Chapter 3
Identification and State Observation of Uncertain Chaotic Systems Using Projectional Differential Neural Networks

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ABSTRACT

The following chapter tackles the nonparametric identification and the state estimation for uncertain chaotic systems by the dynamic neural network approach. The developed algorithms consider the presence of additive noise in the state, for the case of identification, and in the measurable output, for the state estimation case. Mathematical model of the chaotic system is considered unknown, only the chaotic behavior as well as the maximal and minimal bound for each one of state variables are taking into account in the algorithm. Mathematical analysis and simulation results are presented. Application considering the so-called electronic Chua’s circuit is carried out; particularly a scheme of information encryption by the neural network observer with a noisy transmission is showed. Formal mathematical proofs and figures, illustrate the robustness of proposed algorithms mainly in the presence of noises with high magnitude.

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1. INTRODUCTION

Identification, control and synchronization of chaotic systems are gaining great importance and attention in physics and engineering researching topics. Many investigation methods have used modern elegant theories to control chaotic systems, most of them based on the exact chaotic model (differential equations) (Chen & Dong, 1995), (Nijmeijer & Berghuis, 1995), (Gallegos, 1994). If the chaotic system is partly known, for example the differential equation is known but some of the parameters are uncertain, adaptive control methods (Zeng & Singh, 1997) are required.

Alternatively, synchronization of chaotic systems has recently received much attention. Several chaos synchronization schemes have been successfully established (Liao & Huang, 1999), (Jiang, 2002) but their results have been obtained with well-known systems having complete knowledge of system model and full state disposal. Therefore, the synchronization of chaotic systems with parametric uncertainties or different structure is an important issue. Femat proposed an extended form and several schemes have been reported (Femat & Alvarez-Ramirez, 1997), (Femat, Alvarez-Ramirez & Fernández-Anaya, 2000), (Femat & Jauregui-Ortiz, 2001) based on extend state observer theory to solve the problem. On the other hand, (Liao & Tsai, 2000) to solve the chaos synchronization of nonlinear systems specific class with disturbances and unknown parameters by deriving an adaptive observer-based driven system via a scalar transmitted signal.

In all previous control and identification problems, the modeling theory represents the most usual manner to formalize the systems dynamics knowledge. However, in several real chaotically systems, modeling rules may fail generating acceptable reproductions of reality (Meyer, 1992). In those cases, nonparametric identification and estimation (using adaptive methods) can be successfully applied to cover possible model deficiencies. Within the nonparametric identification framework, function approximation techniques play an important role avoiding the necessity of accurate mathematical plant description (Hartmut & Hartmut, 1997).

Nowadays the area of identification has a lot of applications using artificial neural networks (ANN), fuzzy logic and evolutionary algorithms. All these applications born like an alternative to forecast non-linear dynamics like chaos. However, there exist few theoretical results describing how these algorithms map such dynamics if we compared them with the number of reports and publications in the area. The idea of learning applied to identification and control systems is every day more used and some papers search to reduce the existing gap between the learning and identification theory (Campi & Kumar, 1996), (Ljung, 1996). These models, in many cases, require some kind of previous knowledge about the plant to be identified to define the type of model that it is going to be used. This means that it is possible to find many different combinations of algorithms or functions that represent the system dynamics. However, the problem is that sometimes, can be nonlinear and the identified model does not represent this behavior.

In general, unknown chaotic systems are black box belonging to a given class of nonlinear complex systems. Therefore, a non model-based method is suitable. Among others, NN have become an attractive tool for modeling complex non-linear systems. Their inherent ability to approximate arbitrary continuous functions supports the last statement. NN are particularly powerful for handling large-scale problems. However, NN implementation suffers from lack of efficient constructive approaches, both for choosing network structures and for determining the neuron parameters. It has been proven that artificial NN can approximate a wide range of nonlinear functions to any desired degree of accuracy under specific constrains (Omidvar & Elliot, 1997). It is generally understood that NN training algorithm selection plays an important role for NN applications. In instance, in conventional gradient-descent-type weight