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MACD Indicator with the Modified Signal Line and Trading Weight Inference in Fuzzy Environment

Prachya Boonprasurt [a], Pipat Sampaokit [b] and Wichai Witayakiattilerd*[a]
[a] Department of Mathematics and Statistics, Faculty of Science and Technology, Thammasat University, Pathumthani, Thailand.
[b] Department of Mathematics, Faculty of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand.
*Corresponding author; e-mail: wichai@mathstat.sci.tu.ac.th

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Abstract

This research proposes improvements to moving average convergence divergence (MACD) by modifying the signal line. MACD with the modified signal line is called MACDP. It can signal trading faster than traditional MACD. The confidence level defined from a fuzzy logic process is applied to interpret the MACDP in each period. Furthermore, the research presents trading weight inference using a fuzzy logic process to increase the efficiency of trading. We analyze the recent stock movement of the SET100 group in the stock exchange of Thailand as a case study.

Keywords: Moving average, fuzzy logic, trading system, technical analysis.

1. Introduction

Stock trading is high risk-high return. The risk is the possibility of losing principal or receiving a lower return than expected. This is induced by fluctuations in prices which are affected by many factors such as economic conditions or company performance, and these cannot be predicted. Therefore, investors need tools to analyze and make decisions on the choice of profitable stocks.

Moving average convergence divergence (MACD) is one of the most popular and widely trusted technical indicators. It is easy to understand and easy to use. However, MACD has a disadvantage, which is signaling transmission delay. MACD has been continuously developed and improved. In "A Refined MACD Indicator – Evidence against the Random Walk Hypothesis?", Meissner et al. (2001) introduced two MACD improvements called MACDR1 and MACDR2. For MACDR1, they added a condition to the purchase by buying shares when the MACD line breaks above the signal line for a period of time. For MACDR2, they added some conditions on buying and selling. The term of the purchase is the same as MACDR1 and the term of sale is that a profit is gained.

Fuzzy logic processes are emergent techniques used in the design of information processing systems such as transaction processing, decision making, or workflow management, (see, for example, Murthy and Pal 1990, Gamilet et al. 200, Wu and Mendel 2007, Sylvie and Boukezzoula 2009, Thirunavukarasu and Maheswari 2013, Yodmun and Witayakiattilerd 2016, Kesamoon and Witayakiattilerd 2019, Witayakiattilerd 2019 and others). Many researchers have used fuzzy logic processes to improve MACD. Cheung and Kaymak (2000) examined a trading model that amalgamates fuzzy logic and technical analysis to seek patterns and trends in stock market indices. Dong and Wan (2009) investigated buy and sell timing using a fuzzy approach. Marques et al. (2010) presented a new methodology for the parameterization of technical analysis of financial market indicators. Ijegwa et al. (2014) applied fuzzy inference to stock market analysis, using four technical indicators to deal with probabilities in the decision-making process.

MACD is a trend-following momentum indicator that shows the relationship between two moving averages of prices. It is calculated by subtracting the long-day exponential moving average (EMA) from the short-day EMA. Therefore, the change in the price of a stock will occur faster than the signal of price change of the MACD, and this will affect the trading signals. In the current study, we used fuzzy logic to induce MACD to deliver faster trading signals, with the goal of improving profitability. Our concept differed from previous approaches. We applied trading weight inference using fuzzy logic to increase the efficiency of trading. We analyzed stock movements in the SET100 group of the Stock Exchange of Thailand as a case study. We did this by measuring the performance of the proposed MACD using trading success rates and profit margins as indicators. The results were compared with those from traditional MACD, MACDR1, and MACDR2.

The paper is organized as follows: in Section 2 , we recall some basic concepts and notation which are used in the following sections. In Section 3, we present the conditions and procedures for trading. In Sections 4 and 5, we introduce the modified signal line and trading weight.

2. Background

2.1. Fuzzy number

The concept of fuzzy logic was introduced by Zadeh (1965). Let A be a crisp set of universe $\mathcal{U}$. Fuzzy set $\mathcal{A}$ on the crisp set A is defined by $\mathcal{A}=\{(x,\mu_{\mathcal{A}}(x)) \mid x\in A \text{ and } \mu_{\mathcal{A}}(x)\in[0,1]\}$, where $\mu_{\mathcal{A}}: A\to[0,1]$ is called a membership function of the fuzzy set $\mathcal{A}$. The α-cut, $[\mu_{\mathcal{A}}]^{\alpha}$, is defined by $[\mu_{\mathcal{A}}]^{\alpha}=\{x\in A \mid \mu_{\mathcal{A}}(x)\geq\alpha\}$ if $\alpha>0$, and $[\mu_{\mathcal{A}}]^{0}=\overline{\{x\in A \mid \mu_{\mathcal{A}}(x)>0\}}$ ($\overline{A}$ is denoted by closure of A). A fuzzy number κ is defined on the universe $\mathbb{R}$ as a convex and normalized fuzzy set which for each $\alpha\in[0,1]$, $[\mu_{\kappa}]^{\alpha}=[a,b]$ for some interval $[a,b]$. The fuzzy numbers in this research will be almost always triangular fuzzy number or trapezoidal fuzzy number. A Triangular fuzzy number η is defined by three numbers $a_1<b<a_2$ where its base is the interval $[a_1,a_2]$ and its top (the membership equals one) is at $x=b$. We denote $\tau=\langle a_1,b,a_2\rangle$ for triangular fuzzy number. A trapezoidal fuzzy number τ is defined by four numbers $a_1<b_1<b_2<a_2$ where its base is the interval $[a_1,a_2]$ and its top (the membership equals one) is over $[b_1,b_2]$. We denote $\tau=\langle a_1,b_1,b_2,a_2\rangle$ for trapezoidal fuzzy number.

2.2. Fuzzy proposition and inference

Fuzzy propositions consist of linguistic terms, linguistic variables, and connectors. A linguistic term is an element that conveys human feelings, ideas, and knowledge. A linguistic variable is a fuzzy set that defines those words in the natural language that convey the meaning of the set as humanly understood. A linguistic variable refers to the characteristics of a phenomenon. Each linguistic term can be defined with the membership function of the fuzzy set. A fuzzy rule is defined as a conditional statement of the following form:

Rule-1 if x_1 is $\mathcal{A}_{11}$ and x_2 is $\mathcal{A}_{12}$ … and x_n is $\mathcal{A}_{1n}$ then y is $\mathcal{B}_1$,

Rule-2 if x_1 is $\mathcal{A}_{21}$ and x_2 is $\mathcal{A}_{22}$ … and x_n is $\mathcal{A}_{2n}$ then y is $\mathcal{B}_2$,

$\vdots$ $\vdots$ $\vdots$

Rule-m if x_1 is $\mathcal{A}_{m1}$ and x_2 is $\mathcal{A}_{m2}$ …and x_n is $\mathcal{A}_{mn}$ then y is $\mathcal{B}_m$,

where x_j, for $j=1,...,n$ are linguistic variables; $\mathcal{A}_{ij}$ and $\mathcal{B}_i$, $i=1,...,m$, $j=1,...,n$ are fuzzy sets representing linguistic terms on the universe of discourse A_{ij} and B_i. Fuzzy logic inference is an operation from a set of fuzzy rules to a set of facts. In this paper, the Mamdani method is applied for the inference. The fuzzy output is converted to real values by a defuzzification process. The defuzzification method used was the widely-accepted center of gravity method. This method finds a real-valued output as a weighted average of every point z in domain B, where the weight is the ratio of $u_{\mathcal{B}}(z)$ to the area under the curve of $u_{\mathcal{B}}$, i.e., a real-value output z_{cg} is defined as

$$z_{cg} = \int_B z w_z dz = \int_B z u_{\mathcal{B}}(z) dz \bigg/ \int_B u_{\mathcal{B}}(z) dz.$$

2.3. MACD indicator

Exponential moving average or EMA, is one of the most important tools for finding time-varying data representations from historical data. It determines the importance or weight value with the latest data, rather than the older data in the exponential manner. The EMA is used to smooth price graph customization, which enables us to forecast trends and price movements better. Let $\{\tau\}=\{t_1,t_2,...,t_n\}$ be a time sequence corresponding to a price sequence $\{p\}=\{p_t \mid t\in\{\tau\}\}$. The graph $P=\{(t,p_t) \mid t\in\{\tau\}\}$ is called the price line.

Definition 1 *Let $0<\alpha<1$ and $t\in\{\tau\}$. The exponential moving average at t, $EMA(t)$, is defined by*

$$EMA(t) = EMA(t-1) + \alpha(p_t - EMA(t-1)). \tag{1}$$

The graph $EMA=\{(t,EMA(t)) \mid t\in\{\tau\}\}$ is called exponential moving average line, and α is called smoothing constant.

The study of Hutson (1991) found that $\alpha = 2/(N+1)$, $N\geq 2$ is suitable for calculating the EMA. The EMA with $\alpha=2/(N+1)$ is called N-day exponential moving average denoting by $EMA_N(t)$, i.e.,

$$EMA_N(t) = EMA_N(t-1) + \frac{2}{N+1}(p_t - EMA_N(t-1)), \quad t \geq N. \tag{2}$$

MACD is a trend-following momentum indicator that shows the relationship between two moving averages of prices, which is defined as the following.

Definition 2 *Let* $n_1, n_2 \in \mathbb{N}$ *such that* $n_1 < n_2$ *and let* EMA_{n_1} *and* EMA_{n_2} *be the exponential moving average. Then moving average convergence divergence is denoted* $MACD_{n_1,n_2}$ *and defined by*

$$MACD_{n_1,n_2}(t) = EMA_{n_1}(t) - EMA_{n_2}(t), \quad \text{for all } t \in \{\tau\}, \tag{2}$$

where EMA_{n_1} *is called a short-day EMA and* EMA_{n_2} *is called a long-day EMA. The graph* $MACD_{n_1,n_2} = \{(t, MACD_{n_1,n_2}(t)) \mid t \in \{\tau\}\}$ *is called the MACD line.*

Definition 3 *Let* $MACD_{n_1,n_2}$ *be the MACD and* $n_3 \in \mathbb{N}$. *The* n_3*-day EMA of* $MACD_{n_1,n_2}$ *is called signal of* $MACD_{n_1,n_2}$ *and denoted by* $Sig_{n_3}(t)$, *i.e.,* $Sig_{n_3}(t) = EMA_{n_3}^{MACD}(t)$, *for all* $t \in \{\tau\}$ *and the graph* $Sig_{n_3} = \{(t, Sig_{n_3}(t)) \mid t \in \{\tau\}\}$ *is called signal line.*

Note: In this paper, we set $n_1 = 12$, $n_2 = 26$ and $n_3 = 9$.

3. Conditions and Trading Procedures

This section, we discuss trading schedules, trading conditions and assumptions in the research. Let $MACD$ and Sig be a MACD and signal, respectively.

Definition 4 *A time* $t^{\uparrow} \in \{\tau\}$ *is called go-up point, if* $t^{\uparrow}$ *satisfies only one of the following conditions:*

1) $MACD(t^{\uparrow}) > Sig(t^{\uparrow})$ *and* $MACD(t^{\uparrow}-1) < Sig(t^{\uparrow}-1)$,

2) $MACD(t^{\uparrow}) > Sig(t^{\uparrow})$, $MACD(t^{\uparrow}-1) = Sig(t^{\uparrow}-1)$, *and* $MACD(t^{\uparrow}-2) < Sig(t^{\uparrow}-2)$.

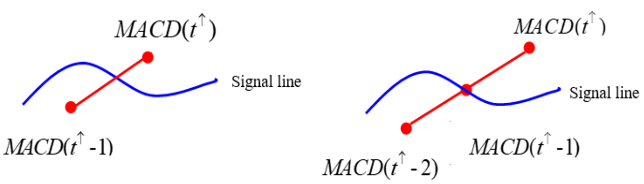

Figure 1 Show go-up point

Definition 5 *A time* $t^{\downarrow} \in \{\tau\}$ *is called go-down point, if* $t^{\downarrow}$ *satisfies only one of the following conditions:*

1) $MACD(t^{\downarrow}) < Sig(t^{\downarrow})$ *and* $MACD(t^{\downarrow}-1) > Sig(t^{\downarrow}-1)$,

2) $MACD(t^{\downarrow}) < Sig(t^{\downarrow})$, $MACD(t^{\downarrow}-1) = Sig(t^{\downarrow}-1)$ *and* $MACD(t^{\downarrow}-2) > Sig(t^{\downarrow}-2)$.

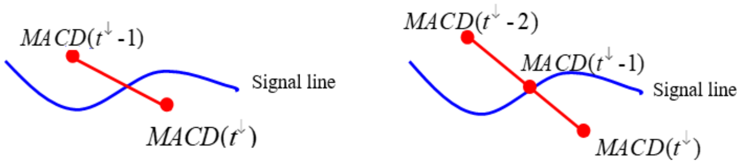

Figure 2 Show go-down point

Definition 6 *Let* $t^{\downarrow_i}$ *and* $t^{\downarrow_{i+1}}$ *be two adjacent go-down points, where* $t^{\downarrow_i} < t^{\downarrow_{i+1}}$. *The sequence* $\{\tau_i\} = \left[t^{\downarrow_i}, t^{\downarrow_{i+1}}\right] \cap \{\tau\}$ *is called the* i^{th} *-period of trading.*

Let $\{\tau_i\}$ *be the* i^{th} *-period of trading and* $\left|\{\tau_i\}\right| = \theta_i$, *i.e.,* $\{\tau_i\} = \left\{t_{(i,1)}, t_{(i,2)}, \ldots, t_{(i,\theta_i)}\right\}$. *Then* $t_{(i,1)} = t^{\downarrow_i}$ *(starting point) and* $t_{(i,\theta_i)} = t^{\downarrow_{i+1}}$ *(ending point). For convenience, the following symbols will be defined as follows:*

$\{p_i\} = \left\{p_{t_{(i,1)}}, p_{t_{(i,2)}}, \ldots, p_{t_{(i,\theta_i)}}\right\}$ *denotes the sequence of stock prices corresponding to* $\{\tau_i\}$,

$\{m_i\} = \left\{m_{t_{(i,1)}}, m_{t_{(i,2)}}, \ldots, m_{t_{(i,\theta_i)}}\right\}$ *denotes the sequence of* $MACD$ *corresponding to* $\{\tau_i\}$,

$\{s_i\} = \left\{s_{t_{(i,1)}}, s_{t_{(i,2)}}, \ldots, s_{t_{(i,\theta_i)}}\right\}$ *denotes the sequence of* Sig *corresponding to* $\{\tau_i\}$.

3.2. Trading conditions

In this paper, the assumptions for trading are as follows:

(H1) In each $\{\tau_i\}$, $i = 1, 2, \ldots, r$, only one round of trading will occur and must end in a single period. That is, there will be a one-time purchase at the time ${}_i t^b \in \{\tau_i\}$ with C_i baht. After that, all the shares will be sold only once at the time ${}_i t^s \in \{\tau_i\}$. We will represent the time of purchase, the time of sale and the amount invested by a 3-tuple $\left({}_i t^b, {}_i t^s, {}_i C\right)$.

(H2) The number of shares purchased can be any positive real number. That is, if giving $p_{{}_i t^b}$ as a stock price at time ${}_i t^b$ and investing in the amount of C_i baht, the number of shares purchased can be equal to ${}_i C \big/ p_{{}_i t^b}$ units (not necessarily a positive integer only).

(H3) The $(k+1)^{\text{th}}$ -trading will only occur when the k^{th} -trading is completed. That is, ${}_i t^{s_k} <_i t^{b_{k+1}}$ for all $k = 1, 2, \ldots, n_i - 1$.

3.3. Success rate and average profit rate

In this paper, the efficiency of various trading methods is measured using the success rate and the average profit margin, which has the following definitions. Let $\left({}_i t^b, {}_i t^s, {}_i C\right)$ be the trading in the period $\{\tau_i\}$, $i = 1, 2, \ldots, r$.

Definition 7 *Earnings per share (denoting* ${}_iP^1$ *) from the trading* $\left({}_it^b, {}_it^s, {}_iC\right)$ *in the* i^{th} *-period is the difference between the purchase price and the selling price at the time* ${}_it^b$ *and* ${}_it^s$, *respectively. That is,*

$$ {}_iP^1 = \left(p_{{}_it^s} - p_{{}_it^b}\right)\left(\frac{{}_iC}{p_{{}_it^b}}\right) = \left(\frac{p_{{}_it^s}}{p_{{}_it^b}} - 1\right)_i C. \tag{4} $$

Then the profit rate, let's say ${}_i\tilde{P}^1$

$$ {}_i\tilde{P}^1 = \frac{p_{{}_it^s}}{p_{{}_it^b}} - 1. \tag{5} $$

By condition (H1), we will see that in each period of trading, there may be more than one trading round. Let n_i be the number of trading rounds in the period $\{\tau_i\}$, $i = 1, 2, ..., r$ and let $\left({}_it^b, {}_it^s, {}_iC^k\right)$ be the k^{th}-trading round. Then, the total profit (loss) ${}_iP$ in the period $\{\tau_i\}$, is

$$ {}_iP = \sum_{k=1}^{n_i} {}_iP^k = \sum_{k=1}^{n_i} \left(\frac{p^k_{{}_it^s}}{p^k_{{}_it^b}} - 1\right)_i C^k. \tag{6} $$

The total profit in time $\{\tau\}$, is

$$ \sum_{i=1}^{r}\sum_{k=1}^{n_i} {}_iP^k = \sum_{i=1}^{r}\sum_{k=1}^{n_i} \left(\frac{p^k_{{}_it^s}}{p^k_{{}_it^b}} - 1\right)_i C^k. \tag{7} $$

Hence, the average profit margin (PR) in time $\{\tau\}$, equals

$$ \mathrm{PR} = \frac{1}{r}\sum_{i=1}^{r}\sum_{k=1}^{n_i} {}_iP^k = \frac{1}{r}\sum_{i=1}^{r}\sum_{k=1}^{n_i} \left(\frac{p^k_{{}_it^s}}{p^k_{{}_it^b}} - 1\right)_i C^k. \tag{8} $$

Definition 8 *Let* ${}_iP$ *be the profit (loss) in the period* $\{\tau_i\}$, $i = 1, 2, ..., r$. *A transaction in the period* $\{\tau_i\}$ *which* ${}_iP > 0$, *is said to be success (resp. failure).*

Definition 9 *The success rate (SR) of trading in time* $\{\tau\}$, *is defined by*

$$ SR = \frac{\sum_{i=1}^{r} {}_i\mathrm{S}}{r}, \tag{9} $$

where r *is the number of trading rounds in time* $\{\tau\}$ *and* ${}_iS = \begin{cases} 1, & {}_iP > 0, \\ 0, & \text{otherwise.} \end{cases}$

3.4. Additional trading conditions

Let $\left({}_it^b, {}_it^s, {}_iC\right)$ be a transaction in period $\{\tau_i\}$, $i = 1,2,...,r$ in $\{\tau\}$. In this paper, the assumptions for investment are as follows:

(H) The amount of funds for each transaction must be equal, i.e., for all $k = 1,2,...,n_i$, ${}_iC^k = C$ for some $C > 0$.

(CA) The capital algorithm,

Step 1. Trading with starting money $C_i^1 = C$.

Step 2. Check $k = n_k$ or not. Stop if yes. Go to Step 3 if not.

Step 3. Check ${}_iP^k \geq 0$ or not. If yes, go to Step 4. If not, go to Step 5.

Step 4. Invest in the $(k+1)^{\text{th}}$ with money $C_i^{k+1} = C$, then go back to Step 2.

Step 5. Top up the amount of $-{}_iP^k$ to make the port have the amount of C and continue investing in the $(k+1)^{\text{th}}$ with the amount of C after that, go to Step 2.

Let $n = \sum_{i=1}^{r} n_i$ be the number of all trading rounds and let P^k be the profit (loss) in the trading period k, $k = 1,2,...,n$. From Condition (H) and Algorithm (CA), the total investment amount equals

$$C + \sum_{k=1}^{n-1} \max\left\{0, -P^k\right\}. \tag{10}$$

The cumulative amount from trading on $\{\tau\}$ is equal to

$$C + P^n + \sum_{k=1}^{n-1} \max\left\{0, P^k\right\}. \tag{11}$$

Consequently, the average profit rate on $\{\tau\}$ that we shall denote by $\tilde{P}_\tau$ can be defined as

$$\tilde{P}_\tau = \begin{cases} P^1 / C, & n = 1 \\ \sum_{k=1}^{n} P^k \bigg/ \left(C - \sum_{k=1}^{n-1} \min\left\{0, P^k\right\}\right), & n > 1. \end{cases} \tag{12}$$

3.5. Trading with traditional MACD

From the previous section, we have known that the trading period is determined by using two adjacent cutting-down points. Suppose that $t^{\downarrow_i}$ and $t^{\downarrow(i+1)}$ are the beginning point and the ending point of trading period $\{\tau_i\}$, $i = 1,2,...,r$, respectively. The trading with traditional MACD is defined as follows.

Definition 10 *The trading with traditional MACD is a trading that determines the buying point* ${}_it^b = t^{\uparrow i}$ *and the selling point* ${}_it^s = t^{\uparrow(i+1)}$.

From Definition 10, there is only one transaction in each period $\{\tau_i\},\ i=1,2,...,r,$ denoted by $\left(t^{\uparrow_i}, t^{\downarrow_{(i+1)}}, C\right)$ for some constant $C>0.$ As a consequence, $n=\sum_{i=1}^{r} n_i = r$ and the average profit rate on $\{\tau\}$ of transactions with traditional MACD is

$$\tilde{P}_\tau = \begin{cases} P^1/C, & r=1, \\ \sum_{k=1}^{r} P^k \Big/ \left(C - \sum_{k=1}^{r-1} \min\left\{0, P^k\right\}\right), & r>1. \end{cases} \tag{13}$$

3.6. Trading with MACDR1

For trading with MACDR1, we shall determine the time point of purchasing as 3 points from the cutting-up point and the time point of selling as the time point. Set the selling point to be a point where the gross profit margin is not less than 3% , but if no such point is found then sell at the intersection.

Definition 11 *Let $\{\tau_i\},\ i=1,2,...,r$ be the trading period. The MACDR1 trading method is the method that specifies the trading $\left({}_i t^b, {}_i t^s, C\right)$ in $\{\tau_i\},\ i=1,2,...,r,$ as follows:*

- the buy point ${}_i t^b$ is any point $t_{(i,j)} \in \{\tau_i\}$ where 1) $m_{t_{(i,j)}} > s_{t_{(i,j)}}$ and $m_{t_{(i,j-1)}} > s_{t_{(i,j-1)}}$, 2) $m_{t_{(i,j-2)}} \geq s_{t_{(i,j-2)}}$ and $m_{t_{(i,j-3)}} < s_{t_{(i,j-3)}}$, ($t_{(i,j-3)}$ is the intersection point),

- the selling point ${}_i t^s$ is any point $t_{(i,j)} \in (\tau_i)$ which $\left(p_{t_{(i,j)}} - p_{t_i^b}\right)\Big/ p_{t_i^b} \geq 0.03$ or $t_{(i,j)} = t_{(i,\theta_i)}$.

3.7. Trading with MACDR2

Trading with MACDR2 will specify the same trading point as MACDR1, but there will be additional conditions for the buying point, which is to buy when the difference between the MACD line and the signal line has a difference of not less than 0.5 percent of the share price and set a selling point like trading with MACDR1.

Definition 12 *Let $\{\tau_i\},\ i=1,2,...,r$ be the trading period. The MACDR2 trading method is the method that specifies the trading $\left({}_i t^b, {}_i t^s, C\right)$ in $\{\tau_i\},\ i=1,2,...,r,$ as follows,*

- the buy point ${}_i t^b$ is any point $t_{(i,j)} \in \{\tau_i\}$ where

1) $m_{t_{(i,j)}} > s_{t_{(i,j)}}$ and $m_{t_{(i,j-1)}} > s_{t_{(i,j-1)}}$,

2) $m_{t_{(i,j-2)}} \geq s_{t_{(i,j-2)}}$ and $m_{t_{(i,j-3)}} < s_{t_{(i,j-3)}}$, ($t_{(i,j-3)}$ is the intersection point),

3) $\left(m_{t_{(i,j)}} - s_{t_{(i,j)}}\right)\Big/ p_{t_{(i,j)}} \geq 0.005.$

- the selling point ${}_i t^s$ is any point $t_{(i,j)} \in (\tau_i)$ which $\left(p_{t_{(i,j)}} - p_{t_i^b}\right)\Big/ p_{t_i^b} \geq 0.03$ or $t_{(i,j)} = t_{(i,\theta_i)}$.

4. Modified Signal Line

In this topic, we will examine the improvement of the MACD index to solve the delayed signals in buying and selling. This will help signals work faster through the modification of the signal line, referred to as the "modified signal line." The idea originated from the observation of the MACD points on the graph that intersect with the signal line, which is the selling and buying points, that would most likely follow the peak price or its lowest price point at a certain time frame. To move the selling point and buying point in the given time between the original selling and buying point and the peak price point and lowest price point during that period would likely result in higher gains from the greater difference between the buying price and the selling price.

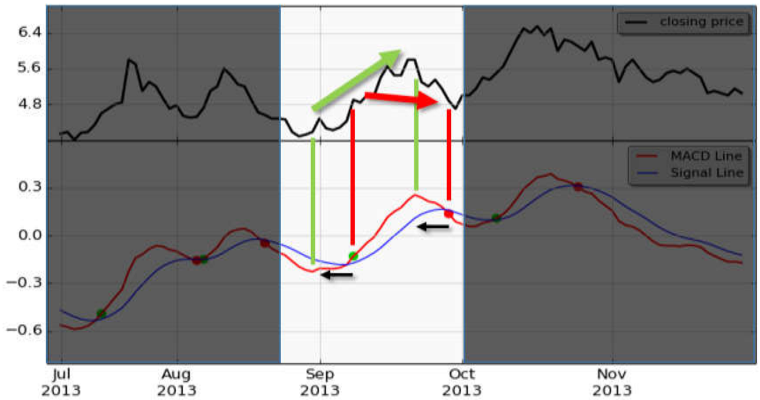

Figure 3 The figure illustrates that moving the trading signals slightly forward, just before the intersection line can result in higher gains and success rate

In the white area in Figure 3, with stock buying and selling through the traditional MACD, the entry point is indicated in the green dot while the exit point is the red dot. Notice that the stock price at the sell date may be lower than the buy date (see red arrow and red vertical lines). However, if we place the exit point on where the green dot is located, this will result in stock prices on its sell date to become higher than its buy date.

4.1. Modified signal line

As previously discussed, the methods to determine the traditional MACD sell-and-buy points is defined by the cutting-up point as the buying point, and the cutting-down point as the selling point in each trading period, and was found that the signal transmission becomes delayed. This research aims to introduce a new approach to the selling point and buying point that is faster than the traditional method between the sell-and-buy point, and the peak price point and lowest price point in a trading period.

The lowest price point in each trading period is where the MACD line is at its lowest value. This is based on when the MACD line is underneath the signal line. In other words, from the beginning point of the trading period until before the cutting-up point, if there is a point where the MACD line is at its lowest value in the said time frame of more than 1 point, the most recent point will be considered as the lowest price point.

Let $\{\tau_i\} = \{t_{(i,1)}, t_{(i,2)}, ..., t_{(i,\theta_i)}\}$, $i = 1, 2, ..., r$ be any trading period, m_t be MACD at t and $t_{(i,j^*)} = t^{\uparrow_i}$ be the cutting-up point in the period $\{\tau_i\}$.

Definition 13 *Lowest price point in period* $\{\tau_i\}$ *denoted by* ${}_it^{\min}$ *is the latest point of time in the period of* $\{t_{(i,1)}, t_{(i,2)}, ..., t_{(i,j^*-1)}\}$ *which* $m_{{}_it^{\min}} \le m_{t_{(i,j)}}$ *for every* $t_{(i,j)} \in \{t_{(i,1)}, t_{(i,2)}, ..., t_{(i,j^*-1)}\}$.

Likewise, the peak price point in a certain period is where the MACD line is at its highest value, based on the period that the MACD line is above the signal line. In other words, from the beginning of the cutting-up point until the final point of the trading period, if there is an MACD line with the highest value of more than one point, the most recent point will be considered the peak price point.

Definition 14 *Peak price point in period* $\{\tau_i\}$ *denoted by* ${}_it^{\max}$ *is the most recent point of time in the period of* $\{t_{(i,j^*)}, t_{(i,j^*+1)}, ..., t_{(i,\theta_i-1)}\}$ *which* $m_{{}_it^{\max}} \ge m_{t_{(i,j)}}$ *for every* $t_{(i,j)} \in \{t_{(i,j^*)}, t_{(i,j^*+1)}, ..., t_{(i,\theta_i-1)}\}$.

Realistically speaking, we cannot foresee the price data that lies ahead. Therefore, we cannot presume whether the current price point is at its lowest or at its peak. In order to test out the trading process with the previous data obtained in a certain point in time, and in a certain trading period, there must be a realistic role-play scenario which hypothesizes that a certain point in time that analyzes a certain trading period would be the current point, without the foreknowledge of the future data. So, in order to receive data on the lowest price point would be when the present time is the cutting-up point and onwards. Likewise, obtaining data about ‘at what point is the peak trading point?’ can only happen when the present point is the ending point of the trading period. As for the case where we could not know the cutting-up point or the point at the end of trading period, we would select the lowest price point or the peak price point based on the data from the start of the trading period to the most current, and define that as that the lowest price point (or peak price point) from the current data at hand, as defined in the following.

Definition 15 *Let* $t_{(i,x)} \in \{\tau_i\}$ *be the current time before the cutting-up point* $t_{(i,j^*)} = t^{\uparrow_i}$. *The lowest price point taken from data at hand at the time of* $t_{(i,x)}$ *or* $t^{\min*}_{(i,x)}$ *is the point in the period of* $\{t_{(i,1)}, t_{(i,2)}, ..., t_{(i,x)}\}$ *which* $m_{t^{\min*}_{(i,x)}} \le m_{t_{(i,j)}}$ *for every* $t_{(i,j)} \in \{t_{(i,1)}, t_{(i,2)}, ..., t_{(i,x)}\}$.

Definition 16 *Let* $t_{(i,x)} \in \{\tau_i\}$ *be the current time before the cutting-up point* $t_{(i,j^*)} = t^{\uparrow_i}$. *The peak price point taken from data at hand at the time of* $t_{(i,x)}$ *or* $t^{\max*}_{(i,x)}$ *is the most recent point in the period of* $\{t_{(i,j^*)}, t_{(i,j^*+1)}, ..., t_{(i,x)}\}$ *which* $m_{t^{\max*}_{(i,x)}} \ge m_{t_{(i,j)}}$ *for every* $t_{(i,j)} \in \{t_{(i,j^*)}, t_{(i,j^*+1)}, ..., t_{(i,x)}\}$.

The lowest price point (peak price point) from the data at hand at the most current time may well be the true lowest price point (peak price point) (as per Definition 15 and Definition 16) or may not. Therefore, to define the confidence level at the lowest price point (peak price point) from the data at hand at the lowest price point (peak price point), we shall use the data from the ratio distance between the MACD line and the signal line at the most current time and the lowest price point (peak price point) from the data at hand.

Definition 17 *Let* $t_{(i,x)} \in \left\{t_{(i,1)}, t_{(i,2)}, \ldots, t_{(i,j^*-1)}\right\}$ *be the current time, let* $t_{(i,x)}^{\min *}$ *be the lowest price point from the data at hand at the time of* $t_{(i,x)}$ *and let* ${}_i t^{\min}$ *be the lowest price point in the trading period of* $\{\tau_i\}$. *The lowest confidence level at the lowest price point at time* $t_{(i,x)}$ *or* $d_{t_{(i,x)}}^{\min}$ *is the actual number in the period of* $[0,1]$ *that expresses the confidence level* $t_{(i,x)}^{\min *} =_i t^{\min}$ *at time* $t_{(i,x)}$ *calculated by*

$$d_{t_{(i,x)}}^{\min} = \begin{cases} 1 - h_{t_{(i,x)}} \Big/ h_{t_{(i,x)}^{\min *}}, & h_{t_{(i,x)}^{\min *}} \neq 0, \\ 1, & h_{t_{(i,x)}^{\min *}} = 0, \end{cases} \tag{14}$$

which $h_{t_{(i,x)}} = m_{t_{(i,x)}} - s_{t_{(i,x)}}$ *and* $h_{t_{(i,x)}^{\min *}} = m_{t_{(i,x)}^{\min *}} - s_{t_{(i,x)}^{\min *}}$.

Definition 18 *Let* $t_{(i,x)} \in \left\{t_{(i,j^*)}, t_{(i,j^*+1)}, \ldots, t_{(i,\theta_i-1)}\right\}$ *be the current time, let* $t_{(i,x)}^{\max *}$ *be the most recent peak price point from the data at hand at the time of* $t_{(i,x)}$ *and let* ${}_i t^{\max}$ *be the peak price point in the trading period of* $\{\tau_i\}$. *The highest confidence level at time* $t_{(i,x)}$ *or* $d_{t_{(i,x)}}^{\max}$ *is the actual number at the period of* $[0,1]$ *that expresses the confidence level* $t_{(i,x)}^{\max *} =_i t^{\max}$ *at time* $t_{(i,x)}$ *calculated by*

$$d_{t_{(i,x)}}^{\max} = \begin{cases} 1 - h_{t_{(i,x)}} \Big/ h_{t_{(i,x)}^{\max}}, & h_{t_{(i,x)}^{\max}} \neq 0, \\ 1, & h_{t_{(i,x)}^{\max}} = 0, \end{cases} \tag{15}$$

which $h_{t_{(i,x)}} = m_{t_{(i,x)}} - s_{t_{(i,x)}}$ *and* $h_{t_{(i,x)}^{\max}} = m_{t_{(i,x)}^{\max}} - s_{t_{(i,x)}^{\max}}$.

The lowest price point (peak price point) from the data at hand and the lowest (highest) confidence level can be used to formulate the modified signal line which concaves towards the lowest price point (peak price point) in each trading period as follows:

Let $t_{(i,j)}^{\min *}$ be the lowest price point from the data at hand at the time of $t_{(i,j)} \in \{\tau_i\}$, $t_{(i,j)}^{\max *}$ be the highest price point from the data at hand at the time of $t_{(i,j)} \in \{\tau_i\}$, let $h_{t_{(i,j)}^{\min *}} = m_{t_{(i,j)}^{\min *}} - s_{t_{(i,j)}^{\min *}}$ and $h_{t_{(i,j)}^{\max *}} = m_{t_{(i,j)}^{\max *}} - s_{t_{(i,j)}^{\max *}}$, let $d_{t_{(i,j)}}^{\min}$ be the lowest confidence level at the time of $t_{(i,j)} \in \left\{t_{(i,1)}, t_{(i,2)}, \ldots, t_{(i,j^*-1)}\right\}$, let $d_{t_{(i,j)}}^{\max}$ be the highest confidence level at the time of $t_{(i,j)} \in \left\{t_{(i,j^*)}, t_{(i,j^*+1)}, \ldots, t_{(i,\theta_i-1)}\right\}$.

Definition 19 *We sequence that* $\{\tilde{s}_i\} = \{\tilde{s}_{t_{(i,1)}}, \tilde{s}_{t_{(i,2)}}, \ldots, \tilde{s}_{t_{(i,\theta_i)}}\}$ *is the modified signal line at trading period* i *with the parameter* $K \geq 0$, *while* $\tilde{s}_{t_{(i,j)}}$ *being the modified signal line at the time of* $t_{(i,j)} \in \{\tau_i\}$ *calculated by*

$$\tilde{s}_{t_{(i,j)}} = \begin{cases} s_{t_{(i,j)}} + h_{t^{\min}_{(i,j)}} \left(d^{\min}_{t_{(i,j)}}\right)^K, & t_{(i,j)} \in \left\{t_{(i,1)}, t_{(i,2)}, \ldots, t_{(i,j^*-1)}\right\}, \\ s_{t_{(i,j)}} + h_{t^{\max}_{(i,j)}} \left(d^{\max}_{t_{(i,j)}}\right)^K, & t_{(i,j)} \in \left\{t_{(i,j^*)}, t_{(i,j^*+1)}, \ldots, t_{(i,\theta_i-1)}\right\}, \\ s_{t_{(i,j)}}, & t_{(i,j)} = t_{(i,\theta_i)}, \end{cases} \tag{16}$$

The parameter $K \geq 0$ is defined as the concave adjustment that results in modifying the concave curvature of the modified signal line. Therefore, if $K = 0$, the modified signal line will have a sharper inward curve, and if $K \to \infty$, the modified signal line will flatten towards the actual signal line.

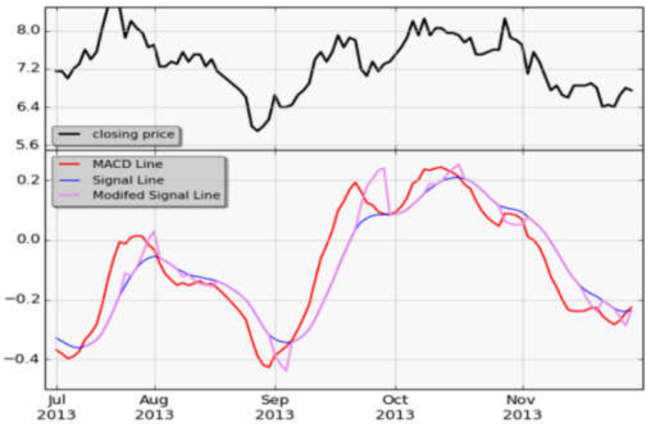

Figure 4 Example of modified signal line graph modified signal line graph (purple line) concaves towards the lowest price point or the relative maximum in a single trading period

4.2. Methods of selling and buying using the modified signal line

Using the same principle as the traditional MACD sell-buy methods that let the MACD line at its cutting-up point, the signal line be the buying point and the MACD at its cutting-down point be the buying point. The trading method through this modified signal line will let the MACD line at its cutting-up point be the buying point, and the MACD at its cutting-down point be the selling point, on the additional condition that there must not be any more buying activities after the buying point of the traditional MACD (cutting-up point) trading method.

Definition 20 *Let us define that any* $t_{(i,j)} \in \{\tau_i\}$ *point as the modified cutting-up point, the point of* k *in the period of* $\{\tau_i\}$ *and uses the symbol* ${}_i t^{\Uparrow_k}$ *if* $t_{(i,j)}$ *is the point where* k *conforms to only one of the following conditions:*

1) $m_{t_{(i,j)}} > \tilde{s}_{t_{(i,j)}}$ *and* $m_{t_{(i,j-1)}} < \tilde{s}_{t_{(i,j-1)}}$,

2) $m_{t_{(i,j)}} > \tilde{s}_{t_{(i,j)}}$, $m_{t_{(i,j-1)}} = \tilde{s}_{t_{(i,j-1)}}$ and $m_{t_{(i,j-2)}} < \tilde{s}_{t_{(i,j-2)}}$.

Definition 21 *Let us define that any* $t_{(i,j)} \in \{\tau_i\}$ *is the modified cutting-down point, the point of* k *in the period of* $\{\tau_i\}$ *and uses the symbol* ${}_i t^{\Downarrow_k}$ *if* $t_{(i,j)}$ *is the point where* k *conforms to only one of the following conditions:*

1) $m_{t_{(i,j)}} < \tilde{s}_{t_{(i,j)}}$ and $m_{t_{(i,j-1)}} > \tilde{s}_{t_{(i,j-1)}}$,

2) $m_{t_{(i,j)}} < \tilde{s}_{t_{(i,j)}}$, $m_{t_{(i,j-1)}} = \tilde{s}_{t_{(i,j-1)}}$ and $m_{t_{(i,j-2)}} > \tilde{s}_{t_{(i,j-2)}}$.

Definition 22 *Let* ${}_i t^{\Uparrow_k}$ *and* ${}_i t^{\Downarrow_k}$ *be the modified cutting-up point and cutting-down point at* k *that occurs at the trading period of* $\{\tau_i\}$, *respectively, and let* $t^{\uparrow_i}$ *be the cutting-up point at i. The trading method using modified signal line is an approach to stock trading defined as* $\left({}_i t^{b_k}, {}_i t^{s_k}, C\right)$, $k = 1, 2, \ldots, n_i$ *where the buying point is* ${}_i t^{b_k} = {}_i t^{\Uparrow_k}$ *which* ${}_i t^{\Uparrow_k} \le t^{\uparrow_i}$ *and the selling point is* ${}_i t^{s_k} = {}_i t^{\Downarrow_k}$ *when* $C > 0$ *is a constant number.*

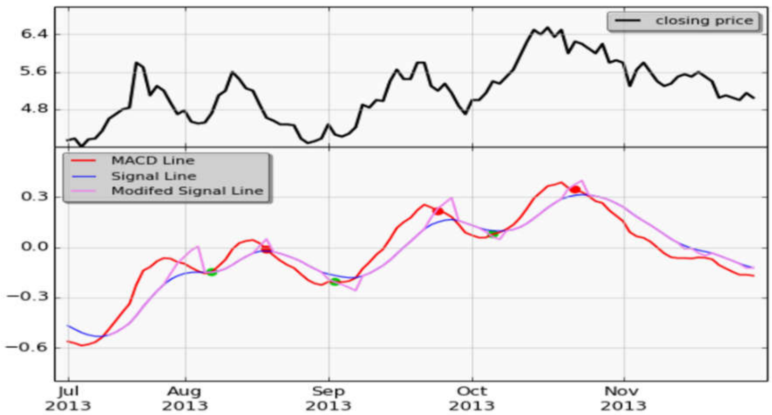

Figure 5 Illustration of modified signal line: modified signal line (purple) is characterized by its concave curves towards the peak price point or lowest price point in a certain trading period. The trading is performed when the MACD line (red) intersects with the modified signal line (purple)

The process of assessing the success and the gains rate can be performed when the trading period is complete, which can be a timeframe that is divided by the intersected MACD line and the signal line. In one trading period, there may be more than 1 round of trading performed, where each round consists of buying the stocks one time off and then selling them one time off with the total number of stocks purchased.

5. Trading Weight

In the previous section, we have developed the modified signal line as a solution for delayed trade signals. However, this created an issue of false signals that can occur. To reduce loss from false signals, we shall use the fuzzy logic on the buy point that occurs during that trading point to determine whether the trade activity can lend confidence that the signal is a verified signal, and for each trade, through the weighted cost of capital with the said confidence level that could reduce the amount of loss that may occur from false signals.

5.1. Confidence level of actual signal

Realistically speaking, in order to know whether any trading occurrence is an actual signal or false signal, is only when the buying and selling has been completed. To decide on whether the trader should buy or sell stocks, one must perform the trade on the buy date, which does not guarantee whether this is an actual signal or not. Therefore, the researcher will introduce fuzzy logic as an approach to analyze the date of buying to see if that particular trading activity will lend confidence on the signal to be an actual signal, including the particular confidence level number that will be put into the formula to arrive at its price-weighted stock. This is done through a hypothesis that the buying point is the most current point in time, without being exposed to the knowledge of the subsequent data. The said confidence level and fuzzy sets can be defined and analyzed through the following methods:

Let $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$ be the trading order at k number of times in the trading period of $\{\tau_i\}$, $i = 1, 2, \ldots, r$.

Definition 23 *Let* ${}_i t^{s_k}$ *be the trading time without prior knowledge of the data. The confidence level of the actual signal of the* k*in the trading period of* $\{\tau_i\}$ *symbolized by* ${}_i z^k$, *is the actual number in the interval* $[0,1]$ *that expresses the confidence level that* $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$ *is the actual signal at the time of* ${}_i t^{b_k}$.

Upon this precedent, the researchers have developed a fuzzy set definition to determine the confidence level of the actual trading signal into 2 fuzzy sets as follows:

"TRADE-CONFIDENCE" represents the fuzzy set of the confidence level of the actual trading signal ${}_i z^k$ that has high value, using the symbol C_z.

"TRADE-DOUBT" represents the fuzzy set of the confidence level of the actual trading signal ${}_i z^k$ that has a low value, using the symbol D_z.

In this instance, let $C_z = \langle 0,1,1 \rangle$ and $D_z = \langle 0,0,1 \rangle$ where both fuzzy sets can be illustrated in Figure 6.

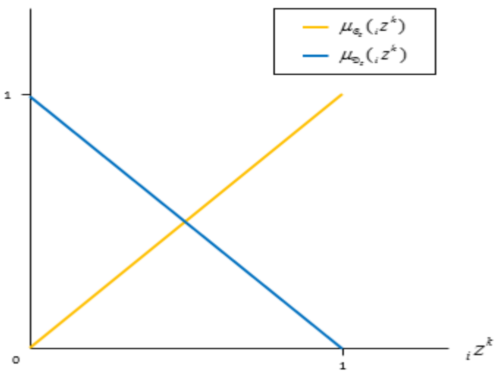

Figure 6 Membership function graph - confidence level of actual signal, the orange line is the membership function graph of TRADE-CONFIDENCE, the blue line is the membership function of TRADE-DOUBT

5.2. Data from the confidence level of the actual trading signal

The method of inference through fuzzy estimates is a form of data conversion of data history on a group of data into a queried data by using fuzzy rules as the approach to this conversion. The results we aim to obtain is the confidence level of the actual signal. In this discussion, we will examine the data history that will be used for the inference. Fuzzy rules will be discussed in the next section. In this research, we will use the 2 sets of data history as the inference to achieve the confidence level of actual signal of any $\left({}_it^{b_k},{}_it^{s_k},{}_iC^k\right)$ in the period of $\{\tau_i\}$, $i=1,2,...,r$ which are:

1) The lowest confidence level point at the time of ${}_it^{b_k}$ using the symbol $d^{\min}_{{}_it^{b_k}}$.

2) The value of MACD line at the time of ${}_it^{*b_k}$ using the symbol $m_{{}_it^{*b_k}}$ when ${}_it^{*b_k}$ is the most recent lowest point at the time of ${}_it^{b_k}$.

5.2.1. Data from the lowest point of confidence level

For the trading of any $\left({}_it^{b_k},{}_it^{s_k},{}_iC^k\right)$ in the period of $\{\tau_i\}$, $i=1,2,...,r$, let ${}_it^{*b_k}$ be the most recent lowest point from the data at hand at the time of ${}_it^{b_k}$ and let $d^{\min}_{{}_it^{b_k}}=\left(1-h_{{}_it^{b_k}}/h_{{}_it^{*b_k}}\right)$ be the lowest point of confidence level at the time of ${}_it^{b_k}$ when $h_{{}_it^{b_k}}=m_{{}_it^{b_k}}-s_{{}_it^{b_k}}$ and $h_{{}_it^{*b_k}}=m_{{}_it^{*b_k}}-s_{{}_it^{*b_k}}$. Because the lowest point of confidence level will have a higher value when the value of the MACD line at the current time is converging towards the signal line. Therefore, we can see that this lowest confidence level point represents the confidence level point at the most current time, and where the MACD line can also intersect upwards with the signal line. If the current point in time is the buying point of a particular trading activity while being the cutting-up point, we can also determine that this particular trading activity is the actual signal. For these reasons, we have chosen $d^{\min}_{{}_it^{b_k}}$ as the inferential data on the confidence level of actual trading signal of

$\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$ where we can interpret that $d^{\min}_{{}_i t^{b_k}}$ that is higher will have an impact on the confidence level of the actual trading signal as well. A fuzzy set MIN-CONFIDENCE is given as the fuzzy set of the lowest point of confidence level $d^{\min}_{{}_i t^{b_k}}$ at a high value and using the symbol C_d. In this instance, let $C_d = \langle 0,1,1 \rangle$.

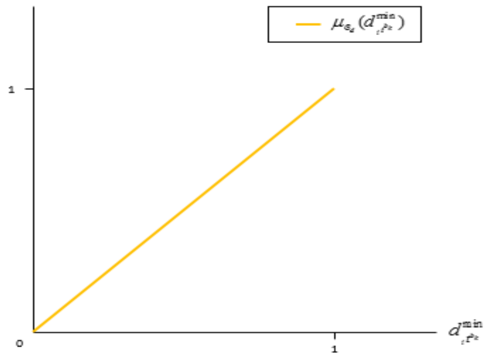

Figure 7 Membership function of MIN-CONFIDENCE

5.2.2. Data of MACD line at its lowest point from data on hand

For the trading of any $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$ in the trading period of $\{\tau_i\}$, $i = 1,2,...,r$. Let $m_{{}_i t^{*b_k}}$ be the value of the MACD line at the time of ${}_i t^{*b_k}$, where ${}_i t^{*b_k}$ is the most recent lowest price point from the data at hand, at the time of ${}_i t^{b_k}$. By testing the modified signal line in the trading system, we observed that the MACD line can be categorized into 3 levels; high, medium and low. It can be said that if $m_{{}_i t^{*b_k}}$ is at its high level or medium level, the $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$ trading is most likely to be a false signal. But if $m_{{}_i t^{*b_k}}$ is at a low level, the $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k, {}_i w^k\right)$ trading is more likely to be the actual signal.

The researchers have applied the theory of the overbought boundary value and the oversold boundary value to classify the MACD line into 3 categories as illustrated in the above paragraph. The overbought boundary value is the standard used in projecting whether the MACD line is at its overvalued price, and shifting from upward trend towards downward trend. Likewise, the oversold boundary value is the standard used in projecting whether the MACD line is at its undervalued price, and shifting from downward trend towards an upward trend. The overbought boundary value and the oversold boundary value is usually determined by using its peak price point and lowest price point from its previous trading period.

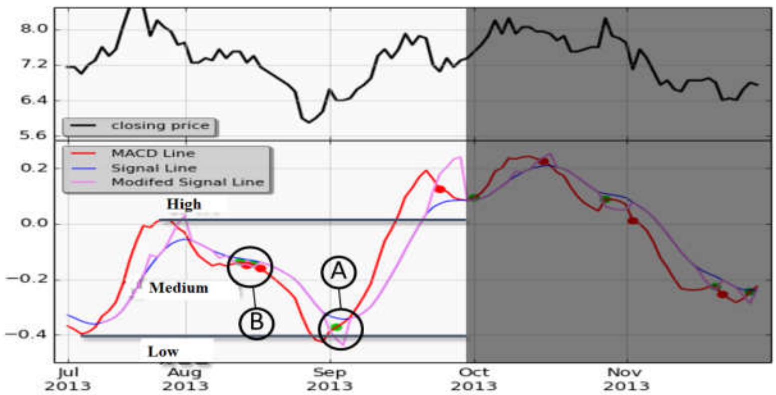

Figure 8 Classification of the 3 MACD lines. Circle B identifies the area where the MACD line is at its medium level, which can mean that trading activity at this point in time is likely to be a false signal. Circle A identifies the area where the MACD line is at its low level, which means that trading activity at this point in time is more likely to be an actual signal

Definition 24 *The overbought boundary value in the trading period of* $\{\tau_i\}$ *uses the symbol* ${}_iM^{high}$ *is the MACD line at its most recent highest price point from its previous trading period of* R *periods,*

$$ {}_iM^{high} = m_{(i-R)}t^{\max}, \tag{17}$$

where $R \geq 1$ *is the parameter.*

Definition 25 *The oversold boundary value in the trading period of* $\{\tau_i\}$ *uses the symbol* ${}_iM^{low}$ *is the MACD line at its most recent lowest price from its previous trading period of* R *periods,*

$$ {}_iM^{low} = m_{(i-R)}t^{\min}, \tag{18}$$

where $R \geq 1$ *is the parameter.*

In the paper, the MACD line in a single trading period will be classified into 3 levels; high (MACD-HIGH), medium (MACD-MEDIUM) and low (MACD-LOW) as defined in the following fuzzy sets:

$\mathrm{H}_m = \left\langle {}_iM^{1/2}, {}_iM^{high}, 9999, 9999 \right\rangle$ is the MACD fuzzy set at its high level,

$\mathrm{M}_m = \left\langle {}_iM^{1/4}, {}_iM^{1/2}, {}_iM^{3/4} \right\rangle$ is the MACD fuzzy set at its medium level,

$\mathrm{L}_m = \left\langle -9999, -9999, {}_iM^{low}, {}_iM^{1/2} \right\rangle$ is the MACD fuzzy set at its low level,

where ${}_iM^{1/2} = \left({}_iM^{high} + {}_iM^{low}\right)/2$, ${}_iM^{1/4} = \left({}_iM^{high} + 3{}_iM^{low}\right)/4$ and ${}_iM^{3/4} = \left(3{}_iM^{high} + {}_iM^{low}\right)/4$. The fuzzy set H_m, M_m and L_m can be illustrated as follows.

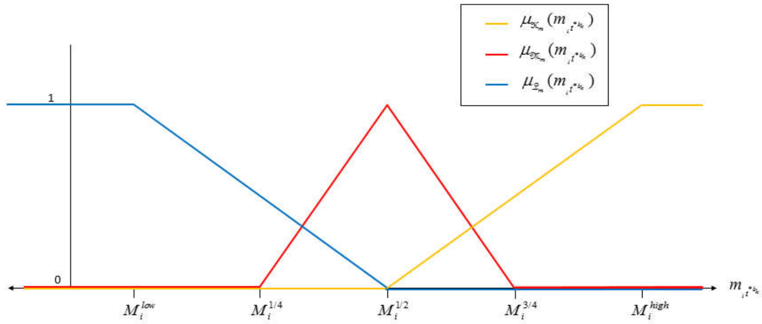

Figure 9 Membership function of the MACD line, the orange line is the membership function of MACD-HIGH, the blue line is the membership function of MACD-LOW. The red line is the membership function of MACD-MEDIUM

5.3. Fuzzy rules

The principles used in Figures 6 and 9 has led to the development of the fuzzy rules used to infer data on the actual confidence signal for trading $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$ in the trading period of $\{\tau_i\},\ i = 1, 2, ..., r.$ Let ${}_i t^{*b_k}$ be the lowest point from the data at hand at the time of ${}_i t^{b_k}$, $m_{{}_i t^{*b_k}}$ be the MACD line at the time of ${}_i t^{*b_k}$, $d^{\min}_{{}_i t^{b_k}}$ be the lowest confidence level at the time of ${}_i t^{b_k}$ and ${}_i z^k$ be the actual confidence level of trading $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$. The fuzzy rules are defined as follows:

Rule 1: if $d^{\min}_{{}_i t^{b_k}}$ is MIN-CONFIDENCE then ${}_i z^k$ is TRADE-CONFIDENCE

Rule 2: if $m_{{}_i t^{*b_k}}$ is MACD-LOW then ${}_i z^k$ is TRADE-CONFIDENCE

Rule 3: if $m_{{}_i t^{*b_1}}$ is MACD-HIGH or $m_{{}_i t^{*b_1}}$ is MACD-MEDIUM then ${}_i z^1$ is TRADE-DOUBT

5.4. Weighted average trading

Let $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$ be the trading round (ordinal) of k in the trading period of $\{\tau_i\},\ i = 1, 2, ..., r.$ Let ${}_i w^k \in [0,1]$ be defined sequentially as $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k, {}_i w^k\right)$ to be the weighted average trading at the ordinal time of k in the trading period of $\{\tau_i\}$. Then the capital invested at the ordinal time of k in the trading period of $\{\tau_i\}$ equals ${}_i C^k {}_i w^k$ baht. Therefore, gains from trading through the weighted average trading method can be calculated by ${}_i P^k = \left(p_{{}_i t^{s_k}} / p_{{}_i t^{b_k}} - 1\right)_i C^k {}_i w^k$. If we let ${}_i z^k \in [0,1]$ be the actual signal of confidence level for trading $\left({}_i t^{b_k}, {}_i t^{s_k}, {}_i C^k\right)$ in the trading period of $\{\tau_i\}$ from the fuzzy logic inference, it would be determined that ${}_i z^k$ is the actual total center of gravity. Therefore, the value of ${}_i z^k$ would be at its highest on the condition that the truth value function equals the membership function of TRADE-CONFIDENCE, and would be at its lowest on the condition that the truth value function equals the membership function of TRADE-DOUBT. That is, the highest value of ${}_iz^k$ is the center of gravity of TRADE-CONFIDENCE, and the lowest value of ${}_iz^k$ is the center of gravity of TRADE-DOUBT. To set the weighted trading price in the interval $[0,1]$ would require to convert the actual signal of confidence into the weighted trading. Therefore, this research will define the term weighted trading ${}_iw^k$. Then we set ${}_iw^k = \left({}_iz^k - \mu^*_{D_z}\right)/\left(\mu^*_{C_z} - \mu^*_{D_z}\right)$, when $\mu^*_{D_z}$ and $\mu^*_{C_z}$ is the actual value of the defuzzification of D_z and C_z using the center of gravity method, respectively.

5.5. Example of inferences on the actual signal of confidence and the conversion of the actual signal of confidence into the weighted trading price

By performing a test on the trading system where the signal line has been modified by parameter $K = 1$ and the recorded data of the MCOT stock from July 5 to November 28, 2013, the trading activity has resulted in the following figure:

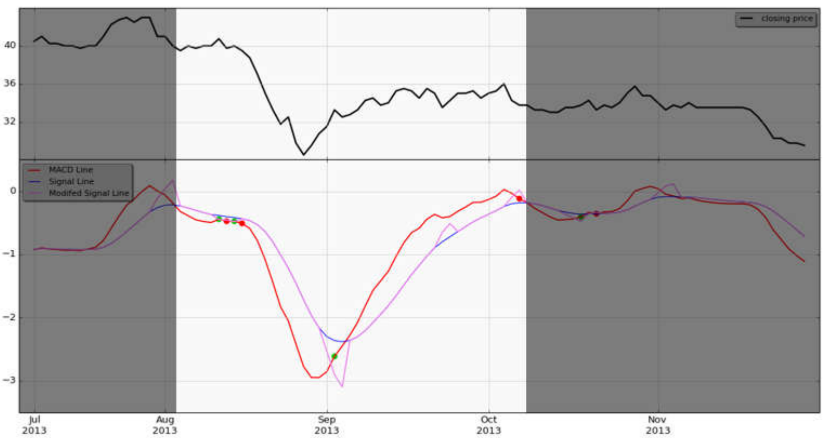

Figure 10 Illustrates the points of selling and buying by using the modified signal line on the MCOT stock

From Figure 10, we have hypothesized that the white area is the trading period of $\{\tau_i\}$. As seen from the data chart, there has been a total of 3 rounds of trading, using the symbols $\left({}_it^{b_1}, {}_it^{s_1}, C\right)$, $\left({}_it^{b_2}, {}_it^{s_2}, C\right)$, $\left({}_it^{b_3}, {}_it^{s_3}, C\right)$. It can be distinguished that the trading of $\left({}_it^{b_1}, {}_it^{s_1}, C\right)$ and $\left({}_it^{b_2}, {}_it^{s_2}, C\right)$ are false signals while $\left({}_it^{b_3}, {}_it^{s_3}, C\right)$ is the actual signal. When tested with the regular trading method (with no weighted trading), let $C = 100$, the gains from each trade and the net gains in the trading period, as shown in Table 1, and when tested with the weighted trading method has yielded results in the following table.

Table 1 Demonstrates the outcome of trading by using the modified signal line

Number of sales (k)	Price at buy date ($p_{{}_i t^{b_k}}$)	Price at sell date ($p_{{}_i t^{s_k}}$)	Gains (${}_i P^k$)
1	40.75	39.75	−2.45399
2	40.00	39.50	−1.24999
3	33.25	33.75	1.50376
Net gains in the trading period of $({}_i\widetilde{P})$ = −0.02122			

Table 2 Demonstrates the outcome of trading by testing the trading system through the modified signal line with weighted trading

Number of sales (k)	Price at buy date ($p_{{}_i t^{b_k}}$)	Price at sell date ($p_{{}_i t^{s_k}}$)	Weighted trading (${}_i w^k$)	Gains (${}_i P^k$)
1	40.75	39.75	0.38247	−0.93858
2	40.00	39.50	0.38284	−0.47855
3	33.25	33.75	1.0	1.50376
Net gains in the trading period of $({}_i\widetilde{P})$ = 0.00085				

Next, we will illustrate the inferential approach on the actual signal of confidence ${}_i z^1$ of the weighted trading $\left({}_i t^{b_1}, {}_i t^{s_1}, C, {}_i w^1\right)$ and the conversion of ${}_i z^1$ into the weighted trading ${}_i w^1$ by classifying it into 4 steps of process as follows:

Step 1. Real valued function inference using fuzzy conditional proposition in each item.

Step 2. Total real valued function inference using fuzzy rules.

Step 3. Selecting actual signal of confidence ${}_i z^1$ using fuzzy rules.

Step 4. Conversion of actual signal of confidence ${}_i z^1$ into weighted trading value ${}_i w^1$.

The actual signal of confidence and the weighted trading of other trading rounds can be calculated in the same manner. The fundamental methods pertaining to fuzzy logic are referred to in Figures 1 to 7.

Various data that are pertinent to the ${}_i z^1$ inference are shown in Table 3, when the buy limit and sell limit value exceeds, using the most recent highest point and the most recent lowest point in the trading period of $\{\tau_{i-1}\}$, respectively, as shown in Figure 11.

Table 3 Pertinent data used as an example for actual signal inference

Lowest level of confidence ($d^{\min}_{{}_i t^{b_1}}$)	Value of MACD line at its lowest point, from data at hand ($m_{{}_i t^{*b_1}}$)	Value of exceeded buy limit (${}_i M^{high}$)	Value of exceeded sell limit (${}_i M^{low}$)
0.53478	−0.49455	0.08829	−0.93989

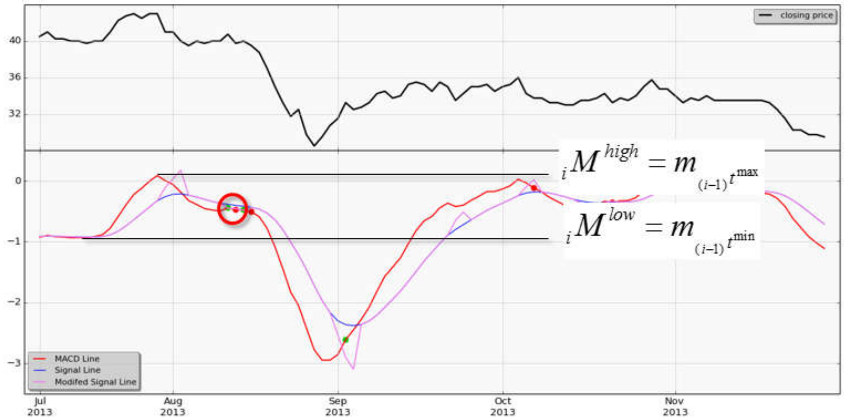

Figure 11 Illustrates the exceeding sell limit value and the exceeding buy limit value determined by the highest point and the lowest point of the previous trading period

Step 1. Inferential approach using fuzzy conditional proposition in each item. To find the real valued function inference using fuzzy rules of conditional proposition of (R1), (R2) and (R3) in each item, can be done as follows:

Conditional proposition R1

"If $d^{\min}_{{}_i t^{b_1}}$ is MIN-CONFIDENCE then ${}_i z^1$ IS TRADE-CONFIDENCE"

On the premise that $d^{\min}_{{}_i t^{b_1}}$ is MIN-CONFIDENCE that has a real value of $\mu_{C_d}(d^{\min}_{{}_i t^{b_1}}) = \mu_{C_d}(0.53478) = 0.53478$ and the result that ${}_i z^1$ is TRADE-CONFIDENT when we let u_1 be the real valued function will result in the real value function for ${}_i z^1 \in [0,1]$ calculated by

$$u_1({}_i z^1) = \min\left\{\mu_{C_d}(d^{\min}_{{}_i t^{b_1}}), \mu_{C_z}({}_i z^1)\right\} = \min\left\{0.53478, \mu_{C_z}({}_i z^1)\right\}. \tag{19}$$

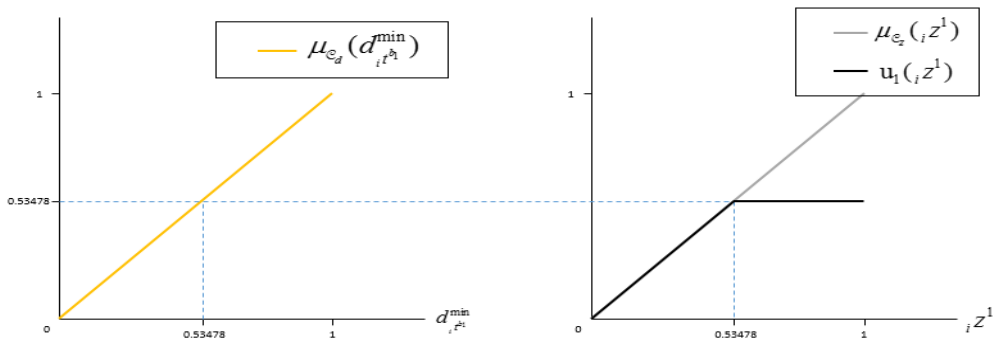

Figure 12 Illustrates the real valued function through inferential approach using fuzzy conditional proposition (R1), (left) the orange line is the membership function of MIN-CONFIDENCE with the lowest confidence point at $d^{\min}_{{}_i t^{b_1}} = 0.53478$ is the membership function of MIN-CONFIDENCE that equals $\mu_{C_d}(d^{\min}_{{}_i t^{b_1}}) = \mu_{C_d}(0.53478) = 0.53478$, (right) the gray line is the membership function of

TRADE-CONFIDENCE , the black line is the real valued function $u_1 : u_1({}_i z^1)$
$= \min\left\{0.53478, \mu_{C_z}({}_i z^1)\right\}$.

Conditional proposition R2

"If $m_{{}_i t^{*b_1}}$ is MACD-LOW then ${}_i z^1$ IS TRADE-CONFIDENCE"

On the premise that $m_{{}_i t^{*b_1}}$ is MACD-LOW that has a real value of $\mu_{L_m}(m_{{}_i t^{*b_1}}) = \mu_{L_m}(-0.49455) = 0.13373$ and the result that ${}_i z^1$ is TRADE-CONFIDENT when we let u_2 be the real valued function will result in the real value function for every ${}_i z^1 \in [0,1]$ calculated by

$$u_2({}_i z^1) = \min\left\{\mu_{L_m}(m_{{}_i t^{*b_1}}), \mu_{C_z}({}_i z^1)\right\} = \min\left\{0.13373, \mu_{C_z}({}_i z^1)\right\}.$$

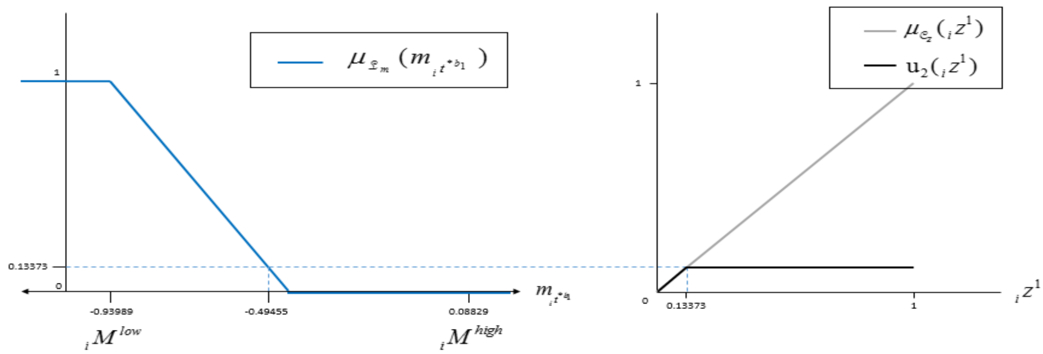

Figure 13 Illustrates the real valued function inference using fuzzy rules of conditional proposition (R2), (left) the blue line is the membership function of MACD-LOW where the value of the MACD line $m_{{}_i t^{*b_1}} = -0.49455$ is the membership function of MACD-LOW equals $\mu_{L_m}(m_{{}_i t^{*b_1}}) = \mu_{L_m}(-0.49455) = 0.13373$, (right) the gray line is the membership function of TRADE-CONFIDENCE, the black line is the real valued function $u_2 : u_2({}_i z^1) = \min\left\{0.13373, \mu_{C_z}({}_i z^1)\right\}$.

Conditional proposition R3

"If ($m_{{}_i t^{*b_1}}$ is MACD-HIGH) or ($m_{{}_i t^{*b_1}}$ is MACD-MEDIUM) then ${}_i z^1$ is TRADE-DOUBT"

On the premise that ($m_{{}_i t^{*b_1}}$ is MACD-HIGH) or ($m_{{}_i t^{*b_1}}$ is MACD-MEDIUM) that has a real value of $\max\left\{\mu_{H_m}(m_{{}_i t^{*b_1}}), \mu_{M_m}(m_{{}_i t^{*b_1}})\right\} = \max\{0, 0.73253\} = 0.73253$ and the result that ${}_i z^1$ is TRADE-DOUBT when we let u_3 be the real valued function will result in the real value function for every ${}_i z^1 \in [0,1]$ calculated by

$$u_3({}_i z^1) = \min\left\{\max\left\{\mu_{H_m}(m_{{}_i t^{*b_1}}), \mu_{M_m}(m_{{}_i t^{*b_1}})\right\}, \mu_{C_z}({}_i z^1)\right\} = \min\left\{0.73253, \mu_{C_z}({}_i z^1)\right\}.$$

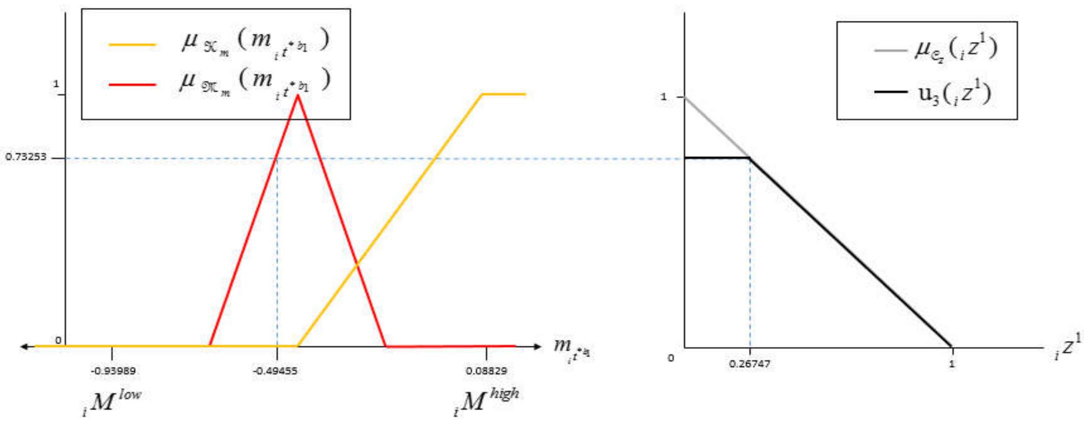

Figure 14 Illustrates the real valued function inference using fuzzy rules of conditional proposition (R3), the orange line (left) is the membership function of MACD-HIGH, and the red line is the membership function of MACD-MEDIUM, whereas the premise of proposition in the conditional proposition (R3) has the real value that equals $\max\left\{\mu_{H_m}(m_{_it^{*b_1}}), \mu_{M_m}(m_{_it^{*b_1}})\right\} = 0.73253,$ the gray line (right) is the membership function of TRADE-DOUBT, the black line is the real valued function $u_3(_iz^1) = \min\left\{0.73253, \mu_{C_z}(_iz^1)\right\}.$

Step 2. Finding the real valued function inference using fuzzy rules.

Let $\tilde{u}$ be the total real valued function, the total real valued function for every $_iz^1 \in [0,1]$ is calculated by

$$\tilde{u}(_iz^1) = \max\left\{u_1(_iz^1), u_2(_iz^1), u_3(_iz^1)\right\}.$$

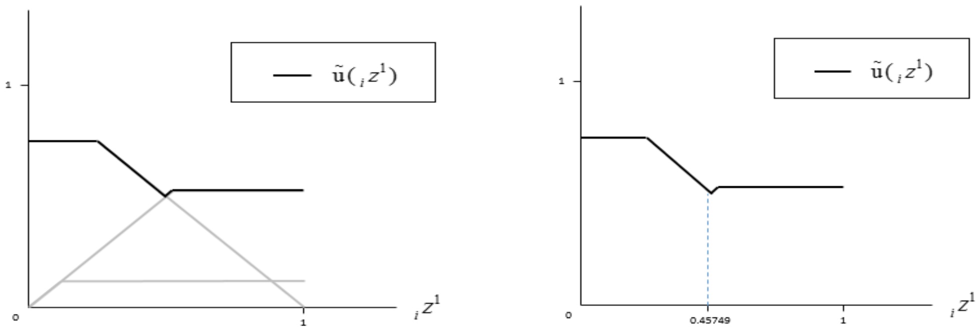

Figure 15 Illustrates the total valued function, the black line is the real valued function calculated from the real valued function u_1, u_2 and u_3 (gray line), the total real-valued function center of gravity from the fuzzy rules inference equals 0.45749

Step 3. Selecting actual signal of confidence ${}_iz^1$ from the total real valued function, let $\tilde{u}^*$ be the center of gravity of the total real valued function $\tilde{u}$, this will result in $\tilde{u}^* = \int_0^1 {}_iz^1\tilde{u}({}_iz^1)\,\mathrm{d}_iz^1 \Big/ \int_0^1 \tilde{u}({}_iz^1)\,\mathrm{d}_iz^1 = 0.45749.$

Step 4. Converting the actual signal of confidence level ${}_iz^1$ into the weighted trading value ${}_iw^1$, when designating ${}_iz^1 = \tilde{u}^* = 0.45749$ as the actual signal of confidence level of the weighted trading, $\left({}_it^{b_1}, {}_it^{s_1}, C, {}_iw^1\right)$ we can calculate the weighted trading ${}_iw^1$ as ${}_iw^1 = \left({}_iz^1 - \mu^*_{D_z}\right)\big/\left(\mu^*_{C_z} - \mu^*_{D_z}\right) = (0.45749 - 0.33)/(0.66 - 0.33) = 0.38633,$ when $\mu^*_{D_z}$ is the center of gravity of D_z, and $\mu^*_{C_z}$ is the center of gravity of C_z.

6. Case study: Stock Exchange of Thailand

When performing tests on different methods of trading as detailed in Section 5, we have demonstrated the tests on each stock in the SET-100 group on July 5 to November 28, 2013. The results were measured using the average success rate and the average gains from testing on each individual stock. The outcome is as follows.

6.1. Results from trading using the modified signal line

The success rate and average gains yielded from the various concave adjustments is shown in Table 4. From Table 4, notice that the lesser the K value, the better the results. The best results occur when $K = 0.1$ which yields the success rate of 0. 57257 while the average gains equal 0.03280. This resulted from the smoothness of the MACD line in the SET-100 stocks that produced minimal false signals. Therefore, we can select the K value at its lowest level in order to create a soon-as-possible trading signal, which would allow it to yield higher gains.

Table 4 Show the results from trading using the modified signal line

K	Success rate	Average gains
0.1	0.57257	0.03280
0.2	0.53819	0.02796
0.4	0.50243	0.02469
0.6	0.48090	0.02347
0.8	0.45156	0.02273
1.0	0.45122	0.02220
1.2	0.43785	0.02051
1.4	0.43785	0.02022

6.2. Test results from trading using the modified signal line through weighted gravity trading

The success rate and the average gains yielded, using the various parameters of K and R in Table 5. From Table 5, it can be seen from the test that when R is at the same number, the lesser the K value, the better the results. This is in line with the experiment in Table 5, where the best results occur when $K = 0.1$ and $R = 1$ with the success rate of 0.61018 and the average gains is 0.03788.

However, it cannot be determined whether the R value has conclusive impact on the results, due to the small size of sample data used.

Table 5 Illustrates the results from trading using the modified signal line through weighted gravity trading

K	R	Success rate	Average gains
0.1	1	0.61018	0.03788
0.5	1	0.55228	0.03163
1.0	1	0.52158	0.03129
0.1	2	0.55313	0.02269
0.5	2	0.50520	0.02100
1.0	2	0.45938	0.02030

6.3. Results comparison of the various trading methods

Table 6 shows the results from trading using the modified signal line, when compared with the traditional MACD, MACDR1 and MACDR2. From Table 6, it can be observed that the trading with the highest success rate is MACDR2 (0.74573), followed by the modified signal line and weighted gravity trading (0.61018), and the regular modified signal line (0.57257). Notice that even though trading with the modified signal line yielded a success rate that is lower than MACDR2, but this method can yield higher gains rate at 0.03280, or more than MACDR2 (0.02416). Also, when applied with weighted gravity trading, the gains rate was able to move up to 0.03788.

Table 6 Illustrates the results of stock trading using the different MACD methods

Methods	Success rate	Average gains
MACD	0.36440	0.00498
MACDR1	0.56042	0.00712
MACDR2	0.74573	0.02416
Modified signal line	0.57257	0.03280
Modified signal line and weighted gravity trading	0.61018	0.03788

7. Research summary

This paper proposed the modified signal line in place of the traditional signal for stock market decision making based on technical analysis. The model was modified to apply for the concept of the fuzzy logic process controller. It can be signal for trading faster than traditional MACD. However, this created an issue of false signals that can be occurred. Technically, to reduce loss from false signals, we shall use the fuzzy logic process at the buy point having been occurred during that trading point to determine whether the trade activity can lend confidence so that the signal is a verified signal, for each trade, through the weighted cost of capital with the said confidence level that could reduce the amount of loss which may be occurred from the false signals. By applying the weighted gravity trading from the fuzzy rules inference may help to mitigate this issue as well as to boost the average gains and success rates. The model was verified and tested using real data form SET100 stock symbols in the stock exchange of Thailand.The results were satisfactory, so they were in the higher success rates and gains. In addition, when performing the test by comparing with MACD, MACDR1 and MACDR2, even though the success rate was less, the average gains rate and the business-day closing price of each stock yielded the higher in the SET-100 on November 28, 2013.

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