DECISION MAKING IN THE INDONESIAN STOCK EXCHANGE USING A FUZZY LOGIC METHOD

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ABSTRACT

Defining the best strategy to trade stocks is difficult, especially on the Indonesian stock exchange. A small mistake can lead to a huge loss. Investors analyze stock behavior of targeted companies to make decisions to buy, sell, and hold. Various technical analysis methods use a combination of chart indicators to make these decisions. This study proposes combining four existing indicators with fuzzy logic to create a method for predicting the appropriate action for a stock. This method will use the Moving Average Convergence/Divergence (MACD), the Relative Strength Index (RSI), the Stochastic Oscillator (SO), and the On-Balance Volume (OBV) indicators to recommend a buy, sell or hold decision to an investor. This experiment used two Indonesian companies to test the accuracy of the algorithm. Based on 2014 data, using the fuzzy logic method, accuracy of the algorithm reached 66.67% and 75% for the two companies.

Keywords: *Fuzzy Logic*, *Stock*, *Moving Average Convergence/Divergence*, *Relative Strength Index*, *Stochastic Oscillator*

1. INTRODUCTION

Investing has always been a popular method of fulfilling current needs and maintaining a standard of living during retirement. In economics, business investment refers to the purchase of a physical asset, such as buildings, equipment, or inventory. It can also refer to an individual's purchase of a new home [1]. No longer just about gold or property, investing now includes company stocks that can earn large profits. Stocks are securities or certificates representing fractional company ownership and can be purchased as an investment [2]. In Indonesia, the place that provides stock trading is called Indonesia Stock Exchange (IDX).

On buy and selling activity of stocks or usually called trading, the parties involved are companies registered on the Indonesia Stock Exchange, potential investors, and brokers. Stockbroker is a firm or individual entity that role as a representative or intermediary on stock exchanging for the investors so that the investors might able to have a transaction online and real time. Investors sometimes asked for a help on stock analyst to decide which stock that potentially earn a good benefit before conducting some transaction represented by the broker. Stock analyst will analyze the stock exchange condition before give their advice to their clients. They might be use some scientific method to decide which stock that reccomended to be bought or sold.

To prevent loss, investors usually analyze the price of stocks before making a trade decision. There are two philosophies to stock analysis, technical and fundamental. Fundamental analysis is a study of a company's financial strength, based on historical data, sector and industry position, company management, dividend history, and the potential for future growth. Technical analysis is a study of a company stock price as it changes in freely traded markets. Both philosophies are used for making profitable trading or investment decisions. Technical

analysis has various indicators that can be used as tools to predict stock's price. Some of the technical analysis indicators used by traders are the Moving Average Convergence/Divergence (MACD), the Relative Strength Index (RSI), the Stochastics Oscillator (SO), the On-Balance Volume (OBV) indicator.

Fuzzy logic is a multivalued extension of Boolean logic based on the fuzzy set theory on which truth values are extended from the endpoints of the interval [0, 1] to a range through the entire interval [3]. In other research using fuzzy logic for stock trading, a combination of technical indicators is used to recommend market entry and investment amount [4]. There are several research that also implementing fuzzy concept as in Fuzzy method on classification problems, for example [5] use Fuzzy Kernel K-medoids to classify several classification benchmark dataset. While at [6], Karayiannis and Bezdek discuss about Fuzzy Learning Vector Quantitation and they also propose a new concept to choose different fuziness degree on each iteration at the classiffier. On [7], Rustam and Talita use Fuzzy Kernel k-medoids on security problem, involving anomaly detection problem. In this paper, fuzzy logic will be used with MACD, RSI, SO, and OBV to determine a trade decision of buy, sell or hold. On this paper, we choose our experimental data based on LQ 45 index which is a regular index published by Indonesia Stock Exchange every six months with periods February-July and August-January. Some of the company criteria to be included on the LQ 45 index are:

- The company must be in the top 60 rank on the total stock exchange on regular market (average transactions value for the last six months).

- Rank based on market capitalization.

- Registered on Indonesia Stock Exchange minimal three months respectively.

- Have a good monetary condition with a positive prospect of growth.

The stocks on LQ 45 will be monitored for evaluation every six months. It is possible for a included stock to be left out of the list if it fails to fulfilled the requirement. The company data that was used to test the algorithm is listed in the IDX.

2. FUZZY SYSTEM MEMBERSHIP FUNCTION

Fuzzy set is a set that each element on it have a membership value between 0 and 1. Membership function of a fuzzy set map each object on the universe into a space that assumed as a unit interval.

If X define a set which member is x, then fuzzy set A on X represented by ordered pair, $A = \{(x, \mu_A(x)|x \in X)\}$.

It was introduced first by Lotfi A. Zadeh on 1965. He defined fuzzy logic as a system with a logic as approximate reasoning. Approximate reasoning is a process aim to build a imprecise possible conclusion from chaning premises. Fuzzy logic works by fuzzy inference system.

Fuzzy Inference System (FIS) is a computation system that works based on fuzzy logic principal that is to process input value into output value. In practice, Fuzzy inference system can be divided into 3 steps, fuzzification, inference rules, and final step the inverse transformation of fuzzification which is defuzzification.

On fuzzification, numerical variable or the input will be transformed into fizzy variable known as linguistic variable. On this step, the input in crisp data form will be transformed into fuzzy set form. Other than that, on this step we also determine the membership function that will be used and also deciding the values of the parameters on the membership function.

The membership function is used for mapping the elements from domain to the membership value or degree of membership between [0,1] [8].

On inference rules, we set a rules regarding every input to get an output. In general, the rules infolfing implication If-Then rules. There are two types known in general about inference rules, but on this paper we use Mamdani rules, where the general form is:

IF x_1 is A_1 AND…AND x_n is A_n THEN y is B

Where $A_1, A_2, …, A_n$ and B is a fuzzy set with x and y as scalars. The variables used on Mamdani rules gives on Table 1.

Table 1: Variables on Mamdani Rules

Variabel	Definition
x_i	Input on variable –i on the form of crisp data where $x \in A$
$\mu_A(x)$	Membership value on fuzzy set A
$\mu_B(x)$	Membership value on fuzzy set B
$\mu_{sf}(x_i)$	Membership value on the fuzzy solution until i-th rule.

$\mu_{kf}(x_i)$	Membership value of fuzzy consequent until i-th rule.

The last step on FIS is defuzzification that is a process to transform linguistic variable into numerical variable. There are several defuzzification methods, in this paper we use Center of Area Method.

Crisp solution was computed by taking the center (z*) from domain of the fuzzy which is $\mu_A(z)$.

For continuous variable, the formula is:

$$z^* = \frac{\int z\mu_A(z)dz}{\int \mu_A(z)dz} \quad (1)$$

For discrete variable, the formula is:

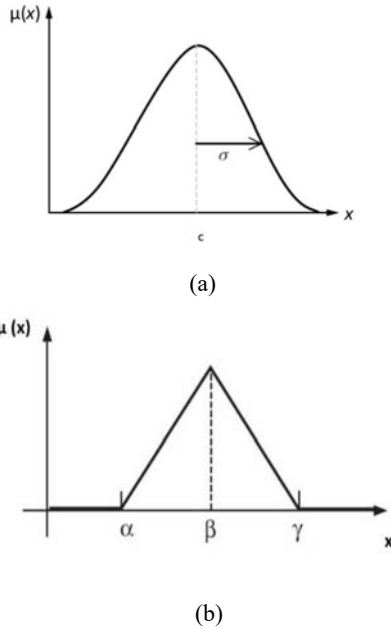$$z^* = \frac{\sum_{j=1}^n z_j\mu_A(z_j)}{\sum_{j=1}^n \mu_A(z_j)} \quad (2)$$

(a)

(b)

Figure 1 : Membership Function of Fuzzy Logic

From Figure 1, there are two types of membership functions that will be used in this paper:

(a) Gaussian Membership Function for the inputs, where c is middle point of the interval, and σ is a curve's width as shown in Eq. (3).

$$gaussian(x; c, \sigma) = e^{-\left(\frac{1}{2}\right)\left(\frac{(x-c)}{\sigma}\right)^2} \quad (3)$$

(b) Triangular Membership Function for the output is shown in Eq. (4).

$$triangular\ (x; \alpha, \beta, \gamma) = \begin{cases} 0, & x \leq \alpha \\ \frac{x-\alpha}{\beta-\alpha}, & \alpha \leq x \leq \beta \\ \frac{\gamma-x}{\gamma-\beta}, & \beta \leq x \leq \gamma \\ 0, & x > \gamma \end{cases} \quad (4)$$

3. FUZZY SET OPERATOR AND FUZZY INFERENCE SYSTEM FUNCTIONS

A fuzzy set operator defines a combination of two or more fuzzy sets. An operator that is used in this paper is the intersection of fuzzy sets, with the 'and' operator. The intersection of two fuzzy sets A and B is the fuzzy set C, written as $C = A \cap B$ or $C = A\ and\ B$ [8], whose membership function is related to those of A and B by Eq. (5).

$$\mu_C(x) = \min\big(\mu_A(x), \mu_B(x)\big) \quad (5)$$

Following Mamdani Fuzzy Models, fuzzy logic works by a system called the fuzzy inference system (FIS), that process an input to become an output. There are three steps in FIS [8]:

Step 1, Fuzzification, takes the numeric variable or input and converts it to a fuzzy variable or linguistic variable. The membership function is determined in this step. Tables 2–5 define the fuzzification process for the input where d is distance or dissimilarity function. And $m \in [1, \infty)$ is the fuzziness degree for cluster partition.

Table 2: Fuzzification for MACD

Numeric Variable	Fuzzy Variable	Membership function
$0 \leq x_1 \leq 5$	LOW	$\mu(x_1) = \exp\left[-\frac{1}{2}\left(\frac{x_1}{2.123}\right)^2\right]$
$5 < x_1 \leq 10$	HIGH	$\mu(x_1) = \exp\left[-\frac{1}{2}\left(\frac{x_1 - 10}{2.123}\right)^2\right]$

On practice with fuzzy logic, MACD defined as two Gaussian forms. Before we compute its membership values, we need to find the parameters values c and σ first. Since MACD has only two membership function (MF), then the shape of the line MF is area on the right side and half on the left side. Parameter c and σ will be found by triangular MF so that for MACD with range input [0,5] will results in the right side area with the peak point or

the value of c is 0, inParams (1) = 0 and inParams (2) = 5. Next we will find σ:

$$rtWaist = (1 - yWaist) \times (inParams(2) - c) + c \qquad (6)$$

$$rtWaist = 2.5 \qquad (7)$$

$$\sigma = \left| \frac{rtWaist - c}{\sqrt{-2\ln(yWaist)}} \right| = 2.123 \qquad (8)$$

Table 3: Fuzzification for RSI

Numeric Variable	Fuzzy Variable	Membership function
$0 \leq x_2 < 30$	LOW	$\mu(x_2) = \exp\left[-\frac{1}{2}\left(\frac{x_2}{10.82}\right)^2\right]$
$30 \leq x_2 \leq 70$	MEDIUM	$\mu(x_2) = \exp\left[-\frac{1}{2}\left(\frac{x_1 - 50}{8.493}\right)^2\right]$
$70 < x_2 \leq 100$	HIGH	$\mu(x_2) = \exp\left[-\frac{1}{2}\left(\frac{x_1 - 100}{10.82}\right)^2\right]$

RSI as a leading indicator will be defined with three MF, gaussian type. RSI divided into three areas, left, right and the middle. For the right area, the range is (0,30) where c equal to 0, inParams (1) = 0, inParams (2) = 30. Next we will compute the value of σ.

$$rtWaist = (1 - 0.5) \times (30 - 0) + 0 = 15 \qquad (9)$$

$$\sigma = \left| \frac{(15 - 0)}{\sqrt{-2\ln(0.5)}} \right| = 10.82 \qquad (10)$$

While for the mid area, the range is (30,70) and its peak point inParams (1) = 30, inParams (2)=70, so the σ is:

$$rtWaist = (1 - 0.5) \times (70 - 50) + 50 = 60 \qquad (11)$$

$$\sigma = \left| \frac{(60 - 50)}{\sqrt{-2\ln(0.5)}} \right| = 8.493 \qquad (12)$$

Table 4: Fuzzification for SO

Numeric Variable	Fuzzy Variable	Membership function
$0 \leq x_3 < 20$	LOW	$\mu(x_3) = \exp\left[-\frac{1}{2}\left(\frac{x_3}{8.493}\right)^2\right]$
$20 \leq x_3 \leq 80$	MEDIUM	$\mu(x_3) = \exp\left[-\frac{1}{2}\left(\frac{x_3 - 50}{10.82}\right)^2\right]$
$80 < x_3 \leq 100$	HIGH	$\mu(x_3) = \exp\left[-\frac{1}{2}\left(\frac{x_3 - 100}{8.493}\right)^2\right]$

Similar with RSI, SO will be also defined by three Gaussian MF. Numerical variable of SO will be changed into fuzzy variable and we will find the membership value. The computation of c, σ is a bit similar with on SO, but differ in range of its input. For the first area, which is the right side the range is [0, 20] with the peak point is 0, while inParams (2) = 20. SO that we have σ:

$$rtWaist = (1 - 0.5) \times (20 - 0) + 0 = 10 \qquad (13)$$

$$\sigma = \left| \frac{(10 - 0)}{\sqrt{-2\ln(0.5)}} \right| = 8.493 \qquad (14)$$

While for the mid area, the range is (30,70) and its peak point inParams (1) = 30, inParams (2)=70, so the σ is:

$$rtWaist = (1 - 0.5) \times (70 - 50) + 50 = 60 \qquad (15)$$

$$\sigma = \left| \frac{(60 - 50)}{\sqrt{-2\ln(0.5)}} \right| = 8.493 \qquad (16)$$

Table 5: Fuzzification for OBV

Numeric Variable	Fuzzy Variable	Membership function
$0 \leq x_4 \leq 5$	LOW	$\mu(x_4) = \exp\left[-\frac{1}{2}\left(\frac{x_4}{2.123}\right)^2\right]$
$5 < x_4 \leq 10$	HIGH	$\mu(x_4) = \exp\left[-\frac{1}{2}\left(\frac{x_4 - 10}{2.123}\right)^2\right]$

After fuzzification, the second step defines a set of rules for each input. The rules are in an 'If-Then' format, for example:

R01 : If x_1= LOW AND x_2= LOW AND x_3= LOW AND x_4= LOW then $z = z^*$.

R02 : If x_1= LOW AND x_2= MEDIUM AND x_3= MEDIUM AND x_4= LOW then $z = z^*$.

Previous research has used 9 rules [9], but on this paper there will be 20 rules as defined in Table 7.

The last step of FIS is defuzzification where the linguictic variable will be converted to a numeric variable again.

Each value of z^* will be described in Table 6.

Table 6: Classification of Output

z*	Reccomendation
$0 \leq z < 10$	SELL
$10 \leq z \leq 20$	HOLD
$20 < z \leq 30$	BUY

The MACD indicator was first introduced by Gerrad [10]. MACD is calculated by subtracting a 26-day exponential moving average (EMA) of a stock's price from a 12-day EMA [11]. The result is an indicator that oscillates above and below zero. When the result is above zero, it means a 12-day EMA is higher than a 26-day EMA, and implying a bullish trend (investors expect upward price movement in the stock market). On the other hand, when the result is below zero, a 12-day EMA is less than a 26-day EMA, and implying a bearish trend (the investors expect downward price movement). Besides those two EMA, there is another 9-day EMA as a trigger line to know when to buy or sell.

Table 7: Inference Rules

No.	MACD	RSI	SO
R01	LOW	LOW	LOW
R02	LOW	MEDIUM	MEDIUM
R03	LOW	MEDIUM	HIGH
R04	LOW	HIGH	MEDIUM
R05	LOW	HIGH	HIGH
R06	HIGH	LOW	LOW
R07	HIGH	LOW	MEDIUM
R08	HIGH	MEDIUM	MEDIUM
R09	HIGH	MEDIUM	LOW
R10	HIGH	MEDIUM	LOW
R11	HIGH	MEDIUM	MEDIUM
R12	HIGH	HIGH	HIGH
R13	LOW	MEDIUM	MEDIUM
R14	LOW	HIGH	HIGH
R15	HIGH	LOW	LOW
R16	HIGH	MEDIUM	MEDIUM
R17	-	LOW	LOW
R18	-	MEDIUM	MEDIUM
R19	-	HIGH	HIGH
R20	-	MEDIUM	MEDIUM

No.	OBV	Recommendation
R01	LOW	SELL
R02	LOW	SELL
R03	LOW	SELL
R04	LOW	SELL
R05	LOW	SELL
R06	HIGH	BUY
R07	HIGH	BUY
R08	HIGH	BUY
R09	LOW	HOLD
R10	HIGH	BUY
R11	LOW	HOLD
R12	HIGH	BUY
R13	-	HOLD
R14	-	SELL
R15	-	BUY
R16	-	HOLD
R17	HIGH	BUY
R18	HIGH	HOLD
R19	LOW	SELL
R20	LOW	HOLD

$$MACD = EMA_{12} - EMA_{26} \quad (17)$$

$$MA_i = \begin{cases} (C_i \times \alpha) + \left(SMA \times (1 - \alpha)\right), \ i = N \\ (C_i \times \alpha) + \left(EMA_{i-1} \times (1 - \alpha)\right), \ i > N \end{cases} \quad (18)$$

$$SMA = \frac{\sum_{i=1}^{N} C_i}{N} \quad (19)$$

$$\alpha = \frac{2}{N+1} \quad (20)$$

where EMA_i is the exponential moving average of i-th day and C_i is the close price of i-th day, for $N = 12$ and $N = 26$ [4].

RSI indicates if the market is in an overbought (a security that traders believe is trading above its true value) or oversold condition (a security price fall below its true value). The RSI is most typically used on a 14-day timeframe, and measured on a scale from 0 to 100 [11]. If the RSI is below 30, the market is in the oversold condition, but if the RSI is above 70, the market is in the overbought condition.

$$RSI = 100 - \left(\frac{100}{1+RS}\right) \qquad (21)$$

$$RS = \frac{AG}{AL} \qquad (22)$$

The variable RS means relative strength, AG is average gaining, and AL is the average loss.

Stochastic Oscillator (SO) compares where a stock's price closed relative to its price range over a given time period [11]. SO is displayed as two lines. The first line is called %K and the second line is called %D.

$$\%K = \left(\frac{today's\ close - lowest\ close\ in\ \%K\ periods}{Highest\ close\ in\ \%K\ periods - lowest\ close\ in\ \%K\ periods}\right) \times 100 \qquad (23)$$

$$\%D = \left(\frac{\sum_{n=1}^{3} \%K_n}{3}\right) \times 100 \qquad (24)$$

If SO is above 80, the market is overbought. But if the SO is below 20, the market is oversold.

On-Balance Volume (OBV) relates the company stock price to its volume [11]. Up-volume is a condition when today's close price is higher than yesterday. Down-volume is a condition when today's close price is less than yesterday.

$$OBV = OBV_{previous} + \begin{cases} volume, & if\ close > close_{previous} \\ 0, & if\ close = close_{previous} \\ -volume, & if\ close < close_{previous} \end{cases} \qquad (25)$$

4. RESULTS AND DISCUSSION

The companies that were used to test the program were PT Media Nusantara Citra Tbk and PT Lippo Karawaci Tbk, and the company stock data for the year 2014 are listed below in Tables 8 and 9, respectively. There are 24 data sets from two companies; each data set represents the stock technical indicators for the year 2014.

All data using in this paper are available at the following links.

- https://finance.yahoo.com/quote/LPKR.JK?p= LPKR.JK&.tsrc=fin-srch
- https://finance.yahoo.com/quote/MNCN.JK?p= MNCN.JK&.tsrc=fin-srch

Table 8: PT Media Nusantara Citra Tbk Stock Data

Date	MACD	RSI	SO	OBV
Jan 6, 2014	10	45.3	48.6	2
Feb 3, 2014	2	29.3	35	10
March 3, 2014	10	73.3	84.7	2
Apr 3, 2014	2	41.5	48.8	10
May 2, 2014	2	48.8	27.7	2
June 1, 2014	10	62.7	96	2
July 1, 2014	2	39.9	47.2	2
August 4, 2014	10	54.1	76.4	10
Sept 1, 2014	2	44.3	22.2	10
Oct 1, 2014	10	80.1	84.8	2
Nov 3, 2014	2	38.1	30.3	2
Dec 9, 2014	10	36	4	2

Table 9: PT Lippo Karawaci Tbk Stock Data

Date	MACD	RSI	SO	OBV
Jan 6, 2014	10	22.2	35	2
Feb 3, 2014	2	60	42	2
March 3, 2014	2	52.9	43.1	2
Apr 3, 2014	2	61	42.3	10
May 2, 2014	2	36.6	28.5	10
June 1, 2014	2	42.3	7.3	2
July 1, 2014	2	23.6	18.7	2
August 4, 2014	2	57.3	37.9	10
Sept 1, 2014	2	16.3	7.8	2
Oct 1, 2014	2	28.5	7.1	2
Nov 3, 2014	10	78.1	95.2	10
Dec 9, 2014	2	58.6	37.4	2

Each company stock was processed in FIS to produce the best recommendation based on the fuzzy logic method. The accuracy of the system was

determined by comparing the resulting recommendation to the open price for seven days following the recommendation date. Figure 2 shows the membership function editor in the Matlab program.
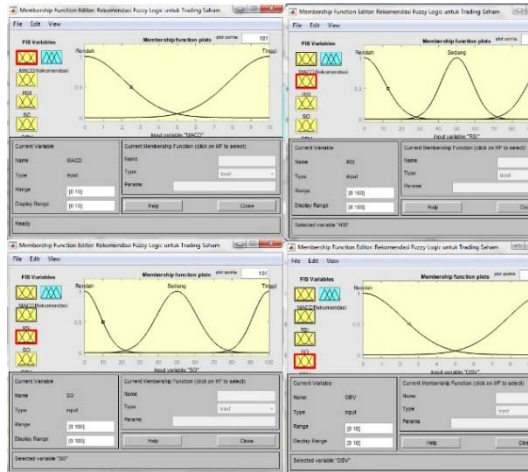

Figure 2 : Membership Function Editor

For example, on February 3, 2014, the stock price from PT Media Nusantara Citra Tbk was at Rp. 2250,00 (US\$ 0.16)with MACD at 10, RSI at 29.5, SO at 35, and OBV at 10. In Figure 3(a), the algorithm shows a result of 15.2 to this combination of indicators, recommending Hold for the stock. To confirm this, we compared the result with the close price to the next 7 days. On February 10, 2014, there was no drastic increase in stock price since the price increased by only Rp. 45,00. The candle bar in Figure 3(b) shows a stable stock price. Thus, the recommendation from the system is correct.

(a)

(b)

Figure 3 : (a) System Result, (b) Candle Bar in Feb 2014

As an example for the computation and steps on fuzzification and the invers process, we choose a historical data from PT. Telekomunikasi Indonesia on September 18th 2014 that was given on the Table 10.

Table 10: Numerical Variabel for PT. Telekomunikasi Indonesia

Date	August 4th 2014
MACD	10
RSI	81
SO	93
OBV	10

The first step is fuzzification process, on this step input data is a crisp data that will be transformed into fuzzy data.

- For MACD

Since the value of $x_1 = 10$, which is the fuzzy variable of x_1 is quite high, then the low fuzzy membership value is   0, while the high fuzzy membership value can be compute by:

$$\mu(x_1) = \exp\left(\frac{-1}{2}\left(\frac{x_1 - 10}{2.123}\right)^2\right)$$

$$\mu(10) = \exp\left(\frac{-1}{2}\left(\frac{10-10}{2.123}\right)^2\right) = 1 \qquad (26)$$

- For RSI

The fuzzy variable for $x_2 = 81$ is quite high, with the low and mid fuzzy membership value is 0. For the high fuzzy membership value will be compute as follows.

$$\mu(x_2) = \exp\left(\frac{-1}{2}\left(\frac{x_2 - 100}{10.82}\right)^2\right)$$

$$\mu(81) = \exp\left(\frac{-1}{2}\left(\frac{81-100}{10.82}\right)^2\right) = 0.214 \qquad (27)$$

So the high fuzzy membership value for x_2 is 0.214.

- For SO

The fuzzy variable for $x_3 = 93$ is quite high, with the low and mid fuzzy membership value is 0. For the high fuzzy membership value will be compute as follows.

$$\mu(x_3) = \exp\left(\frac{-1}{2}\left(\frac{x_3 - 100}{8.493}\right)^2\right)$$

$$\mu(93) = \exp\left(\frac{-1}{2}\left(\frac{93-100}{8.493}\right)^2\right) = 0.712 \qquad (28)$$

We have the high fuzzy membership value for x_3 is 0.712.

- For OBV

For the last component of the input with value is 10, the low fuzzy membership value is 0, while the computation for finding the high fuzzy membership value is given as follow.

$$\mu(x_4) = \exp\left(\frac{-1}{2}\left(\frac{x_4 - 10}{2.123}\right)^2\right)$$

$$\mu(10) = \exp\left(\frac{-1}{2}\left(\frac{10-10}{2.123}\right)^2\right) = 1 \qquad (29)$$

The summary for four input variable was given on Table 11.

Table 11: Fuzzy Varible Computation Results

	Numerical	Fuzzy	$\mu(x)$
MACD	10	Low	0
		High	1
RSI	81	Low	0
		Mid	0
		High	0.214
SO	93	Low	0
		Mid	0
		High	0.712
OBV	10	Low	0
		High	1

After we successfully compute the fuzzy variable, the next step is inference rules. By using Mamdani rule, the implication function that was used is minimum function that is looking for $\alpha - cut_i$ for each rules with

$$\alpha - cut_i = \min\{\mu(x_1), \mu(x_2), \mu(x_3), \mu(x_4)\}$$
for $R01 \leq i \leq R20$.

The system itself consist on several condition, then for the next step we use composite rule with maximum function. One thing that is important to be considered is the domain results from each rule. If there exist two or more results from different domain then domain for $\mu(z)$ is results from combining those domains. But if there exist more than one results from the same domain then $\mu(z) = \max\{\alpha - cut_i\}$.

Table 12: . $\alpha - cut$ Values For Each Rules

i	$\alpha - cut_i$
R01	Min {0, 0, 0, 0} = 0
R02	Min {0, 0, 0, 0} = 0
R03	Min {0, 0, 0.712, 0} = 0
R04	Min {0, 0.214, 0, 0} = 0
R05	Min {0, 0.214, 0.712, 0} = 0
R06	Min {1, 0, 0, 1} = 0
R07	Min {1, 0, 0, 1} = 0
R08	Min {1, 0, 0, 1} = 0
R09	Min {1, 0, 0, 0} = 0

R10	Min {1, 0, 0, 1} = 0
R11	Min {1, 0, 0, 0} = 0
R12	Min {1, 0.214, 0.712, 1} = 0.214
R13	Min {0, 0, 0} = 0
R14	Min {0, 0.214, 0.712, 1} = 0
R15	Min {1, 0, 0} = 0
R16	Min {1, 0, 0} = 0
R17	Min { 0, 0, 1} = 0
R18	Min { 0, 0, 1} = 0
R19	Min { 0.214, 0.712, 0} = 0
R20	Min {0, 0, 0} = 0

Based on $\alpha - cut$ computation results on Table 12, there is only one domain that is non zero, which is $\pi(z) = 0.214$ from R12, where on that rule, the domain is fuzzy variable "buy" with interval [20, 30].

The last step is defuzzification, the invers transformation from fuzzy variable to numerical variable. We use Center of Area (Centroid) with $\mu(z) = 0.1427, 20 \leq z \leq 30$. The solution z* is computed by formula below.

$$z^* = \frac{\int z\mu(z)dz}{\int \mu(z)dz} = \frac{\int_{20}^{30} 0.214\, z\, dz}{\int_{20}^{30} 0.214\, dz} = 25. \qquad (30)$$

So we have the output for input data MACD = 10, RSI = 81, SO = 93, and OBV = 10 have output 25 that is to recommend "BUY".

The results of analysis for two companies using the following data are summarized in Tables 13 and 14, where Rec means recommendation and Y = Yes, N = No.

Table 13: PT Media Nusantara Citra Tbk Results

Date	z^*	Rec	Price Difference	Accurate
Jan 6, 2014	15	HOLD	−30	Y
Feb 3, 2014	15.2	HOLD	+45	Y

Date	z^*	Rec	Price Difference	Accurate
March 3, 2014	6.41	SELL	+85	Y
Apr 1, 2014	10	HOLD	+85	N
May 2, 2014	10.1	HOLD	−35	Y
June 2, 2014	10	HOLD	−35	Y
July 1, 2014	10	HOLD	−5	Y
August 4, 2014	20	HOLD	+90	N
Sept 1, 2014	15.2	HOLD	−25	Y
Oct 1, 2014	5.21	SELL	−225	N
Nov 3, 2014	10	HOLD	−230	N
Dec 9, 2014	9.48	SELL	+140	Y

Table 14: . PT Lippo Karawaci Tbk Results

Date	z^*	Rec	Price Difference	Accurate
Jan 6, 2014	16.4	HOLD	−10	Y
Feb 3, 2014	10	HOLD	−10	Y
March 3, 2014	10	SELL	+95	Y
Apr 1, 2014	15	HOLD	+110	N
May 2, 2014	15.2	HOLD	−15	Y
June 2, 2014	16.6	HOLD	+10	Y
July 1, 2014	6.04	SELL	+100	Y
August 4, 2014	15	HOLD	+50	Y
Sept 1, 2014	15.08	HOLD	−20	Y
Oct 3, 2014	5.81	SELL	−15	N
Nov 3, 2014	25	BUY	−60	Y
Dec 9, 2014	10	SELL	−85	N

Next on another comparison, by using PT Media Nusantara Citra Tbk data, on the next one week, stock price on 15th January 2014 declined by 35, because it only decrease slightly the the recommendation is already quite effective. We perform 12 experiment results in Table 15, where

Acc means accuracy, recc means recommendation, Y means that it is a good recommendation and N for not a good recommendation.

Table 15: Experiment results accuracy by time period

Date	z^*	Recc	Acc	
			1 week	1 month
January 3, 2014	15	HOLD	Y	N
February 3, 2014	15.2	HOLD	Y	N
March 3, 2014	6.41	SELL	Y	Y
April 1, 2014	10	HOLD	N	Y
May 2, 2014	10.1	HOLD	Y	Y
June 2, 2014	10	HOLD	Y	N
July 1, 2014	10	HOLD	Y	N
August 5, 2014	15.1	HOLD	N	Y
September 1, 2014	15.2	HOLD	Y	N
October 3, 2014	10	HOLD	Y	N
November 3, 2014	10	HOLD	N	N
December 9, 2014	9.48	SELL	Y	Y

Based on Table 15, from 12 experiments, on 1 week period, there exists three failed experiment where the recommendation is not good, so we have one week period accuracy is 75%. While on a month period, the accuracy decline to 41.67%.

5. CONCLUSION AND FUTURE WORKS

The algorithm showed the four recommendations differed from the real-time conditions, so the accuracy level for PT Media Nusantara Citra Tbk was 66.67%. For PT Lippo Karawaci, there were only had three recommendations that differed from the real-time conditions, so the accuracy level for it was 75%. Therefore, this method can provide accurate recommendations for decision-making in stock trading.

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REFERENCES

[1] Herbert B. Mayo, Investment: An Introduction, 10th ed, Mason, OH, South-Western Cengage Learning, 2011, pp. 3-20.

[2] George A. Fontanills, T. Gentile, and R. M. Cawood, The Stock Market Course, New York, John Wiley & Sons, Inc, 2001, pp. 1-6.

[3] Timothy J. Ross, Fuzzy Logic With Engineering Applications, 3rd ed*, Chicheste, West Sussex, John Wiley & Sons, Ltd, 2010, pp. 117-139.

[4] R. Naranjo, A. Meco, J. Arroyo, and M. Santos, "An Intelligent Trading System with Fuzzy Rules and Fuzzy Capital Management", *International Journal of Intelligent Systems*, Vol. 30, No. 8, 2015, pp. 963-983.

[5] Z. Rustam and A. S. Talita, "Fuzzy Kernel K-Medoids Algorithm for Multiclass Multidimensional Data Classification", *Journal of Theoretical and Applied Information Technology*, Vol. 80, Issue 1, October 2015, pp 147-151.

[6] N. B. Karayiannis and J. C. Bezdek, "An Integrated Approach to Fuzzy Learning Vector Quantization and Fuzzy C-Means Clustering", *IEEE Trans. Fuzzy Systems*, Vol. 5, No. 4, 1997, pp. 622-628.

[7] Z. Rustam and A.S. Talita, "Fuzzy Kernel k-Medoids Algorithm for Anomaly Detection Problem", AIP Conference Proceedings 1862 (1), 2017, 030154.

[8] J. R. Jang, C. Sun, E. Mizutani, Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, New Jersey, Prentice Hall, 1997, pp. 73-89.

[9] A.D. Ijegawa, V.O. Rebecca, F. Olusegun, and O. O. Isaac, "A Predictive Stock Market Technical Analysis Using Fuzzy Logic", *Computer and Information Science Journal*, Vol. 7, No. 3, 2014, pp. 1-17.

[10] G. Appel, Technical Analysis Power Tools for Active Investors, New Jersey, Pearson education, Inc, 2005, pp. 166.

[11] S. B. Achelis, Technical Analysis from A to Z, USA, Mc-Graw Hill, 2000, pp. 1-35.