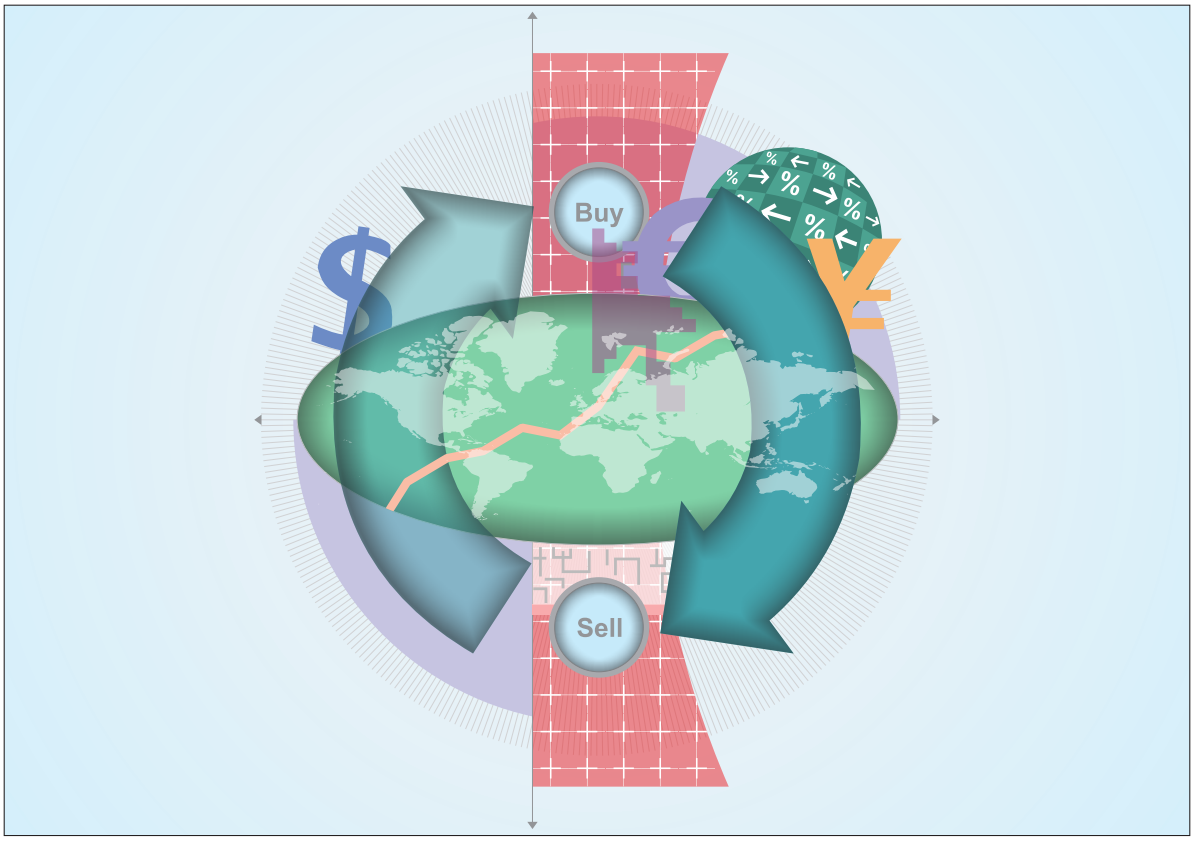

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Implementation of Fuzzy Rule Based Technical Indicator in Share Market

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ABSTRACT

Technical indicators are used in the stock and the currency markets for buying and selling decisions. The aim of this study was to develop a fuzzy rule based technical indicator for stock markets. Generalized volumes and generalized prices are used as linguistic variables. The Z-shaped, S-shaped and Triangular fuzzy numbers are used in this study. Success rates have been tested by real time trading and backward testing method. This fuzzy rule based indicator indicates a buy, hold or sell signal. The signals are agreed well with the classical technical indicators.

Key words: Fuzzy logic, fuzzy rule, defuzzification, aggregation, implication, technical indicator

INTRODUCTION

Advanced modeling techniques such as stochastic, Fuzzy Logic Controllers (FLC), Artificial Neural Networks (ANN) and Genetic Algorithm (GA) have a vast array of applications in finance and economics. More complex problem can be address by combining these techniques. This study combines fuzzy rule with trend line to know the market state and investment advise. The main objective of this paper is to develop fuzzy rule based technical indicator for stock market.

Due to the high expectation of profit, stock trading is becoming very risky (Gamil *et al*., 2007; Dashore and Jain, 2010). Fundamental, financial and technical analysis may reduce the risk of investment. In this study, a fuzzy rule based inference system, we call it Fuzzy rule based technical indicator abbreviated as FRBTI has been presented to make a decision, on investment in the stock market. Generalized volume and price are taken as input and FRBTI will indicate a buy, hold and sell signals as output. Fuzzy rule was applied to perform fundamental analysis of stock trading (Kwasnicka and Ciosmak, 2001). The price based analysis using fuzzy logic was mentioned (Gamil *et al*., 2007). Volume based stock analysis is more effective than price based analysis. AmiBroker software has been used to compare the proposed FIS with the other technical indicators. Empirical simulations have been observed using the actual data taking from DSE (Dhaka Stock Exchange, Bangladesh). The results found from FIS are agreed and sometimes better in comparing with the other indicators (Achelis, 2001). Therefore, the objective of this study was to develop a fuzzy rule based technical indicator for stock markets.

FUNDAMENTAL CONCEPTS

Definition 1: Let X be a non-empty set and I = [0, 1] be an unit interval. By fuzzy set on X we mean simply a membership function $\mu: X \to I, x \mapsto \mu(x)$, where $\mu(x)$ is interpreted as the grade of membership of $x \in X$ under μ.

Definition 2: A fuzzy set T: $\Re \to I$ is called Triangular fuzzy number if T has a membership function defined by:

$$T(x) = \begin{cases} 0, & \text{for } x < a \\ \dfrac{x-a}{b-a}, & \text{for } a \le x \le b, \\ \dfrac{c-x}{c-b}, & \text{for } b \le x \le c \\ 0, & \text{for } x > c \end{cases}$$

The parameters a and c locate the feet of the triangle and the parameter b locates the peak.

Definition 3: A fuzzy set Z: $\Re \to I$ is called Z-Shaped fuzzy number if Z has a membership function defined by:

$$Z(x) = \begin{cases} 1, & \text{for } x \le a \\ 1 - 2\left(\dfrac{x-a}{b-a}\right)^2, & \text{for } a \le x \le \dfrac{a+b}{2} \\ 2\left(\dfrac{x-b}{b-a}\right)^2, & \text{for } \dfrac{a+b}{2} \le x \le b \\ 0, & \text{for } x \ge b \end{cases}$$

Definition 4: A fuzzy set S: $\Re \to I$ is called S-Shaped fuzzy number if S has a membership function defined by:

$$S(x) = \begin{cases} 1, & \text{for } x \le a \\ 2\left(\dfrac{x-a}{b-a}\right)^2, & \text{for } a \le x \le \dfrac{a+b}{2} \\ 1 - 2\left(\dfrac{x-b}{b-a}\right)^2, & \text{for } \dfrac{a+b}{2} \le x \le b \\ 1, & \text{for } x \ge b \end{cases}$$

FUZZY RULES

Fuzzy logic based systems are classified according to the types of fuzzy rules. The three major types of rules are Mamdani type, Takagi-Sugeno-Kang type (TSK model) and Tsukamoto type (Ganesh, 2009; Ross, 1995).

Mamdani type: The rule has the following format:

$$R_k : \text{If } [x_1 \text{ is } A_{1k}] \text{ and } [x_2 \text{ is } A_{2k}] \text{ and } \cdots\cdots \text{ and } [x_n \text{ is } A_{nk}] \text{ then } [y \text{ is } B_k]$$

where R_k is the k-th rule in the fuzzy rule base system and (k = 1,2,..,k). Here A_{jk} and B_k are fuzzy sets on appropriate domains (j = 1,2,..n) (Mamdani and Assilian, 1975).

Takagi-Sugeno-Kang type: The rule appears like the following format:

$$R_k : \text{If}[x_1 \text{ is } A_{1k}] \text{and} [x_2 \text{ is } A_{2k}] \text{and} \cdots\cdots \text{and} [x_n \text{ is } A_{nk}] \text{then } y = f(x_1, x_2, \ldots, x_n)$$

where R_k, A_{jk} and B_k have the same meaning as before and $y = f(x_1, x_2, ..., x_n)$ is a real-valued function of n variables (Ganesh, 2009).

Tsukamoto type is same as Mamdani-type with the difference that the fuzzy sets B_k appearing in the consequent must have profiles that are monotonic increasing or decreasing (Ganesh, 2009).

FUZZY RULE BASED SYSTEM

The main modules of a fuzzy rule based system are Fuzzification or Fuzzifier module, fuzzy rules, Inference Engine and Defuzzifier. The components of a fuzzy rule based inference system are shown in Fig. 1.

Fuzzification module: It converts a crisp input of the domain of the input variable to a grade by a fuzzy set.

Fuzzy rules: These are consisting of antecedent and consequent in the form of IF-THEN statements. There are a number of rules and they form a chunk or bunch and which forms the basis for inference (Ganesh, 2009).

Defuzzification module: It acts as the interface between the Fuzzy Logic Control and the Inference system, by providing the crisp output. Regular defuzzification methods are centroid, bisector, mean value of maximum values, smallest value of maximum values and largest value of maximum (Hellendoorn and Thomas, 1993).

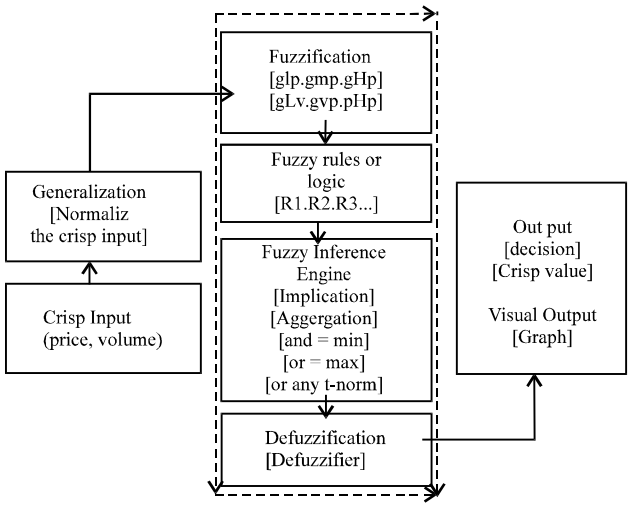

Fig. 1: Main component of fuzzy inference system

THE GENERALIZATION

The normalized moving average of price was introduced by Gamil *et al.* (2007). In this study generalized moving averages of price and volume have been introduced by the equation.

$$X_t = \frac{x_t - \bar{x}_{t,d}}{x_t}; x_t \neq 0, \forall t \in N \quad (1)$$

where $\bar{x}_{t,d}$ is the moving average of order d. Note that generalized price and volume have been calculated by using Eq. 1.

Price generalization: Suppose p(i), i = 1, 2,....., n; are the collection of closing prices of a stock in different days and $\bar{p}(i,d)$ are the moving average of order d.

Then the generalized price calculated as:

$$NP(i) := \frac{p(i) - \bar{p}(i,d)}{p(i)}; p(i) \neq 0, \forall i \in N$$

Volume generalization: Suppose v(i), are the collection of quantities of a stock traded in different days and $\bar{v}(i,d)$ are the moving average of order d.

Then the generalized volume is calculated in this study as:

$$NV(i) := \frac{v(i) - \bar{v}(i,d)}{v(i)}; v(i) \neq 0, \forall i \in N$$

FUZZY SYSTEM FORMULATIONS

Fuzzy logic or rule based system requires some Fuzzy Linguistic variables, fuzzy rules, implication, aggregation and defuzzification process.

Linguistic variable: Consider two generalized variables for volume and price of a stock. The variable $x \in X \subseteq \Re$ is a crisp variable where the set X is considered as Universe.

Volume is a linguistic variable: The Z-Shaped, Triangular and S-Shaped fuzzy numbers are taken to present Low, Medium and High volume. The membership grades of Low, Medium and High Volume have been denoted by Lv, Mv and Hv.

Price is a linguistic variable: The Z-Shaped, Triangular and S-Shaped fuzzy numbers are taken to present Low, Medium and High price. The membership grades of Low, Medium and High Price have been denoted by Lp, Mp and Hp.

Decision is a linguistic variable: The three triangular fuzzy numbers have been taken to define the decision value of Buy, Hold and Sell.

Parameter setting of Linguistic variables: One of the most difficult tasks is to set the parameters value. A statistical study has been made by taking more than 300 records of each company. The parameter value has been taken by statistical analysis and public comments (Table 1).

Table 1: Parameter setting and the values of linguistic variables

Linguistic variables	Fuzzy numbers	Parameters	Parameter value
Price	Z-Shaped for low price	Lp = Z(a,b)	Z(-0.85, -0.20)
	Triangular for medium	Mp = T(a,b,c)	T(-0.62,0 ,0.1)
	S-Shaped for high	Hp = S(a,b)	S(0.05,0.6)
Volume	Z-Shaped for low price	Lv = Z(a,b)	Z(-0.96,0.52)
	Triangular for medium	Mv = T(a,b,c)	T(-0.15, .09, 0.1)
	S-Shaped for high	Hv = S(a,b)	S(0.075, 0.95)
Decision	Buy for triangular	Db = T(a,b,c)	T(-1,-0.25,0.1)
	Hold for triangular	Dh = T(a,b,c)	T(0,0.25,0.5)
	Sell for triangular	Ds = T(a,b,c)	T(0.35,0.75,1)

Membership function selection: To construct a fuzzy system membership functions are plays important role. Observation founds (Gamil *et al*., 2007; Giovanis, 2010; Hellendoorn and Thomas, 1993; Kwasnicka and Ciosmak, 2001) of using triangular and trapezoidal shape membership function in some applications. Earlier describes the membership function is triangular that is normal, convex and bounded. In this study triangular, Z and S shaped membership functions have been used.

The Z-shape membership function is taken for this study because this function is well fitted for setting the parameter value $z(x) = 1$ for all $x<x_1$ and $z(x) = 0$ for all $x_2<x$.

The S-shape membership function is taken for presenting high value because this function is well fitted for setting the parameter value $S(x) = 0$ for all $x<x_1$ and $S(x) = 1$ for all $x_2<x$.

Fuzzification of the crisp variables is the first step of the fuzzy rule based systems. Fuzzification means finding the grade of the input variables. The grades of the crisp variables will be any value in the interval [0 1].

The Fuzzification of price and volume are obtained by passing a crisp value into the corresponding membership function.

Fuzzy rules setting: The following fuzzy rules and logics have been taken with the combination of the values of linguistic variable volume and price for this study are given as:

R1: If [volume is low] and [price is low] then Buy
R2: If [volume is medium] and [price is medium] then Hold
R3: If [volume is high] and [price is high] then Sell
R4: If [volume is low] and [price is medium] then Buy
R5: If [volume is low] and [price is high] then Sell
R6: If [volume is medium] and [price is low] then Hold
R7: If [volume is medium] and [price is high] then Sell
R8: If [volume is high] and [price is low] then Buy
R9: If [volume is high] and [price is medium] then Hold

Implication aggregation and defuzzification process: In this study, Minimum T-norm and Maximum S-norm have been used as Implication and aggregation operation respectively. Centroid defuzzification method has been used as a defuzzification process.

Implication: The generalized mamdani type rule has applied by:

Table 2: Fuzzy implication operators

Name	Definition
Early zadeh	$x \rightarrow y = \max\{1-\min(x, y)\}$
Lukasiewicz	$x \rightarrow y = \min\{1, 1-x+y\}$
Mamdani	$x \rightarrow y = \min(x, y)$
Larsean Standard strict	$x \rightarrow y = \begin{cases} 1 & \text{if } x \le y \quad x \rightarrow y = xy \\ 0 & \text{Otherwise} \end{cases}$
Godel	$x \rightarrow y = \begin{cases} 1 & \text{if } x \le y \\ y & \text{Otherwise} \end{cases}$
Gaines	$x \rightarrow y = \begin{cases} 1 & \text{if } x \le y \\ y / x & \text{Otherwise} \end{cases}$
Kleene-dienes	$x \rightarrow y = \max\{1-x, y\}$
Kleene-dienes-lukasiewicz	$x \rightarrow y = 1-x+xy$
Yager	$x \rightarrow y = y^x$

$$R_i = (Visv_n(x)) \wedge (Pisp_n(x)) \; \Phi \; (Disd_n(x))$$

where, Φ is implication operator. The various implication operators are listed in Table 2. As an implication operator min has been used as:

$$R_i = \min(\min(v_n(x), p_n(x)), \; d_n(x))$$

where, i is 1... 9; n is 1...3. where R_i are fuzzy rule and V, P are Fuzzy variable of generalized volume, price and then D is decision.

Aggregation: $Z(x) = \underset{1 \le i \le n}{\phi} R_i$ or $Z(x) = \underset{1 \le i \le n}{\max}(R_i)$; where φ is aggregation operator here is max. The variable Z belongs to [0, 1] in the domain [-2, 2].

Defuzzification: The conversion of a fuzzy set to a single crisp value is called defuzzification and reverse process is Fuzzification.

To find the Defuzzifi value we used the formula defined as:

$$x^* = \frac{\sum_{i=1}^{n} x_i . Z(x_i)}{\sum_{i=1}^{n} Z(x_i)}$$

Here, n represents the number of elements in the sample, x_i's the elements and $Z(x_i)$ is its membership function.

COMPUTER PROGRAMMING AND SIMULATION

The generalized values of volume and price have been calculated by AmiBroker software, which has the advantage of calculating generalized price and volume of huge stock records. Using AmiBroker, different AFL (Amibroker Formula Language) has been written for analyzing and setting parameters for Linguistic variables. More than 300 records have been chosen to fix the

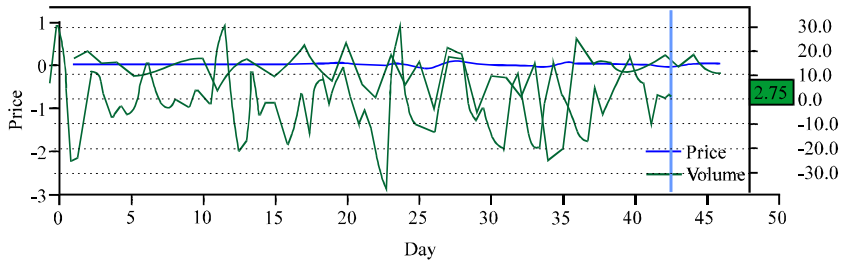

Fig. 2: Generalized price and volume taking moving average of order 3

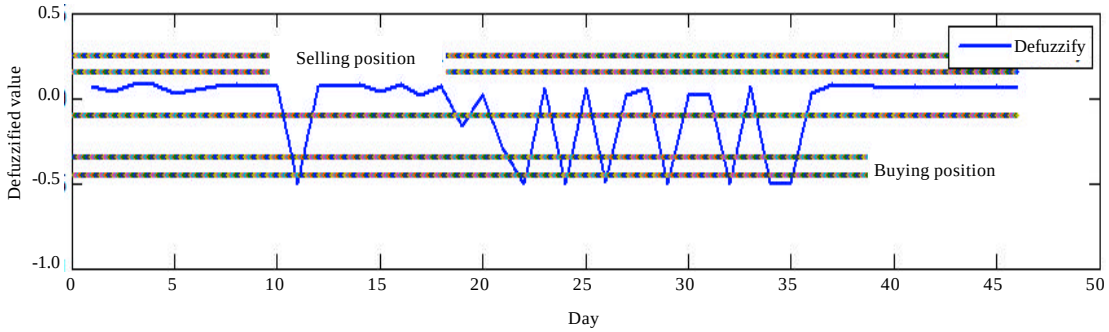

Fig. 3: Buying and selling region generated by fuzzy rule based system

parameters. The low, medium and high values of price and volume range is not fixed it varies. The value of parameters has been accepted by general public. Figure 2 illustrates generalized moving average of price and volume. The MATLAB software has used to develop the fuzzy rule or logic based Technical Indicator. Many modules have been written using MATLAB to analyze the output.

Indicators: The set of defuzzified values are used for making in decision of buy, hold and sell. The crisp values are also used for drawing graph that represents buying, holding and selling region in Fig. 3. The different signals of buy, hold and sell depends on the given range.

Defuzzified value x*	Signal
-1<x*<0.1	Buy
0<x*<0.5	Hold
0.35<x*<1	Sell

Gradient of price: The gradient of market price can observe by drawing gradient chart. The chart is calculated by:

$$X_t = \frac{x_t - \overline{x}_{t,d}}{d}$$

and plot X_t. Figure 4 shows the gradient of the prices.

Data description: The stock market trading data obtained form Dhaka stock exchange website.

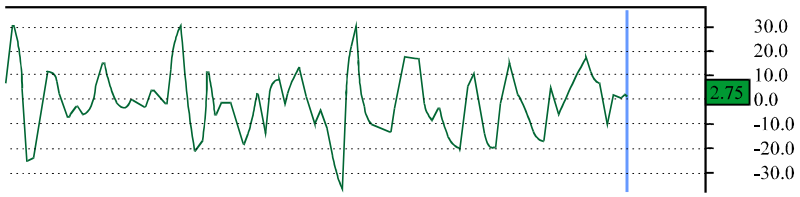

Fig. 4: Divergence of the price

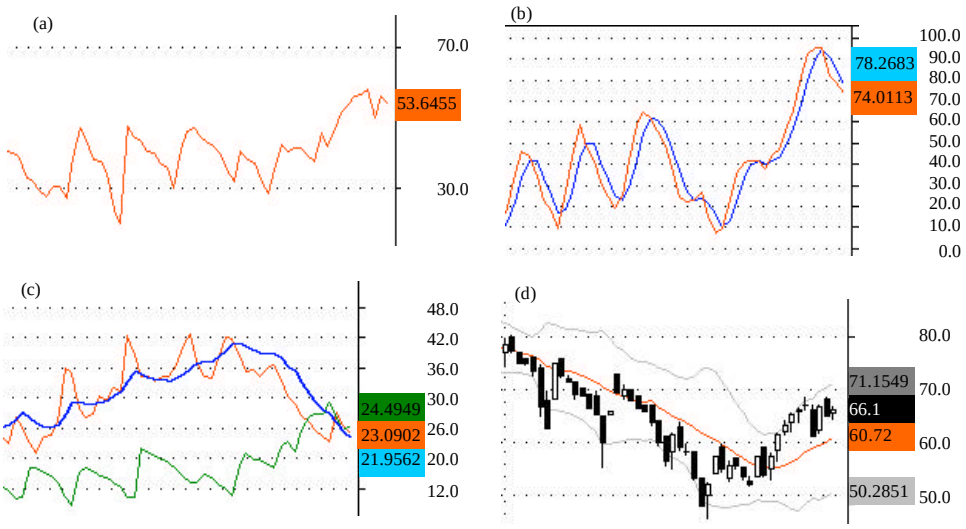

Fig. 5(a-d): Charts of different technical indicators (a) RSI chart, (b) Stochastic %k and %D chart, (c) ADX chart and (d) Bollinger band with candle stick chart

Daily real trading data of DSE (Dhaka Stock Exchange) were taken from the wave site stockbangladesh.com. This data contain daily opening price, low, high, closing price and total quantity of a stock traded in a day. The closing price and volume have been taken for generalization and this generalization price and volume are taken as input.

Technical indicators: Technical indicators are very popular analysis of investing stock and foreign currency trading. In this study, we compare the FRBTI with several well used technical indicators such as RSI, Stochastic, ADX and Bollinger Band. For details of this indicators authors refers study (Achelis, 2001). In this study, Amebroker software is used to investigate and compare the stock price with FRBTI generated signals. Charts of different technical indicators have been shown in Fig. 5.

RESULTS

Fuzzy Rule Based Technical Indicator (FRBTI) on investing in the stock market has been investigated. The investigation has been performed with the help of the fuzzy rule with the minimum T-norm and maximum S-norm. The FRBTI has been developed with a view to taking generalized volume and price as input to give the decision to Buy, Hold or Sell the stocks. Figure 6 has shown the linguistic variables of a volume, price, decision and a signal.

Stock records have been investigated by Amibroker software and developed fuzzy rule based system. For the analysis, the records from 1/1/2010 to 16/3/2011 of the shares of various companies were taken. Figure 2 illustrates the generalized prices and volumes for the last 45-day data. The

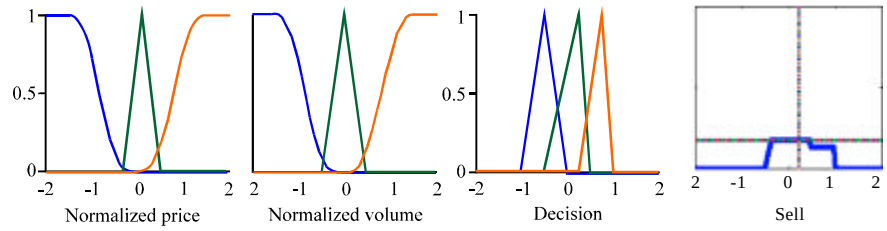

Fig. 6: Fuzzy linguistic variables of price volume, decision and acton

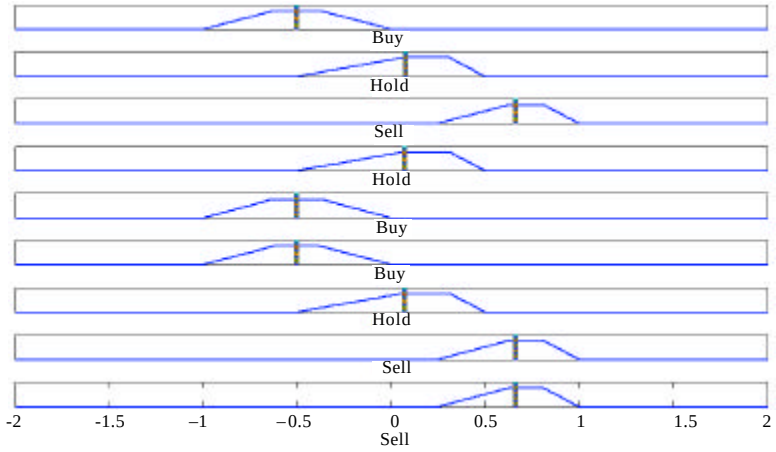

Fig. 7: Fuzzy rule based technical indicators generated signals from the inputs of normalized price and volumes are [-1 0 1 -1 -1 0 0 1 1] and [-1.5 0 1 0 1 -1.5 1 -1.5 0]

investigation of the FRBTI was done by taking data randomly from 30 companies. It is observed from the analysis that after receiving a buy/sell signal, price has started to increase/decrease within a few days of prediction.

Nine fuzzy rules have been set on the combination of the values of linguistic variables of volume and price. Different observations have been recorded on the change of stock volume and price. It can be said that based on FRBTI, market behavior and its physiology can be predicted.

From the historical data, some dummy trades were made. Ten items were marked after receiving a buy signal, ten items after receiving a sell signal and ten items after receiving a hold signal; and it was observed in the first case, the price increased after 3-6 days, in the second case, price declined after 2-5 days and in the third case, prices of seven items increased and three items decreased.

The simulations generated from some inputs are shown in Fig. 7 and 3. They show the Buy, Sell or Hold signals and the buying and selling region generated by FRBTI.

The technical indicators candle stick, bollinger band, moving average cross over and ADX and RSI are compared to the FRBTI. It was found that the signals of the FRBTI agreed well with RSI, Stochastic, ADX and Bollinger Band (Achelis, 2001).

Trading result: Some real trades were made by purchasing and selling the stocks of six companies, based on getting the fuzzy rule based indicator's signal along with a price slop chart. The results are given in Table 3.

Table 3: Some real trades were made form date 10/1/2011 to 17/03/2011 by purchasing and selling the stocks of six companies, based on getting the fuzzy rule based indicator's signal along with a price trend

Items Dte(dd/mm)	Decision	Comment	Items Date(dd/mm)	Decision	Comment
BexTex			**Beximco**		
10/1	Buy Tk63		1/10	Buy Tk275	
16/1	Sell Tk79	Profit	16/1	Sell Tk305	Profit
20/1	Buy Tk59		18/1	Buy Tk298	
1/2	Sell Tk66	Profit	26/2	Sell Tk309	Profit
20/2	Buy Tk58				
10/3	Sell Tk67	Profit			
ABBank			**Bangas**		
10/1	Buy Tk1270		10/1	Buy Tk1850	
16/1	Sell Tk1415	Profit	16/1	Sell Tk1950	Profit
20/1	Buy Tk1200		16/3	Buy Tk1150	
30/1	Sell Tk1385	Profit	16/3	Sell Tk1300	Profit
1/3	Buy Tk920				
8/3	Sell Tk1175	Profit			
Dacca Dye			**MeghnaPet**		
15/1	Buy Tk64		28/2	Buy Tk15	
30/1	Sell Tk80	Profit	10/3	Sell Tk20	Profit
2/3	Buy Tk46				
15/3	Sell Tk72	Profit			

DISCUSSION

Many researchers have applied fuzzy logic in the stock and money market. In this section, a comparative discussion has been presented.

The authors (Gamil *et al*., 2007) have applied fuzzy logic taking the price of normalized moving average and simple moving average. The trading successes, done by fuzzy rule were significant. But we have applied fuzzy logic on generalized volume and generalized prices and success of trading have found significant.

Dashore and Jain (2010) proposed the technique by using fuzzy rules with many indicators, this helps only for long term investment. Short term investment will be risky if one follows the technique. On the other hand, we have used only two linguistic variables generalized volume and generalized price, which will help in both short and long term trade.

In the study the estimation of return on investment in the share market (Ravichandran *et al*., 2005), the author has studied using Artificial Neural Network with various traditional methods. The authors showed that Neural Network System can perform efficiently when certain data is not found. In our study, which deals with fuzzy rule based technique, each linguistic variable has the value in the interval [0 1]. So the technique performs significantly better than NNS and classical systems.

The share market situation was predicted by Thirunavukarasu (2009) by using many indicators that is applied for long term only. On the other hand, fuzzy rule based technical indicator can predict the market situation by looking at the volume size and price, that can be applied for long and short term basis.

The Adaptive Network-Based Fuzzy Inference Autoregressive System (ANFIS) has been shown by Giovanis (2010), examined the performance of forecasting and found that ANFIS outperforms are significant to other models in the most cases. In this study, the fuzzy rule based indicators performs better than the other classical indicators, because expert knowledge is incorporated in the techniques.

Fuzzy logic based approach in various pattern of technical analysis has been discussed by Zhou and Dong (2004), the results show that the system can detect subtle differences in a clearly defined pattern. This system (Zhou and Dong, 2004) may be valuable for investors as a way to incorporate human cognition into historical trading statistics. Where as FRBTI performs signal only taking price and volume as inputs. Invest in stock, using this signal incorporate divergence curve results satisfactory profit.

CONCLUSION

This study proposes a fuzzy logic or rule based technical indicator that takes generalized volume and price as input. It has been found that the system works well when applied with a price slope chart. This indicator gives the buy, hold and sells signal generated by the rules which are by expert analyst. Fuzzy rule based technical indicator may be used for stock market investment.

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