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带时变通信时间延迟的卫星编队姿态协同自适应L_2增益控制

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Adaptive L_2-gain Cooperative Attitude Control of Satellite Formation Flying with Time-varying Delay

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摘要 针对卫星编队姿态协同分布式控制问题,提出一种基于*Lyapunov*方法的编队飞行协同控制策略。首先,考虑到实际编队飞行中星间通信存在时变时间延迟及模型不确定问题,结合变结构控制的思想设计一种针对时滞系统稳定性分析的*Lyapunov*函数,从而由直接*Lyapunov*方法得到可对模型参数进行估计的自适应分布式姿态协同控制器,并论证其构成的闭环系统的稳定性。其次,考虑到外界干扰对系统的性能输出影响,利用L_2增益耗散不等式重新设计控制器参数,使系统满足L_2增益稳定的条件。该控制器不仅能够克服星间时变通信时间延迟对编队卫星姿态协同带来的影响,使编队卫星达到姿态的协同跟踪,同时还能抑制外界干扰对系统输出的影响,使闭环系统满足整体编队输出性能指标要求。最后,将提出的算法应用于双星编队姿态协同控制问题,仿真结果表明该方法具有可行性、有效性及潜在的应用前景。

关键词: 编队飞行 协同控制 L_2增益扰动抑制 时间延迟 *Lyapunov*函数

Abstract: This article develops a new Lyapunov design based cooperative attitude control scheme for satellite formation flying with time-varying delay by explicitly taking attitude tracking performance into account. First, this article introduces a proper Lyapunov function to design an adaptive variable structure control law, with this control law the model uncertainties, external disturbances and even variable time-delay in the inter-satellite communication are explicitly considered simultaneously. Second, the tracking performance is evaluated by L_2-gain from the disturbance input to the penalty output. The novelty of the approach lies in the strategy to construct such a Lyapunov function scarifying the L_2-gain dissipative inequation that ensures not only the stability of a cooperative attitude tracking formation system but also an L_2-gain constraint on the tracking performance. This provides a better closed-form solution to depress the external disturbances in order to achieve a better output performance for satellite formation flying cooperative attitude control as compared with the conventional methods. Complete stability and performance analysis is presented and illustrative simulation results of an application to satellite formation flying show that high precision attitude control with zero steady-error is successfully achieved using various scenarios of time-delay.

Keywords: formation flying cooperative control L_2-gain disturbance attenuation time delay Lyapunov function

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