ON-GROUND PATH PLANNING EXPERIMENTS FOR MULTIPLE SATELLITES

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ABSTRACT

These days the size of satellites is limited due to the available shipping volume of modern launch vehicles. However, larger and larger structures are needed to improve Earth observation capabilities and the resolution of telescopes. Satellite formation flying with two or more satellites can be used to overcome this restriction. This involves coordinated flight between two or more satellites, in which new challenges arise. One of these challenges is the development of new guidance, navigation and control algorithms for formation acquisition, reconfiguration and collision avoidance.

To test these algorithms in a realistic environment the Test Environment for Applications of Multiple Spacecraft (TEAMS) test facility has been developed and built up at the Institute of Space Systems in Bremen, Germany. The testbed is a laboratory for simulating the forces and torque free dynamics of several satellites on ground. It consists of two highly smooth and even 4m x 2.5m granite tables on which several air cushion vehicles can glide. To simulate precise formation flying, as in astronomical missions, 2 vehicles can be used to simulate 5 degrees of freedom (TEAMS_5D). The vehicles consist of 2 parts: a lower translation platform and an upper attitude platform. Both platforms are connected by a spherical air bearing which allows the attitude platform to rotate freely. Air tanks mounted on the translation platform supply the air cushion pads and the spherical air bearing. The attitude platform contains components for satellite attitude and orbit control like an inertial measurement unit, magnetometers, reaction wheels, cold gas thrusters and an on-board computer. This allows the dynamic behaviour of one or more satellites to be simulated.
To simulate satellite swarms smaller vehicles with 3 degrees of freedom can be used (TEAMS_3D). These vehicles do not have a rotating upper platform and can only rotate around one axis. They are used to test formation acquisition, formation reorientation and path planning algorithms.
The main task of the TEAMS facility is to test satellite formation control algorithms on ground. However, sensors for relative attitude and position as well as spacecraft behaviour during berthing and docking manoeuvres (contact dynamics) can also be investigated using this facility.

This paper presents the implementation of an autonomous and distributed path planning algorithm for multiple satellite applications in simulation as well as on the TEAMS testbed. The algorithm is based on the virtual potential method. This gives the possibility to include different generic behaviours like gathering, docking and avoiding. From the potentials desired velocities are computed which are controlled using different methods like Sliding-Mode or Q-Guidance.
The algorithm has not only been implemented in simulation to show its functionality but is also used to guide and control the vehicles of the TEAMS testbed. The guidance algorithm is running in real-time on the on-board computer together with a Kalman Filter for state estimation, attitude control and thruster actuation algorithms.

Experiments performed in simulation and on the testbed include formation acquisition and reconfiguration, collision avoidance and tracking of one chief satellite by several deputy satellites.

This paper presents a short overview on the TEAMS test facility and gives an introduction on the used guidance algorithms. The main focus lies on the result of the experiments performed on the testbed showing the performance and the robustness of the implemented guidance algorithm.