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Autonomous Navigation for Distributed Space Systems via Spacecraft to Spacecraft Absolute Tracking

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A distributed space system utilizes multiple spacecraft working in tandem to complete unified objectives. Distributed architectures are appealing because they can provide enhanced robustness for reduced costs over traditional monolithic spacecraft. Additionally, utilizing multiple vehicles allows for the capacity to fly sensor in large formations which can enable novel science. While distributed systems are promising, they require more complex planning to properly operate. Particularly, there is a need to navigate every vehicle in the system. Spacecraft navigation traditionally relies on ground-based sensor networks but scheduling observation time for each vehicle is not only costly, but potentially intractable. Thus, there is a need to examine autonomous navigation methods for distributed space systems.

In this dissertation we examine the feasibility of generating a full state estimate for every vehicle in a distributed system from relative measurements between vehicles in the system. We show that a full state estimate can be obtained due to nonlinearities in spacecraft motion, and therefore such a method could provide fully autonomous navigation. Still, even if the full state can be observed, there are regions of the state space which are slow to accrue information. To abate this, we develop guidance policies to minimize state uncertainty along a desired state projection. The policies are analytic and well suited for autonomous computation. Finally, we include methods to identify and classify unknown maneuvers on target vehicles. Having the capacity to capture and label unknown behaviors improves the robustness of the navigation solutions when communication or cooperation is not available. Overall, the combination of methods presented form a completely autonomous navigation method for distributed space systems which can improve its own state estimate and account for unmodeled events.