CHAPTER 7

Conclusions and Future Research Directions

7.1 Conclusions

In this research, a combination architecture between fuzzy inference system and neural network called Fuzzy Rule Emulated Network (FREN) is proposed. This network has a simpler structure and lower computational load than other neuro-fuzzy networks. The network structure of FREN is created by using human knowledge in the form of the fuzzy IF-THEN rules. By setting appropriate membership functions and linear consequence parameters, the FREN can be functional equivalent to the conventional fuzzy inference system such as Mamdani.

The application of FREN as a direct adaptive controller for the nonlinear discrete-time system is presented. The parameter adaptation and the learning rate selection techniques based on Lyapunov stability criteria are accomplished by using the *plant information* signal. Superior performances comparing with other controllers such as native neural networks, PID and other self-adjustable networks of this proposed control are demonstrated via many computer simulation experiments with some nonlinear plants.

To improve the stability of controllers based on the artificial intelligent technologies, the stable bounds computation based on the modified sliding mode control technique is proposed. The value of the control effort generated by the FREN controller is kept within these stable bounds. The performance of the proposed technique can be clearly observed from the results of computer simulations of the discrete-time robotic system and some chaotic systems. The technique can be applied to other artificial intelligent controller as well.

The FREN is firstly designed for using as a direct controller based on the parallel structure since the number of the fuzzy IF-THEN rules is small and only one input channel of FREN is enough. However, in other applications such as the nonlinear system identification, multi-input networks is needed. For such applications, the multi-input FREN or MIFREN is invented. By using MIFREN together with the sliding bound, it is found that the tracking performance is faster than that of FREN with the sliding bound. Furthermore, MIFREN is applied as the nonlinear system identification. In this application, the hybrid learning algorithm using the modified adaptive filter technique and the gradient-descent to tune up linear and nonlinear parameters respectively is proposed. The superior performance of MIFREN and its hybrid learning can be seen from the computer simulations.

7.2 Future Research Directions

For the future research directions, the author thinks that this work should be extended in the following areas:

- In this work, only the SISO controlled plant is considered. The controller for MIMO systems based on the adjustable network like FREN or MIFREN should be investigated.
- When defining the IF-THEN rules, how to select the number of linguistic values of the input variables is one of the most important problems. If the number of linguistic values is too few then the resolution of the input variables is not enough. On the other hand, when the number of linguistic values is too many, the number of rules and adajustable parameters is large. In many applications, the optimal number of linguistic values is needed to design the control rules. A structure learning phase will be included to FREN or MIFREN to cope with this problem.
- The major reason that the conventional control literature is resistant to neural network and fuzzy controllers is the lack of stability analysis. Thus the stability analysis for FREN and MIFREN controllers should be studied in more detail.