1. Introduction

Nonlinear system identification was a method to use input-output dataset to estimate system's nonlinear mathematical model. Among many system identification methods, artificial neural network (ANN) was frequently used to simulate the dynamic relationship between output and input of nonlinear system, and the effect of its application in function approximation) was pretty good [1-2], it not only had good fault-tolerant ability, but also had good generalization ability, however, its learned result was a black-box, therefore, it did not have ability of explanation to the user, and ANN's applications in many fields were limited in certain degree. Relative to ANN, fuzzy inference system was another alternative that can be applied in system identification [3-4]; through fuzzy inference, human's knowledge and experiences could be converted into fuzzy principles that are easy to understand. However, although the behavior of the use of fuzzy system to simulate nonlinear system had feature of linguistic information, yet it was lack of accurate quantitative analysis and learning ability of numerical value calibration.

Traditional fuzzy technique had to rely on expert's experience provided by expert to set up fuzzy system, however, ANN's ability to conduct learning and extract knowledge through training data had created complementary characteristic to fuzzy technique, and neuro-fuzzy systems was developed under such design concept. Jang, in 1993, had associated two algorithms of fuzzy theory and ANN to propose an innovative architecture of ANFIS [6]. Generally speaking, ANFIS used BP algorithm and LSE method to adjust the parameter of membership function so that it can fully exploit model's processing capability on system uncertainty and imprecision, and lots of literature had shown that ANFIS had good result on the identification of nonlinear system [5-7].

The architecture design of ANFIS model can generally be divided into two stages of structure identification and parameters identification. In structure identification stage, theoretically, when more rules were used, it will be more helpful to construct a more complicated system, however, it will cause the increase of calculation amount at the same time. Therefore, when we were constructing fuzzy system, the first thing needed to do was to summarize input spaces with similar outputs and to use appropriate fuzzy set to describe each input space with similar characteristic, therefore, it will be easy to use several fuzzy rules to construct a complicated nonlinear system. For ANFIS design method associating clustering technique, each cluster center obtained through cluster analysis can generate a fuzzy region, and can be mapped to a fuzzy rule in ANFIS architecture. Competitive learning algorithm was a self-organization learning method in its nature, and it can find from unlabeled samples for some similar features, rules or relationship, then these samples with similar features were gathered into the same class. In other words, competitive learning algorithm can find automatically from training data the inherent class rule, and the similarity of the processed data or its distribution state in high dimensional space can also be displayed; therefore, competitive learning was also very suitable to be applied in structure identification of ANFIS.

The parameter identification of traditional ANFIS has adopted ANN learning algorithm to obtain network parameters. Presently, all ANN designs almost adopted design procedure of design-evaluate-test cycle; in the structure design stage, it was needed to set up first parameters such as network structure, connection topology, transfer function or learning rate; in the evaluation stage, the learning example was conducted with simulation and evaluation; in the final test stage, unlearned data were used for the test. If the obtained results were not perfect, then the original design structure needed to be changed, that is, to start a new design cycle. Such design procedure meant that ANN designer was in an all possible network configuration space to use random method to search an optimized network configuration, and this also explained that ANN design can be seen as an optimization problem; therefore, many researches further proposed design method associating evolutionary computation to enhance the effectiveness of ANFIS [8-10].

In this study, evolutionary ANFIS modeling approach was proposed based on competitive learning. First, competitive learning rule was used to conduct input space partitioning of fuzzy inference system (FIS) so as to explore effectively the clustering distribution state of training data, meanwhile, the obtained result was used in fulfilling coarse-level structure identification of ANFIS. After finishing structure identification of ANFIS, through hybrid learning scheme associating PSO algorithm and least square estimation (LSE), premise parameters were finely tuned, and consequent parameters were learned, finally, parameter identification work of ANFIS model was finished.