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HIGH GAIN OBSERVER BASED SYNCHRONIZATION FOR A CLASS OF TIME-DELAY CHAOTIC SYSTEMS: APPLICATION TO SECURE COMMUNICATIONS

Estelle Cherrier, Mohammed M'Saad and Mondher Farza †

Abstract. This work investigates high gain observer design to synchronize a time-delay chaotic system. It is shown that the underlying class of nonlinear systems can be put into the canonical observable form, and thus high gain observer design framework can be extended to chaotic synchronization problem. Our approach is motivated by its simplicity of implementation: the observer gain synthesis relies on the explicit resolution of a time-invariant algebraic Lyapunov equation, which leads to a single parameter design. The proposed synchronization scheme is validated in a real-time experimental setup, based on Analog/Digital dSpace electronic device. At the end of the paper an information transmission process is provided, based on the previous synchronization scheme.

Keywords. Chaos, synchronization, nonlinear observer, high-gain techniques, time-delay system.

1 Introduction

If state estimation of linear systems has been widely treated through the last four decades, the nonlinear case, which concerns most of physical processes, remains however an open and very active research field. Among the recent applications of nonlinear state estimation theory, chaotic synchronization represents a pregnant issue, even if the words "chaos" and "synchronization" themselves have seemed incompatible for a long time. Indeed, on the one hand, the word "synchronization" come from the Greek roots $\sigma\upsilon\gamma$ (*syn*), which means "with", and $\chi\rho o\nu o\varsigma$(*chronos*), which means "time". Hence we can give a first definition of synchronization notion: it characterizes two systems having the same behavior at the same time. In fact, synchronization effects have been observed since the XVIIth century, when the Dutch mathematician Huygens noticed the synchronization of two pendulum clocks placed against the same wall. Consequently, synchronization was reserved to periodic systems (two signals were said synchronized if their periods were identical). On the other hand, among nonlinear systems, chaotic systems are characterized by a very complex behavior, asymptotically aperiodic. *A priori*, the nature of chaotic systems would seem to challenge the notion of synchronization. No further attention was paid to this issue, until 1983, and the work of Yamada and Fujisaka [33]. They noticed that, by coupling oscillators which on their own evolved chaotically, it was possible under certain hypotheses to force them to evolve in an identical manner. This happened even if the two systems did not start with the same initial conditions. Despite this breakthrough, the subject of chaotic synchronization seemed to have no obvious applications until 1990. In their pioneering paper [28], Pecora and Carroll gave necessary and sufficient conditions under which two chaotic systems would synchronize. They also indicated that by using chaotic synchronization it might be possible to communicate in a secure way, by using the chaotic signal as a mask, used to hide the information-bearing message. This promising application gave rise to a huge number of papers concerned with chaotic synchronization. For general surveys on this subject, the reader is referred to the references [29], [4], [3]. Then synchronization has become a state estimation issue. The papers [26], [27] have shown that it is possible to estimate chaotic systems states, using nonlinear control theory.

Indeed, the chaotic transmitter belongs to the wide class of nonlinear dynamical systems, whereas the receiver can be viewed as a nonlinear observer of the transmitter system. Furthermore, nonlinear estimation theory can be used to design a receiver which synchronizes with the driving system. This nonlinear control point of view brings many approaches to the receiver conception problem, and the underlying synchronization analysis problem. Among the huge amount of references on this subject, we can quote [25], which builds an observer-based synchronization scheme, guaranteeing an exponential synchronization. A generalization to a larger class of nonlinearities is proposed in [5]. [2] details a particular observer design, whose gain can be expressed in function of the desired convergence speed. But other approaches can also be found in the tremendous literature. For instance, the synchronization problem is addressed as a chaos suppression issue in [18]. A synchronization criterion based on a linear feedback

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†Estelle Cherrier, Mohammed M'Saad and Mondher Farza are with GREYC UMR 6072 CNRS, Boulevard du Maréchal Juin, 14050 Caen France. E-mails: estelle.cherrier@greyc.ensicaen.fr, mohammed.msaad@greyc.ensicaen.fr, mondher.farza@greyc.ensicaen.fr