Forecasting of Time Series with Fuzzy Logic

Abstract. There are different methods used as supports for forecasting. Nowadays the new theories of soft computing are used for these purposes. The applications on stock market have specific features in comparison with others. The processes are focused on private corporate attempts at money making; therefore the details of applications, successful or not, are not published very often. The fuzzy logic helps in decentralization of decision-making processes to be standardized, reproduced, and documented.

1 Introduction

There are various forecasting methods used in economics, and finance: classical ones and methods using soft computing. The forecasting processes are very complicated because they include political, social, psychological, economic, financial, and other phenomena. Many variables are difficult to measure; they are characterized by imprecision, uncertainty, vagueness, semi-truth, approximation, nonlinearity, etc. The fuzzy logic could be used under these conditions.

The program FuzzyTech® and MATLAB® with Global Optimization Toolbox is used. The chapter is focussed only on applications. The fuzzy logic theory is described in many books such as [Alliev, 02], [Altroc,96], [Dostál,11], [Dostál,13], [Chen,04], [Chen,07], [Kazabov,98], [Klir,95], [Ribeiro,99].

2 Case study 1

Let us mention an example of the use of fuzzy logic for prediction of a time series. At first it is necessary to say that the time series is a sequence of values that are dependent on time t. The value at time $t = 1$ is denoted x_1, at time $t = 2$ is denoted x_2, and so on, and the value in time $t = \mathrm{N}$ is denoted x_N, when N signifies the number of values in the time series. The time series can be expressed as a vector of values $x = (x_1, x_2, \ldots, x_\mathrm{N})$. For needs of prediction we specify that the value x_N will be the last known value of the time series and it will correspond to the present. The value $\bullet x_{\mathrm{N}+1}$ will be the first future value predicted, the value $\bullet x_{\mathrm{N}+2}$ will be the second value predicted, etc. (The symbol • is be used to denote predicted values.) The interval between measurement is very often constant, then

$\Delta = t_2 - t_1 = t_3 - t_2 = \ldots = t_N - t_{N-1} =$ const. This interval in the economy (in contrast to technical sciences) has values in the range of minutes, hours, days, weeks, months, years, and their fractions. In this respect we speak about time series with very high (minutes), high (hours), medium (days), low (weeks), and very low (year) frequencies.

The following verbal notes were chosen for the solution of predictions by means of the FuzzyTech program: Delta_1 = $x_N - x_{N-1}$, Delta_2 = $x_{N-1} - x_{N-2}$, Delta_3 = $x_{N-2} - x_{N-3}$, Delta_4 = $x_{N-3} - x_{N-4}$ (the signs of these differences express the trend of the time series). The build-up model for prediction has four input variables Delta_1, Delta_2, Delta_3, Delta_4, one rule box, and one output variable Prediction. See the fuzzy model in Fig. 1.

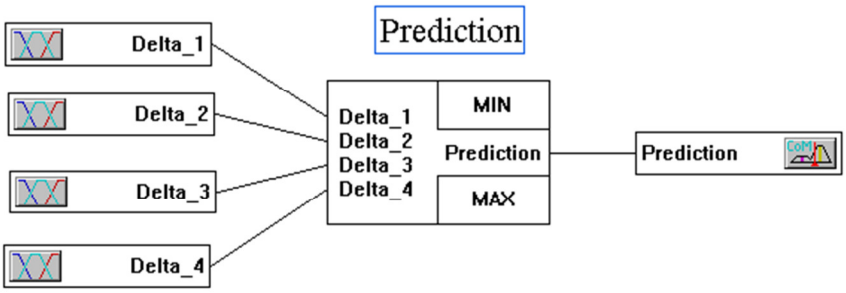

Fig. 1 Fuzzy logic – prediction

The Input variables have five attributes defined by values Delta, specified by their signs and the size of difference of neighbouring values (high positive, positive, zero, negative, high negative difference). As membership functions the shapes Λ, S, and Z are used. The output variable Prediction has five attributes that evaluate the future course of the time series (high increase, increase, stagnation, decrease, high decrease), specifying the situation at time N+1 (the value of prediction •x_{N+1}). The membership functions are spline curves of Λ, Π, S, and Z shapes.

The procedure followed by the program FuzzyTech includes set up of membership functions of input variables Delta_1, Delta_2, Delta_3, Delta_4 and the fuzzy rule box. The fuzzy rule box must be set up on the basis of knowledge, preferably by the experts who understand the problem. The setup of a fuzzy rule box depends on the type of solved case. For example a suitable rule can be similar to the following:

When inputs Delta_1 and Delta_2 and Delta_3 and Delta_4 are high negative, it means that the time series is decreasing and a large increase of the time series Prediction is expected in future.

This situation can be verbally described in capital markets: after a great and long decrease of share values they tend to start a fast increase with 90% probability. The rule can be described by this form:

<When> Delta_1 << 0 <And> Delta_2 << 0 <And> Delta_3 << 0 <And> Delta_4<< 0 <Then> Prediction = High increase <With> s = 0.90.

The rule for the opposite case can be verbally described in a capital market: after a great and long increase of share values they tend to start a fast decrease. The rule has the form

<When> Delta_1 >> 0 <And> Delta_2 >> 0 <And> Delta_3 >> 0 <And> Delta_4 >> 0 <Then> Prediction = High decrease <With> s = 0.90.

It is necessary to set up other rules that are combinations of these two described extreme variants. Figure 2 presents setup attributes and membership functions for the output variable Prediction.

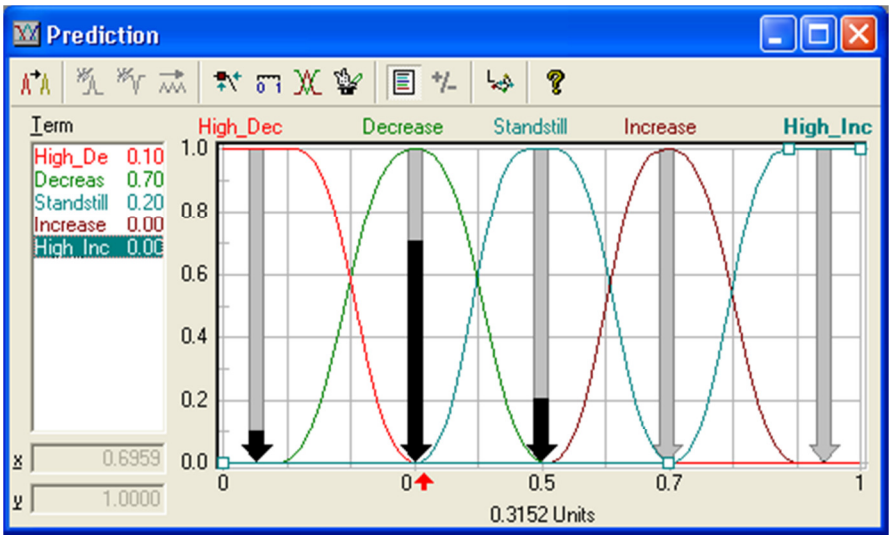

Fig. 2 Membership functions of output variable Prediction

For another case an unsatisfactory model could be set up and it is necessary to choose another number of variables, to define variables in another way, to choose other attributes and membership functions. The model must be tuned to give us good predictions.

3 Case study 2

Let us mention an example that solves the problem of decision making in capital markets: whether to trade in the stock market or not. The model for the FuzzyTech program is presented in Fig. 3.

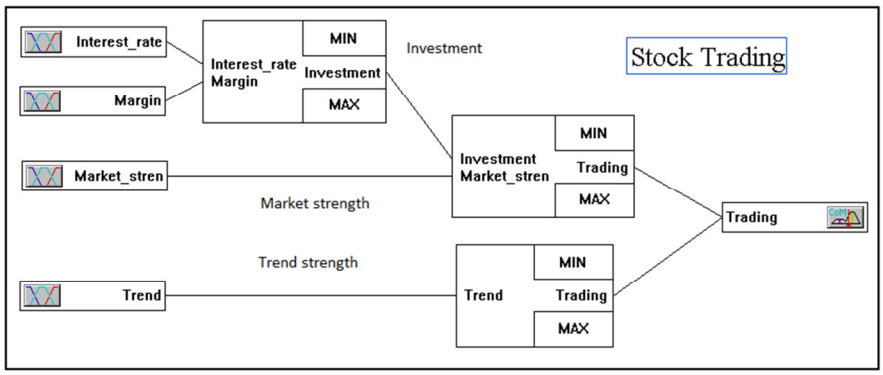

Fig. 3 The diagram of model – stock market

The input variables and their attributes are as follows: Margin (insignificant, significant), Interest rates (low, medium, high), Strength of market (low, medium, high), and Trend the course of time series (deterministic, stochastic).

The rules and attributes are as follows: the box Investment (unsuitable, neutral, suitable) determines the rule of desirability of depositing money in a stock market; the first block Trading (yes, no) evaluates whether trading in the market is suitable from the point of profitability of investment and the strength of the market; the second block Trading (yes, no) gives the decision for trading when the time series is stochastic, meaning that there is no possibility to make a good prediction of future development of time series. The output variable Trading evaluates whether to trade with share, index, commodity, or currency ratio. The membership functions were used in the shapes of Λ, Π, S, and Z.

4 Case study 3

Fuzzy logic can be used in decision making in the stock market. The model will be used for decisions whether to buy, sell, or hold with a share or index. The FuzzyTech program is used for this purpose when the inputs are the values from various analyses and information from the Internet. The diagram of such a model is presented in Fig. 4.

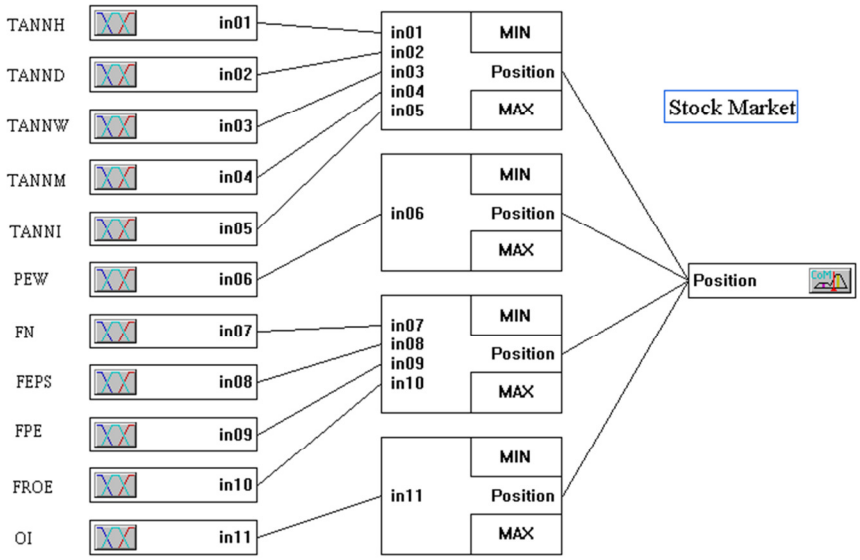

Fig. 4 Diagram of fuzzy model – stock market

The model has eleven inputs with seven attributes, four rule boxes, and one output variable with five attributes. The input variables are the information obtained from technical analyses represented by predictions of share prices by means of a neural network with hour TANNH, day TANND, week TANNT and month periodicity TANNM; predictions of values of an index having influence on predictions of a searched share TANNI; psychological analyses represented by means of Elliott's waves PEW; fundamental analyses represented by information from news FN, economic indexes EPS (earning per share) FEPS, P/E (price-to-earnings ratio) FPE, and ROE (return on equity) FROE, and other knowledge OI, such as for example intuition. The attributes of all input variables are the same and they express the rate of influence on the tendency of a time series (high, medium, low positive, neutral, low, high negative). A positive influence indicates the influence of an increasing tendency of a time series, and a negative influence signifies the influence of a decreasing tendency of a time series.

The rule boxes include technical analyses, psychological, fundamental, and other analyses.

The output variable Position tells the investor what he/she has to do in the stock market: Strong Sell, Sell, Hold, Buy, Strong Buy.

As a membership function, spline curves of shapes of Λ, Π, S, and Z were used. The attributes and membership function for output variable Position are presented with result to Buy in Fig. 5.

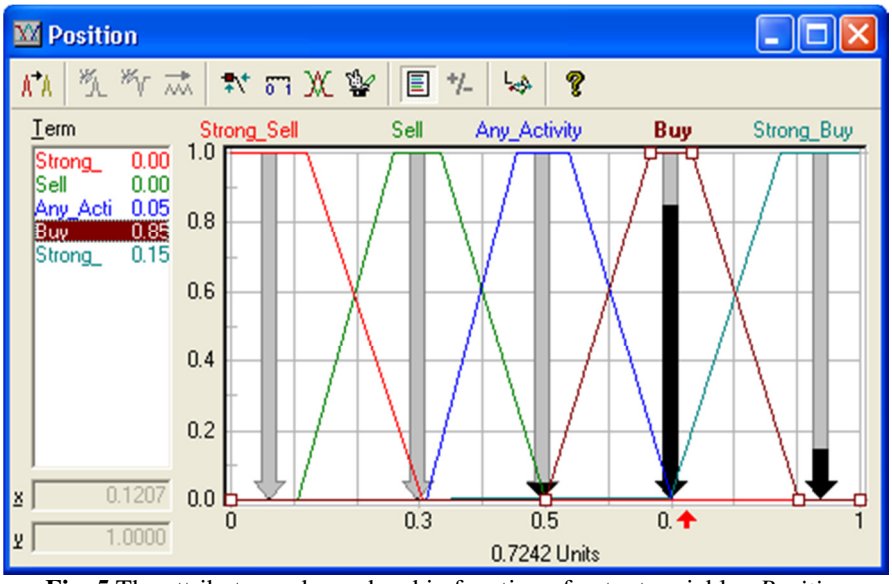

Fig. 5 The attributes and membership function of output variable– *Position*

Conclusion

Examples mentioned above are only a fraction of possible use of fuzzy logic for forecasting. We can use it for any time series created by indexes, shares, commodities, currency ratios, etc. The fuzzy logic helps not only to support decision making, but also to standardized, reproduced, and documented the processes.