854. Synchronization of a chaotic gyroscopic system under settling time constraints

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Abstract. A simple and easy-to-implement method that guarantees the effective active synchronization of a chaotic gyroscopic system within a specified settling time limit is presented. A closed-form expression is given for the determination of the appropriate synchronizing control signal. The method is successfully validated through simulations for various initial conditions of the gyroscopic system.

Keywords: chaotic gyroscopic system, chaos synchronization, nonlinear control.

Introduction

Gyroscopic systems pervade in modern systems such as aerospace systems, electromechanical devices and telecommunication systems. Furthermore, since they are used for precise angular measurements in critical systems, they require accurate control to ascertain the validity of their measurements. Therefore, they deserve rigorous processing mainly when their dynamics are subject to chaos. Some nonlinear dynamical systems may exhibit chaotic behavior due to specific values of their parameters. Besides, in some applications such as secure signal transmission, it may be necessary to control a regular or chaotic signal to make it track the motion of another chaotic system. Basically, the principle of active control of chaotic systems consists in perturbing the dynamics of a given chaotic system by adding control terms to its dynamic model so as to force its overall dynamics to be identical to that of the same or another system departing from totally different initial conditions. The tracking control process of chaotic systems is known as chaos synchronization. Chaos synchronization deals with driving a chaotic system (called the driven system) to track the dynamics of the same or another chaotic system (called the main system) with different initial conditions. The difficulty is that chaotic systems are known to behave in significantly different manner even for relatively close initial conditions. Therefore, the problem of chaos synchronization deserves a special treatment that mostly requires special tools borrowed from control theory. Chaos synchronization has received a high interest in nonlinear science during the last two decades [1-10]. This is due to the fact that many mechanical, electrical and natural systems are prone to vibration phenomena that are in general governed by highly nonlinear dynamics and which may in some conditions degenerate to chaos [11-13]. The present paper deals with the active synchronization of a chaotic gyroscopic system [7]. Existing methods in the research literature [7-9] on the synchronization of such a system mainly deal with a mere asymptotic synchronization without any guarantee that the synchronization will effectively occur within a specified time limit. Furthermore, the methods in use for synchronizing chaotic systems [1-10] require either linearizing the nonlinear model of the system, or finding Lyapunov function candidates that are usually cumbersome to achieve for time-varying systems. The present paper proposes a nonlinear control method that guarantees the synchronization of a chaotic gyroscopic system within a pre-specified settling time. The paper is organized as follows: the following section describes the model of the chaotic gyroscopic system that is subject to the synchronization problem and states the problem to be solved in the paper; then the next section deals with a nonlinear control law to ascertain an actual synchronization process under settling time constraints; numerical simulation results based on different initial conditions of the main and the driven system are analyzed in a subsequent section to demonstrate the effectiveness of the proposed method.