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TIME-SYNCHRONIZED ATTITUDE TRACKING DURING RENDEZVOUS AND DOCKING MANEUVERS

Abstract

Previous research on attitude tracking control for rendezvous and docking maneuvers focuses on forcing the attitude vector to ultimately converge to the equilibrium, ignoring any consideration of when each attitude element converges relative to the others. However, during rendezvous and docking maneuvers, it is desirable if all the attitude elements reach the target values *at the same time*, namely *time-synchronized attitude tracking*. This convergence property would significantly avoid the chattering and improve the pointing accuracy during rendezvous and docking maneuvers, resulting in a higher mission success rate. To achieve time-synchronized attitude tracking, we first define time-synchronized stability and propose its sufficient Lyapunov-like conditions.

To be more specific, we consider the following general system,

$$\dot{x} = f\left(x\right),\ f\left(0\right) = 0,\ x(0) = x_0, \tag{1}$$

where $x = \left[x_1, \ldots, x_n\right]^T \in \mathbb{R}^n$, and with respect to an open neighborhood $\mathcal{D}_0 \subseteq \mathbb{R}^n$ of the origin, $f : \mathcal{D}_0 \to \mathbb{R}^n$ is continuous. We assume that the system (1) has a unique solution for all initial conditions in forward time. Next, the following well-established results are introduced.

The time-synchronized stability is proposed as follows
Definition: The equilibrium of the system (1) is *time-synchronized stable* if

i. it is finite-time stable;

ii. for an open neighborhood $\mathcal{N}_0 \subseteq \mathcal{D}_0$ of the origin, there exists a function $T : \mathcal{N}_0 \backslash \{0\} \to (0, \infty)$, called the *synchronized settling-time function*, such that for $\forall x_0 \in \mathcal{N}_0 \backslash \{0\}$ and $i \in \{1, 2, \ldots, n\}$, we have $x\left(t\right) \in \mathcal{N}_0$, $\forall t \in [0, \infty)$, and for $x_i(0) \neq 0$,

$$x_i\left(t\right) \neq 0,\ \lim_{t \uparrow T(x_0)} x_i\left(t\right) = 0,\ \forall t \in [0, T(x_0)), \tag{2}$$

where $T\left(x_0\right)$ is the *synchronized settling time*.

The equilibrium is globally time-synchronized stable if it is time-synchronized stable with $\mathcal{N}_0 = \mathcal{D}_0 = \mathbb{R}^n$.

Based on the time-synchronized stability formulations, we further suitably design a time-synchronized attitude tracking control strategy. In addition, the analytical solution of a time-synchronized stable attitude tracking system is obtained and discussed, explicitly offering a quantitative method to preview

and predesign the control system performance during rendezvous and docking maneuvers *in prior*. Finally, numerical simulations are conducted to present the time-synchronized attitude tracking features attained, compared with traditional control strategies; and further explorations of the merits of the time-synchronized convergence are described.