Chapter 16
Analysis and Modelling of Hierarchical Fuzzy Logic Systems

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ABSTRACT

In this article the design and development of a hierarchical fuzzy logic system is investigated. A new method using an evolutionary algorithm for design of hierarchical fuzzy logic system for prediction and modelling of interest rates in Australia is developed. The hierarchical system is developed to model and predict three months (quarterly) interest rate fluctuations. This research study is unique in the way proposed method is applied to design and development of fuzzy logic systems. The new method proposed determines the number of layer for hierarchical fuzzy logic system. The advantages and disadvantages of using fuzzy logic systems for financial modelling is also considered. Conclusions on the accuracy of prediction using hierarchical fuzzy logic systems compared to a back-propagation neural network system and a hierarchical neural network are reported.

INTRODUCTION

Computational intelligence techniques such as neural networks, fuzzy logic, and evolutionary algorithms have been applied successfully in the place of the complex mathematical systems (Kosko, 1992; Cox, 1993). Neural networks and fuzzy logic are active research area (Zadeh, 1965; Kosko, 1992; Lee, 1990; Cox, 1993; Mohammadian & Stonier, 1995; Welstead, 1994). It has been found useful when the process is either difficult to predict or difficult to model by conventional methods. Neural network modelling has numerous practical applications in control, prediction and inference.

Time series (Ruelle, 1998) are a special form of data where past values in the series may influence future values, based on presence of some underlying deterministic forces. Predictive model use trends cycles in the time series data to make prediction about the future trends in the time series. Predictive models attempt to recognise
patterns and trends. Application of linear models to time series found to be inaccurate and there has been a great interest in nonlinear modelling techniques.

Recently techniques from computational intelligence fields have been successfully used in the place of the complex mathematical systems for forecasting of time series. These new techniques are capable of responding quickly and efficiently to the uncertainty and ambiguity of the system.

Fuzzy logic and neural network systems (Welstead, 1994) can be trained in an adaptive manner to map past and future values of a time series and thereby extract hidden structure and relationships governing the data. The systems have been successfully used in the place of the complex mathematical systems and have numerous practical applications in control, prediction and inference. They have been found useful when the system is either difficult to predict and or difficult to model by conventional methods. Fuzzy set theory provides a means for representing uncertainties. The underlying power of fuzzy logic is its ability to represent imprecise values in an understandable form. The majority of fuzzy logic systems to date have been static and based upon knowledge derived from imprecise heuristic knowledge of experienced operators, and where applicable also upon physical laws that governs the dynamics of the process.

Although its application to industrial problems has often produced results superior to classical control, the design procedures are limited by the heuristic rules of the system. It is simply assumed that the rules for the system are readily available or can be obtained. This implicit assumption limits the application of fuzzy logic to the cases of the system with a few parameters. The number of parameters of a system could be large.

Although the number of fuzzy rules of a system is directly dependant on these parameters. As the number of parameters increase, the number of fuzzy rules of the system grows exponentially.

In fuzzy logic systems, there is a direct relationship between the number of fuzzy sets of input parameters of the system and the size of the fuzzy knowledge base (FKB). Kosko (1992) calls this the “Curse of Dimensionality”. The “curse” in this instance is that there is exponential growth in the size of the fuzzy knowledge base (FKB), where \( k \) is the number of rules in the FKB, \( m \) is the number of fuzzy sets for each input and \( n \) is the number of inputs into the fuzzy system.

As the number of fuzzy sets of input parameters increase, the number of rules increases exponentially. There are a number of ways that this exponential growth in the size of the FKB can be contained. The most obvious is to limit the number of inputs that the system is using. However, this may reduce the accuracy of the system, and in many cases, render the system being modelled unusable. Another approach is to reduce the number of fuzzy sets that each input has. Again, this may reduce the accuracy of the system. The number of rules in the FKB can also be trimmed if it is known that some rules are never used. This can be a time-consuming and tedious task, as every rule in the FKB may need to be looked at.

It has been suggested (Raju & Zhou, 1993; Mohammadian & Kingham, 1997; Mohammadian, Kingham & Bignall, 1998) using a hierarchical fuzzy logic structure for such fuzzy logic systems to overcome this problem. By using hierarchical fuzzy logic systems the number of fuzzy rules in the system are reduced, thereby reducing the computational time while maintaining the systems robustness and efficiency. In this article the design and development of a hierarchical fuzzy logic systems using genetic algorithms to model and predict interest rate in Australia is considered. Genetic algorithms are employed as an adaptive method for design and development of hierarchical fuzzy logic systems.
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