Chapter 9
Chaotic Gyros Synchronization

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ABSTRACT

In this chapter, three methods for synchronizing of two chaotic gyros in the presence of uncertainties, external disturbances and dead-zone nonlinearity are studied. In the first method, there is dead-zone nonlinearity in the control input, which limits the performance of accurate control methods. The effects of this nonlinearity will be attenuated using a fuzzy parameter approximator integrated with sliding mode control method. In order to overcome the synchronization problem for a class of unknown nonlinear chaotic gyros a robust adaptive fuzzy sliding mode control scheme is proposed in the second method. In the last method, two different gyro systems have been considered and a fuzzy controller is proposed to eliminate chattering phenomena during the reaching phase of sliding mode control. Simulation results are also provided to illustrate the effectiveness of the proposed methods.

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INTRODUCTION

Although chaotic systems have deterministic behavior, they are extremely sensitive to initial conditions and difficult to predict. Furthermore, some noises, disturbances and uncertainties always exist in the physical systems that can make system instability.

Synchronization of chaotic systems is one of the most interesting fields of chaos control. Many approaches have been introduced to treat this problem in the few past decades. Synchronization can be defined as two coupled systems conducting coupling evolution in time with given different initial conditions (Li, Chen, Shi & Han, 2003), in other words the purpose of synchronization is to use the output of master system to control the slave system, so that the output of slave system achieves asymptotic synchronization with the output of master system.

Since the pioneering work of Pecora & Carroll (1990), various synchronizations such as feedback control (Wu, Yang & Chua, 1996;Salarieh & Shahrokhi, 2008; Li, Xu & Xiao, 2008); Sliding Mode Control (SMC) (Yan, Hung & Liao, 2006;), backstepping design (Parmananda,1998; Yin, Ren & Shan, 2002), H_∞ control (Slotine, 1991) and adaptive control (Hwang, Hyun, Kim & Park, 2009; Roopaei & Zolghadri Jahromi, 2008; Yassen, 2006; Yassen, 2007) methods have been developed for them.

In mechanical devices, such as positioning tables, overhead crane mechanisms, robot manipulators, gyroscopes, etc. Many accurate control methods are required. For many of them, the performance is limited by friction and dead-zone (Zhou, Shen &Tamura, 2009; Lei, Xu & Zheng, 2005). In particular, precise positioning control of very small displacement is an especially difficult problem for micro positioning devices. Due to lack of precise knowledge about the nonlinearities present in actuators and the fact that their exact parameters (e.g. width of dead-zone) are unknown, these systems present a challenge for the control engineering communities.

A variety of physical principles are utilized for rotation sensing, including mechanical sensing, the Sagnac effect for photons (Stedman, 1997; Andronova & Malykin, 2002), the Josephson effect in super fluid and nuclear spin precession (Woodman, Franks & Richards, 1987). However, mechanical gyroscopes operating in a low gravity environment remain so far unchallenged. (Buchman et al. 2000).

A gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. The device is a spinning wheel or disk whose axle is free to take any orientation (Figure 1). This orientation changes much less in response to a given external torque than it would without the large angular momentum associated with the gyroscope high rate of spin. Since external torque is minimized by mounting the device in gimbals, its orientation remains nearly fixed, regardless of any motion of the platform on which it is mounted. Sensitive gyroscopes are used in many applications, from inertial navigation to studies of the Earth rotation and tests of general relativity (Stedman, 1997).

Recent researchs has specified various types of gyro systems with linear/nonlinear damping characteristics. These systems exhibit a diverse range of dynamic behavior including both sub-harmonic and chaotic Motions (Slotin & Li, 1991; Stedman, 1997; Andronova & Malykin 2002).

The chaotic behavior of gyros was initially introduced by Leipnik and Newton (1981). In (Tong & Mrad, 2001; Ge, H.K Chen & H.H. Chen, 1996) the nonlinear dynamics of a symmetric heavy gyroscope, mounted on a vibrating platform was studied. In these works, a linear damping coefficient was assumed for the gyro system. In (Chen, 2002; Dooren, 2003) it was shown that under base harmonic excitation and a nonlinear damping force; the gyro system exhibit chaotic behavior.

Recently, synchronization of chaotic gyros has been widely investigated by many researchers. Synchronization of two gyros is usually used in areas of secure communications (Chen & Lin, 2003) and attitude control of long-duration spacecrafts (Zhou, Shen & Tamura, 2006).