Model predictive control for rigid satellite formation with underactuated propulsive system based on relative orbital elements

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Abstract:

This study is conducted based on a Formation Flying (FF) mission on a sun-synchronous orbit, development by the European Space Agency, Airbus, and Politecnico di Milano, intending to increase the imaging resolution for land and ocean applications by exploiting the virtual aperture given by the formation itself. This FF mission includes three satellites, each of them is equipped with propulsive system, which could provide the continuous forces in tangential and normal directions. During the nominal scientific phase of FF mission, it is required to keep a rigid formation and a safe flight condition. Consequently, an automatic control approach is investigated for maintaining the nominal formation geometry with underactuated propulsive system [1-3], considering the orbital disturbance. This paper proposes a model predictive control approach for rigid satellite formation maintenance scenario with tangential and normal forces based on relative orbital elements.

The rigid formation in T-N plane during the nominal scientific period and relative position are shown in Figure 1, the three satellites of the formation are identified as Sat 1, Sat 2, and Sat 3 respectively, placed at the vertex of an equilateral triangle of 13 m side. The formation is designed by COMPASS group in Politecnico di Milano, considering the balanced fuel consumption, sun shadowing effect, plume impingement, etc. And more details could be viewed on Ref [4].

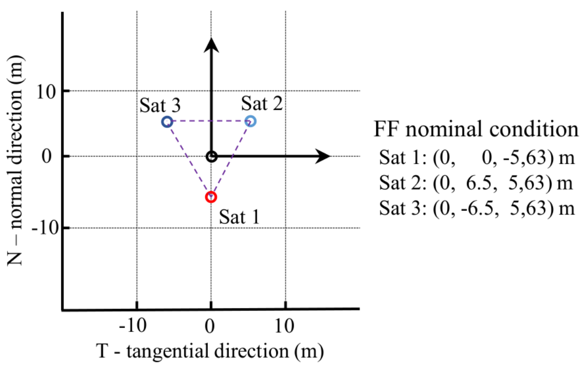

Figure 1. The rigid formation nominal condition

The relative orbital elements of Sat 3 are regarded as the formation hover scenario and analysed to valid the approach proposed in term of tracking control. The ideal trajectory of relative inclination vector $\delta\mathbf{i}$ is time-variant and other relative orbital elements are invariant according to the analytical results. This study puts the emphasis on two aspects. The first one is the maintain control issue in orbital plane with underactuated propulsive system. The second one is the tracking control out of plane under time-variant ideal relative inclination vector $\delta\mathbf{i}$.

The underactuated control equations in the orbital plane is reconstructed by combining the $\Delta\delta a$ and $\Delta\lambda$ to one element to be controlled in model predictive control by means of introducing control coefficient, while the error estimation method is proposed according to the reconstructed control system. The controllability of this method is proved in article. The selection way of this control coefficient is analyzed through the simulated result. And the effects of the underactuated and actuated control system are compared in term of control accuracy and fuel consumption, seen in Figure 2. To achieve the high precision control in the condition of the ideal trajectory of time-variant relative inclination vector $\delta\mathbf{i}$, an approach of dynamic weighted parameter adjustment is proposed. The availability is presented through simulating the scenario based on FF mission and high control accuracy is validated in condition of sampling time of 16 sec.

The introduced approach demonstrates encouraging results, shows a remarkable performance compared with actuated propulsive system, and is operationally applicable in terms of computational expenses.

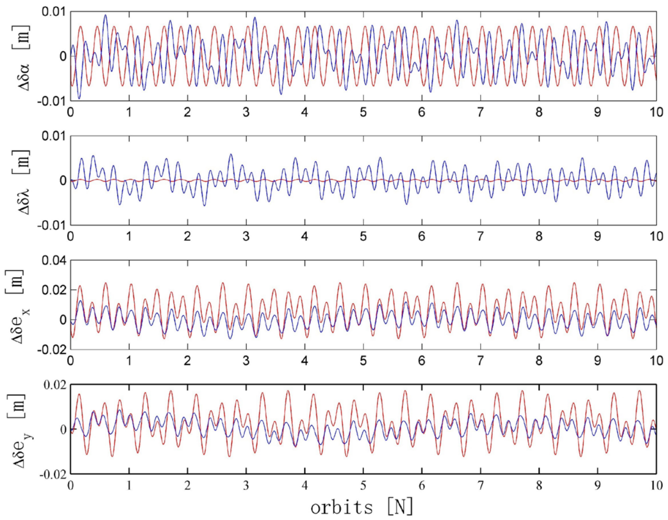

Figure 2. The control accuracy comparison between underactuated and actuated approach. Blue: actuated, red: underactuated; x-axis: 10 orbits, sampling time: 16 sec.

Reference

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