15th IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE (D4)
Strategies for Rapid Implementation of Interstellar Missions: Precursors and Beyond (4)

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UNSUPERVISED LEARNING TO COMPENSATE FOR HIGH LATENCY IN INTERSTELLAR AND OTHER PLANETARY EXPLORATION

Abstract

Planetary exploration can utilize orbital, aerial, surface and potentially sub-surface vehicles at remote locations. At present, most orbital, aerial and surface vehicles are teleoperated from Earth and sub-surface vehicles are problematic, due to the need for a data relay path (which can be obstructed sub-surface). Irrespective of vehicle type, teleoperation requires data to be transmitted over significant distances (taking several minutes or longer). This problem gets progressively more pronounced as vehicles are operated further and further from the Earth. While missions to send humans to deep space and increased spacecraft and rover autonomy both prospectively present partial solutions to this challenge, mission concepts can also benefit from an effective way of human-on-the-loop participation where human controllers participate while having an experience akin to real time in-situ exploration.

This paper explores the use of unsupervised learning for rovers. The proposed technique reduces the amount of data that needs to be sent to provide telemetry to allow remote control the vehicle. It also limits the data transmitted back to Earth to that which is determined as being necessary to satisfy user needs. Prior work, focused on supervised learning, demonstrated how training an expert system to predict user input could be an effective approach. Unsupervised learning, however, facilitates the robot locally updating its decision-making process without having to send data back to Earth and await user feedback. This technique is of particular value in environments where data latency is so high (e.g., missions to the edge of and beyond the solar system) where the delay for telemetry transmission and command reply is time-prohibitive.

Multiple variations of unsupervised learning techniques are evaluated under varying levels of latency. The techniques are evaluated in terms of the scope of exploration facilitated (i.e., the area explored) and the achievement of key user goals (data supporting / refuting specific areas).

The paper begins with a review of prior work in latency compensation and unsupervised learning. Then, the unsupervised approaches are proposed and the mission concept used for testing is presented. Next, the efficacy of this approach is evaluated by simulated test runs, for which the data collected is presented and analyzed. Finally, the paper concludes with a discussion of the implications of the results reported and the future work required to bring this concept to fruition is detailed.