EEG-based Emotion Recognition in the Investment Activities

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Abstract—Emotion plays a significant role during a decision making process and greatly influence investor’s behavior. This paper investigates investors’ emotional perception and exemplify how these emotions may affect their judgement in investment activities. In our experiments, the participants’ emotion were derived from electroencephalogram (EEG) while they were trading in the stock market. A negative emotion can reduce the rationality of the investor in decision making and lead them to lose money. However, positive emotion can help them to minimize the risk of negative consequences. Based on the EEG-based emotion recognition, this paper presents the result of an investor that was influenced by their emotion and behaviors while making an investment decisions.

Keywords—Electroencephalography (EEG); neuro-finance; emotion recognition; decision making;

I. INTRODUCTION

The term stock market is commonly used to refer to the business or activity of buying and selling in which shares of the publicly held companies are issued and traded either through exchanges or over-the-counter markets. Stock market is the aggregation of stock investors which is also a reliable barometer to measure the economic condition of a country and the investors are believed to be the backbone of the securities market [1]. In recent years, there are several researches on the stock investment activities including their performances. Stock market investment is an important component of a free-market economy which is determined by the open market and consumers. A collapse in the stock prices may disrupt the economy sectors. One of the famous cases in the history is when the stock market crash in 1929 of the United States. The stock prices continued to drop and caused the great depression on the economy of 1930s [2]. Due to investors’ poor choices and preferences in the investment activities, they might give up with the most of their stock market profits.

In addition, the current studies in cognitive and neural processes has tended to focus on the investors’ behavior or behavioral finance rather than on the emotion which known to plays a critical role in decision making process. According to a definition provided by Sewel (2010), behavioral finance is a study of psychology which influence the financial practitioners’ behavior and may have the subsequent effect on the investment markets [3]. Behavioral finance would be helpful to maintain the stock market movement and prevent them to make any risky decisions. Both of these factors may affect the investors’ performance and also move the stock market momentum either up or down. As this paper aims to understand the investors’ perception, behavioral finance and emotion which derived from the electroencephalogram (EEG) was observed and analyzed.

This paper will continue as follows. The literature reviews will be presented in section 2 and the methods will be explained in section 3. In section 4, the discussion will be discussed on the investors’ perception based on EEG-based emotion. Lastly, the study will be concluded in the last section of this paper.

II. LITERATURE REVIEW

Since the study aimed to understand the investors’ perception while making a financial decisions, the literature review covers the research in neuro-finance and also the emotion from the EEG. Furthermore, the review will emphasize on the factors that have affected the stock market returns and the factors that should be highlighted on the study of EEG.

Emotions is an affective state of consciousness which experienced joy, sorrow, fear, hate or like. The influence of emotion on the stock market purchase decisions may affects their stock market performance. To date, a number of studies have attempted to evaluate the impact of emotion and mood on the stock market by measuring the public’s responses through the sentiments of social media activities. In a study conducted by Karabulut (2013), the positive or negative values of Facebook’s sentiment shows the ability to predict statistically significant and economically meaningful changes both in daily returns and trading volume in the stock market [4]. In the past, the sentiment of stock market news were also classified by the presence and intensity of emotions’ words as the features and the contextual entropy model was developed to expand a set of seed words generated from there with the sentiment annotation [5]. The studies of sentiments in social activities may be useful to discover more emotion words and their corresponding
intensity, thus improving the classification performance in the stock market.

Emotions are also playing an important role in the stock market purchase decisions which has been characterized as rational in the classical economic sense. The study by Fenton, Soane, Nicholson & Willman (2011) discussed the implications of investors’ emotion and decision making by describing a qualitative study in order to understand the role of emotion, intuition, and emotion regulation in financial decision making and linked them with affectively cued intuitions to see the changes in the decision making performance [6]. A better financial education is needed to have a better way to solve the increasing of economic complexity in the future. Instead of simply dismissing emotion as noisome, irrational agents in the decision making process, Lerner, Li, Valdesolo & Kassam (2015) studied the emotional impact on the judgment and decision making to obtain an understanding of their nature and how they influence the decision making process in order to acquire a better control of them [7].

Behavioral finance is a field that seeks to combine behavioral and cognitive psychological theory to provide the explanations to the stock market anomalies, rise or fall in the stock prices. One study by Bikas, Jurevičienė, Dubinskas & Novickytė, (2013) asserts that how important the financial behavior which examines recognition and emotional factors’ influence on the market changes and concentrates on the limited human rationality [8]. Furthermore, in a study which set out to discover the factors that influence between the property investment decision making and the behavioral finance, a negative emotion can reduce the rationality of the investors in decision making and may lead them to losing their money.

Neuro-finance is an emerging multidisciplinary area of research at the frontiers of Neurosciences, Economy, Finances and Accounting which investigate the brain activity associated with the financial decision. An electroencephalogram (EEG) is believed to be the tool of choice in the study of decision making. As people are expected to develop different financial decision making strategies to cope with their economic needs, Rocha, Vieito & Rocha presented some results on the stock market investment decision and concluded that this kind of knowledge may be a guidance on financial education [9]. Besides, a recent study by Vieito, Pownall, Rocha & Rocha (2014) analyzed if the same brain circuits are used by both gender while making stock decisions and if different circuits are used when the market conditions change such as in market growth and volatility and the study found that the investment decisions is significantly different between them [10].

Moreover, the studies of EEG use several technique to extract their features and classifier for their classifications process. Previous study by Razi, Othman & Wahab (2015), features from the EEG signals was extracted by using the Mel Frequency Cepstral Coefficient (MFCC) and classified by using the Multi-Layer Perceptron (MLP) Neural Network [11]. While, other studies were using Cerebellar Model Articulation Controller (CMAC) [12] and also Kernel Density Estimation (KDE) [13] [14] as their feature extraction technique and most of the researcher were using the same classification technique which is Multi-Layer Perceptron (MLP) as their classifier.

III. METHODS

This section discusses the methods of the study after the literature review was done and the methods as shown in Fig. 1 below.

![Research Methods](image)

**A. Preliminary Study**

For preliminary study, the EEG data from the previous study was used. The game data was used as it has the same procedure in making decisions which the stock market investment applications was also applied the switching and sorting methods before the decision making was made.

In pre-processing process, the sampling frequency used was 250Hz and the elliptic filters were applied to the data for retaining the theta and alpha bands. After that, the feature was extracted by using the Mel-Frequency Cepstral Coefficients (MFCC) methods. Before the classification, EEG emotions data was set target by using the dimensional emotion model. There are three models that were used which is recalibrated speech affective space model (rSASM) and the 12-Point Affective Circumplex (12-PAC) and Radboud Faces Database (RafD) which have been compared in the previous study [14]. The classifier used for the classification process was the multilayer perceptron (MLP). Both data goes through those processes and at last, the game data was trained and tested on the emotions data.
B. Data Collection

The electroencephalogram (EEG) emotions data and investment activity data was collected while an investor purchasing the stocks based on his/her preferences. The real stock market simulation and 19-channels of EEG machine were used in this study. The channels of EEG machine as shown in Fig. 2 below include the Fp1, Fp2, F3, F4, F7, F8, C3, C4, T7, T8, P3, P4, P7, P8, O1, O2, Fz, Cz and Pz channel. The AFz and FCz channel act as the ground and reference channel.

The subscript used for left hemisphere are the odd numbers and the even numbers was used for the right hemisphere. The channels categorized by different regions as described in table 1 below.

<table>
<thead>
<tr>
<th>TABLE 1 TYPE NAMES OF CHANNEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types Name</td>
</tr>
<tr>
<td>Frontal pole (Fp)</td>
</tr>
<tr>
<td>Central (C)</td>
</tr>
<tr>
<td>Parietal (P)</td>
</tr>
<tr>
<td>Occipital (O)</td>
</tr>
<tr>
<td>Temporal (T)</td>
</tr>
<tr>
<td>Midline points(z), which stand for zero</td>
</tr>
</tbody>
</table>

In this study, the participant was given a briefing and need to sign the consent forms before the experiment start. The selected participant known as an active investor, which knows the movement of stock market’s price and also have his own strategy in trading.

The investor was then required to complete the experimental protocol which include the baseline, emotions stimuli and also simulations. The baseline was started with the eyes close and eyes open in about 1 minute for each tasks. The emotions stimuli were tested by using the International Affective Picture System (IAPS) with four basic emotions, Calm, Fear, Happy and Sad in about 2 minutes for each of the emotions. The experiment continues with the trading simulations to purchase the stocks in about 30 minutes and the eyes close and eyes open repeated again to measure their emotions after the simulation activities was done. The complete experiment protocol was shown in Fig. 3 below. The observations were also done through taking a field notes on the behavior and activities of investor while making a decisions to purchase.

C. Data Analysis

The data analysis methods include the pre-processing, feature extraction and also classification that will be explained and shown in Fig. 4 below.

1) Pre-processing
The collected data will go through the pre-processing process the same as the preliminary study was done. The
elliptic filters and 250 Hz of sampling frequency was applied with the function,

\[ [b,a] = \text{ellip}(N,0.1,60,Wp) \]  \hspace{1cm} (1)

The equation (1) returns the transfer function coefficients of an \( N \)th-order of lowpass digital elliptic filter with 0.1 decibels (dB) of peak-to-peak passband ripple and 60 decibels (dB) of stopband attenuation down from the peak passband value as the resulting filter. As in (1), \( Wp \) is the passband edge frequency, specified as a scalar or a two-element vector.

The peripheral or poor channels were also removed. In order to correlates with emotional experiences, the signals applied the bandpass filter which shall eliminate unwanted low frequency ocular artifact.

2) Feature Extraction

The pre-processing data were then proceeds to the feature extraction process by using other existing technique, Kernel Density Estimation (KDE) which is also differ from the preliminary study technique. This technique was chosen as the previous one is not stable and it give a better results.

3) Set Target

Before the classification process, EEG emotion data will set target based on the dimensional model of emotion chosen as the best model from the preliminary study which is the 12-PAC model. The 12-PAC model will classify four emotions, sad, happy, fear and calm, and tested with the activity data in the next process.

4) Classification

In this study, the multilayer perceptron (MLP) classifier was used. The parameter of the MLP network architecture is set to 2 hidden layers with 10 neurons in each layer and 2 outputs. The inputs layer is set to 129 with 255 instances.

IV. RESULTS

This section describes the results based on the EEG-based emotion recognition in the investment activities.

A. Emotion Verification

The verification of emotions was done by trained the emotions data and the simulation data were tested again in the trained data. This process would determine which emotion has the higher percentage of accuracy. The training process used the emotions data and testing process used both emotions and simulation data. Both of the data will start with the analysis process that include in Section III(C).

Figure 5 above shows the percentage of emotions verification in which each of the emotions data were trained tested by using the MLP. The percentage of Calm is 72%, Fear is 75%, Happy is 78% and Sad is 74%. There are only a slight differences between the accuracies of their emotion which is represents as the percentage of emotions verification.

B. Emotion Distribution

The emotion distribution of an investor was shown in Fig. 6 below. The emotion data was distributed according to the 12-PAC model as plotted on the figure with the red dot as fear, blue dot as neutral, green dot as happy and orange dot as sad. From the emotion distribution, the emotions seems to appears as fear and sad which lead to the negative arousal. However, the distribution of emotion was considered as fear.
C. Emotion based on Valence and Arousal

The emotional change was traced while purchasing the stocks market. Figure 7 above shows the flow of valence and arousal representing the dynamic movement of emotion. It is observed that investor’s emotion is appears to be in fear quadrant with a negative valence and positive arousal. However, at a certain point, the valence and arousal turned into neutral (0, 0) and place itself into calm quadrant which then moves to fear quadrant again.

V. CONCLUSION

The study focused on the behavior and reaction in the stock market investment activities on the viewpoint of stock market investor. This paper also highlighted on how important the emotion and behavioral finance which may affect their judgement and perception in investment. As discussed from the previous section, the investor considered in fear which may reduce the investor’s rationality in making a decision and led them to lose money. The investor seems to have a doubt to make an investment as the given time are limited for them to make a decisions and nearest to the time of daily market closed. However, positive emotion can help them to minimize the risk of negative consequences. Therefore, a future work of this study will be focusing on the time-constraint and performance of the investors either they are gaining or losing money.

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