ADAPTIVE CONTROL USING NEURAL NETWORK FOR MINIMUM-PHASE STOCHASTIC NONLINEAR SYSTEM

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ABSTRACT

In this paper, some geometric condition for a stochastic nonlinear system and an adaptive control method for minimum-phase stochastic nonlinear system using neural network are provided. The state feedback linearization is widely used technique for excluding nonlinear terms in nonlinear system. However, in the stochastic environment, even if the minimum phase linear system derived by the feedback linearization is not sufficient to be controlled robustly. In the viewpoint of that, it is necessary to make an additional condition for observation of nonlinear stochastic system, called perfect filtering condition. In addition, on the above stochastic nonlinear observation condition, I propose an adaptive control law using neural network. Computer simulation shows that the stochastic nonlinear system satisfying perfect filtering condition is controllable and the proposed neural adaptive controller is more efficient than the conventional adaptive controller

1. INTRODUCTION

In the past two decades, differential geometry has provide to be an effective means of analysis and design of nonlinear control system as it was in the past for a linear algebra in relation to linear system. Through the study of many researchers in the nonlinear control theory, the geometric approach has been shown to be very efficient in solving various synthesis problems of linear and nonlinear systems as noninteracting control problems and disturbance decoupling problems which has constant DC disturbance or linear combinatorial noise with wide range frequency [6].

However, in the nonlinear system including white noise, the disturbance decoupling problem is not the same to the conventional problem. The reason is that the nonlinear system including white noise is not a system with simple uncertain terms and the white noise is the most complex uncertain terms as unpredictable and unobservable terms. The white noise can represents an uncountably large value even if the probability of that is very low. Hence, essentially, the nonlinear system with a white noise is not a bounded input system in that the disturbance generated by a white noise looks like another input. Consequently, the control of the stochastic system needs very robust control law such that LQ control and various kinds of Kalman filters[8], [9].

Adaptive control is other choice of a nonlinear system control. Over the last 3 decades, adaptive control theory has evolved as a powerful methodology for designing nonlinear feedback controllers for system with parametric uncertainty[2] [10]. However, in the nonlinear control system, adaptive control was not seriously considered until recently. The reason is that adaptive control law is basically based on the linear system, thus, it was very difficult to apply to the nonlinear system. Recently, as the techniques in adaptive control of nonlinear systems were facilitated by advances in geometric nonlinear control theory, in particular, feedback linearization method[6], new adaptive control strategies such as the backstepping procedure, tuning functions, has been developed.

Neural network techniques have been found to be particularly useful for controlling highly uncertain, nonlinear, and complex systems. The feasibility of applying neural network architecture for modeling unknown functions in dynamic environments has been demonstrated by several studies [11] [12]. Most of these studies are based on gradient techniques for deriving parameter adaptive law for system identification[5]. While such schemes are perform well in many cases, in general, there are no systematic analytical methods of ensuring the stability, robustness, and performance properties of the overall systems.

In an attempt to overcome these problems, there have been recent studies of neural network learning algorithms based on Lyapunov's stability theory. The advantage of these training method is that the adaptive law is derived based on the Lyapunov synthesis law and therefore guarantee the stability of the system.

Even though the adaptive control law of nonlinear system control with neural network is derived by Lyapunov's theory, there exist a critical problem. Since most neural network includes the nonlinear functions such as hyperbolic tangent, Gaussian distribution function and various kinds of penalty functions, it is very difficult to develop a certain canonical control law for general case of nonlinear systems. In many cases, therefore, derived control law is well worked in a stability guaranteed region or for some particular nonlinear system.

In addition, it is necessary to develop a novel state space model of neural network. In the nonlinear system control using the feedback linearization method, the nonlinear system is described as the linear state space model called as Brunowski canonical form by coordinate transform of system state vector. Consequently, if there exist a reasonable state space model of neural network, it may be easy to develop the control law for nonlinear system control using neural network .

Furthermore, the feedback linearization for stochastic nonlinear system control needs some additional filtering condition. In attempt to control the stochastic nonlinear system, it is very reasonable viewpoint that states describing system dynamics have to be estimated correctly in the environment of white noise. However, in marked contrast to the case of linear system, the state transition probability has a purely nonlinear transition property governed by estimation (Lie) algebra [3]. Therefore, an innovation process generated by the difference of a system output and estimated output is not defined globally, thus, the conventional Kalman-Bucy filter or extended Kalman filter cannot work correctly in whole R^n.

Consequently, the introduction of an additional filtering condition is prerequisite to a stochastic nonlinear system with the feedback linearization, and using the filtering condition, the state estimation of nonlinear system with feedback linearization can be transformed the conventional linear stochastic system[4].