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# A FRAMEWORK FOR LOW-THRUST-BASED SPACE LOGISTICS MODELLING AND OPTIMIZATION

**Abstract**

This paper proposes a framework that integrates low thrust transportation in space logistics modelling and optimization. One of the classical logistics modelling methods is to combine the time-expanded network with the network flow modelling. However, past literatures only consider transportations using high-thrust propulsion, where the costs of space transportation are pre-computed by solving Lambert problems. The mass of spacecraft changes instantaneously at nodes. Low-thrust propulsion is a much more cost-efficient transportation option, and it is necessarily to include low-transportation option into the network-based logistics modelling. However, introducing low-thrust transportation into the network based modelling is challenging. Firstly, designing low-thrust trajectories requires solving the optimal control problem (OCP), which is a time-consuming process. Meanwhile, the logistic planning process become a nested nonlinear optimization process, which makes problem difficult to solve. Secondly, the feasibility of the proposed low-thrust transfer is unknown before the optimization process ends, most computation effort will be wasted on solving infeasible transfers. Thirdly, low thrust mission timeframe is substantially longer that the high-thrust one as the spacecraft needs longer time to accumulate the required velocity increment. This will lead a significant time-scale differences in the problem. To tackle these challenges, a deep learning based low-thrust optimization is first developed and integrated into the space logistic network modelling. For a given set of nodes, the deep learning model accurately predicts the feasible transfer windows, and output the feasibility of transfers and the corresponding optimal fuel and time consumption. Then, the network nodes can be aggregated for the time period where there is no transportation window between nodes. Enabled by the above method, a bi-level mixed-integer nonlinear programming (MINP) scheme is introduced to solve the case study of asteroid mining logistics problem. The bi-level MINP first solve the problem utilizing the deep-learning-based low-thrust optimization method and convert the problem into a linear one, then use the results as an accurate initial guess for the optimal solution by solving the real optimal control problem(OCP). The results shows that proposed framework significantly reduces 99.5% computing time with a slightly loss (less than 1%) in optimal logistic solution accuracy.