Coordinated control of satellites: the relative position case

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In this project, position control of a formation of satellites is considered. Using methods from nonlinear control theory, controllers and estimators are derived. The theoretical results are supported by simulations.

The major reason for formations of satellites, is the desire to distribute the functionality of large satellites. The ability of small satellites to "fly" in precise formation will make a wide array of new applications possible, including a next-generation Internet, space-based radar and ultra-powerful space telescopes.

There is also an economic aspect to this; often it is more expensive to place one large satellite with all the functions built-in, into orbit than several smaller ones of the same collective weight. Therefore, as the number of missions involving formation flying spacecraft, proposed or under development, still increases, one can imagine assembly lines of standardised spacecraft, thus lowering the production cost drastically. These standardised spacecraft will of course be fully equipped with the proper instruments for their mission.

In this project, the equations of motion, both linear (Hill-Clohessy-Wiltshire) and non-linear, for micro-satellites in the leader/follower architecture were derived. Included in the nonlinear model were relevant disturbances, such as J_2-perturbations, atmospheric drag and fuel-consumption.

In order for the satellites to perform optical measurements and radar measurements, high accuracy in control and determination of position and attitude is required.

Models of gas thrusters and ion thrusters were investigated with respect to fuel consumption and ability to bring the satellites in sufficiently accurate position. To control attitude, four reaction wheels in a tetrahedron configuration were used. GPS, differential GPS and gyros were investigated to find out if they can be used to determine the position with required accuracy.

To synchronize the follower satellite, a nonlinear observer algorithm was used to calculate the necessary estimates of the motion of the leader satellite. Both a state-feedback and a passivity-based controller were derived and used in simulations, using MATLAB® and Simulink®.

In the development of observer and controller, results already achieved on formations of other types of mechanical agents (robots and ocean vehicles) were used.