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LARGE-SCALE SPACECRAFT SWARM DECENTRALIZED FORMATION FLYING CONTROL BASED ON SLIDING MODE CONTROL AND TRACKING DIFFERENTIATOR

Abstract

Spacecraft swarm poses great advantages in various fields that are rapidly evolving with the demands for fulfilling multi-purpose space exploration missions, such as flight observations, environmental awareness, and data transmission. Based on the theory of artificial potential field and sliding mode control method, a new distributed autonomous control method for spacecraft swarm formation flying is developed. Inspired by the dynamic system theory, artificial potential velocity field of the spacecraft swarm is designed by using the nonlinear bifurcation theory to generate desired motion path. The artificial velocity field is mainly used to generate the velocity command, which can set planning path in real time. Each agent in the swarm can be drove to reach some corresponding desired position without external command, which greatly reduces the complexity of the planning algorithm. Sliding mode control is used to ensure the precise tracking control for members and system robustness to eliminate external disturbance and uncertainties. In this paper, the nonlinear dynamic model of spacecraft swarm relative motion in Hill system is proposed, which assumes that each spacecraft can only measure the relative position with all the other members of the swarm, but not the relative velocity. Then a unique filter algorithm is proposed by using so called tracking differentiator method. This filter algorithm can generate the relative velocity signals from the relative position signals, which are necessary in the artificial velocity field command tracking control. The artificial velocity field is established by the hyperbolic-exponential function which has a nonlinear static bifurcation characteristic. Different static configuration can be realized, such as circle, double concentric circles and disc. Sliding mode control is presented to ensure the precise tracking control of the velocity of each spacecraft in the swarm. The sliding manifold and the control law are designed respectively. Sliding manifold is selected to be a simple linear function and the actual speed of the swarm agents can track their desired values. The control law is designed using high order sliding mode Super-Twisting algorithm based on equivalent control so that the approaching motion (non-sliding mode) reaches the sliding manifold quickly and stably over a limited time. Numerical simulations are presented to show the feasibility of the proposed control strategy, which can achieve various desired swarm formation flying configurations and accomplish formation capture, maintenance and reconstruction successfully.