CHAPTER 1

Introduction

1.1 Motivation

In order to design a conventional controller, for example a PID controller [19, 54], it is necessary to have the exact knowledge of the plant's model and parameters. However, in many situations, the mathematical model of plant is nonlinear and rather hard to derive [26, 32]. Moreover, even the model is known, its parameters may not be accurately specified due to measurement errors [25]. These factors make the design of the robust conventional controller complicated [15, 53].

Recently, controllers based on intelligent algorithm have been introduced [1, 16, 38, 41, 51, 63]. One of these techniques is the integration of fuzzy logic and neural network called neuro-fuzzy system [4, 28–30, 44]. This approach combines strong features of both neural network and fuzzy logic control [24,45,52]. It has the learning ability of neural network [11, 35, 47, 50] and the human-like reasoning of fuzzy logic system. Many engineering applications of neuro-fuzzy system have been proposed, for examples, system identification [3, 10, 17, 42, 60], system uncertainty estimation [23, 64], and neuro-fuzzy controller (NFC) [44]. Based on the plant's fuzzy control rules, NFC can be designed without using the accurate mathematical model. Its performance can be further optimized by adjusting some parameter and structure via learning algorithms [37, 58]. Nevertheless, most of these NFC have complex architectures and learning algorithms [67–69].

The objective of this research is to design an adaptive controller using only the knowledge about plant's operation in the form of fuzzy rules. There is no need to obtain the exact mathematical model of the controlled plant. The technique for parameter adaptation is also proposed, in order to cope with the uncertainty in plant's model. Although these properties are similar to NFC, the proposed controller structure and adaptation method will be less complicated.

1.2 Main Contributions

In this dissertation, the self-adjustable network called *Fuzzy Rules Emulated Network*(FREN) and its multi input version called *Multi Input Fuzzy Rules Emulated*

Network(MIFREN), are proposed. The network can encode a knowledge in the form of the fuzzy IF-THEN rules into its structure. To fine tune the network parameters, the gradient based searching algorithm and the adaptive filter theory are modified to adjust these parameters. Some control applications of FREN and MIFREN have been performed by computer simulations. In summary, the following contributions have been accomplished,

1. The FREN controller and its adapatation technique based on the steepest descent algorithm are proposed.
2. The FREN is applied to some direct control systems. The tracking and other performance indices are investigated and the results are satisfied. However, the results are not good when the controller is applied to control some chaotic plants.
3. The discrete time sliding mode control techniques [9,13,33,61] are applied to determine the control effort bounds. Good results are obtained in the chaotic plants.
4. The multi-input extension of FREN namely MIFREN is proposed. It has been sucessfully applied to the system identification application and as the controller for discrete-time nonlinear systems.

This dissertation is organized as follows,

- Chapter 2 reviews some background of related previous researches.
- In chapter 3, the FREN's structure, the learning algorithm and its properties are explained.
- Chapter 4 presents the application of using FREN as the direct controller for nonlinear discrete-time plants. Several computer simulation results are presented and discussed.
- In chapter 5, the sliding mode control is applied to determine the control effort bounds.
- In chapter 6, the FREN is modified to be the multi input network called MIFREN. Examples of its usage as discrete-time nonlinear system identifications and controllers are demonstrated.
- In chapter 7, conclusions and some future research directions are given.