATIONAL AUTONOMY FOR SPACE TRAFFIC MANAGEMENT

Abstract

NASA Ames Research Center has developed a architecture and software prototype of an Space Traffic Management (STM) system, based on open Application Programming Interfaces (APIs) and drawing on previous work by NASA to develop an architecture for low-altitude Unmanned Aerial System Traffic Management (UTM). This system is designed to provide structure to the interactions between spacecraft operators, various regulatory bodies, and service suppliers, while maintaining flexibility of these interactions and ability for new market players to enter easily. Autonomy is an indispensible part of the proposed STM system in enabling efficient data sharing, coordination between STM participants and safe flight operations. Examples of autonomy within STM include syncing multiple non-authoritative catalogs of resident space objects, or to determine which of two spacecraft moves to prevent an impending conjunction between them.

This paper explores the trade-offs between performance and controls in key decisions among spacecraft service providers, and the role of planning tools in aiding such decisions. Specifically, we will compare candidate tools for autonomous decision making between contending spacecraft maneuvers, as well as scheduling such maneuvers within safe margins of operation. The developed autonomous decision-making tool implements autonomy algorithms to intelligently search the space of potential collision avoidance maneuvers. The framework formulates the conjunction scenario as a sequential decision-making problem and recommends optimal maneuvers to the spacecraft operators. This is performed by leveraging algorithms such as partially observable Markov decision processes (POMDPs), which optimize the trade-off between the maneuver cost and maximum probability of collision while complying with safety constraints imposed by the problem. The paper evaluates the effectiveness and feasibility of the autonomous maneuver advising tool compared to a manual decision-making approach.

We have also developed a prototype platform with a few example participants (e.g. a space situational awareness provider, a conjunction assessment supplier, a collision avoidance maneuver trade tool) for demonstrating our proposed STM architecture. This paper will also highlight how the autonomy algorithms described above can flexibly connect to the STM architecture, in the context of the developed software platform and its various flexibly connected players. The STM prototype is being developed on a modern micro-service containerization architecture based on industry standard Docker containers. The system is implemented with OpenAPI standards facilitating easy communication between different services. The system architecture is designed to facilitate adding and replacing services with minimal disruption.