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Human Emotion Detection via Brain Waves Study by Using Electroencephalogram (EEG)

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***Abstract*— Human emotion is very difficult to determine just by looking at the face and also the behavior of a person. This research was conducted to detect or identify human emotion via the study of brain waves. In addition, the research aims to develop computer software that can detect human emotions quickly and easily. This study aims at EEG signals of relationship and human emotions. The main objective of this recognition is to develop "mind-implementation of Robots". While the research methodology is divided into four; (i) both visibility and EEG data were used to extract the date at the same time from the respondent, (ii) the process of complete data record includes the capture of images using the camera and EEG, (iii) pre-processing, classification and feature extraction is done at the same time, (iv) the features extracted is classified using artificial intelligence techniques to emotional faces. Researchers expect the following results; (i) studies brain waves for the purpose of emotions, (ii) the study of human emotion with facial emotions and to relate the brain waves, (iii). In conclusion, this study is very useful for doctors in hospitals and police departments for criminal investigation. As a result of this study, it also helps to develop a software package.**

***Keywords*— electroencephalogram (EEG); brain waves; human emotions**

I. INTRODUCTION

As we know, the basic human emotion that can be detected by facial expression or body movement, but what about the specific type of emotion? Emotional identified in this study either through EEG neuroimaging, functional magnetic resonance imaging (fMRI) and others are still in the early stages they detect a range of emotion shown by humans. However, the basic emotions are described in this area have shown positive growth.

The main objective of this study was to investigate brain waves with a view to detecting human emotion. Through brain waves, the data collected will contribute to the process of classifying the emotion felt by respondents and reactions brain waves before and during the process of detection.

Three objectives of this research are as follows; (i) learn to cope with emotions through the classification process, (ii) study the brain waves become electricity flows of human emotion, and (iii) examine the relationship between understanding human emotion through facial and brain waves of electricity. Based on the data obtained, the next step is to get through the face expression and brain waves detected the existence of human emotion. As a result of the data collected, the results expected and the end result can contribute to developing a software package to identify human emotion through (face expression for Human-Machine interface).

A. Electroencephalogram (EEG)

Electroencephalogram (EEG) is one tool that can directly measure neuronal activity and is the most effective way to measure neurons [1], [2].

Neural activity that moves simultaneously in the brain involves a large number of neurons to generate minimum levels of electric potential to allow EEG can record electrical signals.

From the EEG signals may include signals from other sources, such as Electrooculography (EOG), Electromyography (EMG), Electrocardiogram (ECG) signals from other sources which is considered a nuisance. Elimination disorders can affect important data from EEG recordings [3].

The neural pattern of EEG readings can be contaminated with expressive movement (natural movement) respondents. This interference can undermine the accuracy of a single EEG data. The correlation between EEG data and movement through MARG sensor is moderately high, but this effect appears to occur locally on a segment of time [4].

The expressive pattern of human body movement with their brain is unique. This pattern is a sign of the unique identity of a human being can be seen even from a distance [4]-[7].

The number of EEG channels during use would affect the measurement accuracy by a significant percentage. According to [4], use 10 electrodes finalized in 40-50% accuracy. Meanwhile, in the same study that was done, the information obtained through the 39 channels showing more than 90% accuracy to interpret.

There is research showing that stress levels can increase during the installation of headgear because of the number of installations that too many channels.

B. Brainwaves

Our brain consists of millions of brain cells also called neurons. The neuron in our brain functions to communicate with each other via electric impulse waves. Especially for the communication in the nervous system, the neurons are interconnected with each other by forming into neural nets, related [8] through a passage called 'synapse' which allows activities [9]. When the activity of these neurons occurs, current flows locally produced [8]. In this activity, jointly driven by an electric current flow from one neuron to neuron to another and it will produce wave patterns (waves) and is known as the wave of the brain (brain waves).

C. The Types of Brain Waves

Brain waves generated by a person to change and vary from one state to another depending on their current activities. For example, when a person's brain waves in a relaxed and unpretentious are in stark contrast to someone who is doing their work intensively. These brain waves are classified into 5 classification indicating different conditions. The classification is shown in Table 1.

TABLE I
CLASSIFICATION OF BRAIN WAVES

Types of Wave	Frequency Range	Description
Delta (δ)	0.5-3 Hz	Cure, sleep very well i. The slowest brain waves and is often associated with sleep. ii. Multiple frequencies in the delta range are accompanied by the release of human growth hormone (human growth hormone), which is useful in healing. iii. Delta, if produced in the waking state will provide an opportunity to access the subconscious activity, encourage the flow into conscious thought. iv. The delta situation also often associated with men who have a strong sense of empathy and intuition.
Theta (θ)	3-8 Hz	Deep relaxation, meditation, improved memory i. Occurs when we dream in light sleep or often cited as having a dream consciously. ii. Theta frequency is associated with stress relief and memory recollection long. iii. Twilight conditions (twilight) can be used to reach deeper meditation, resulting in improved overall health, increasing creativity and learning.
Alpha (α)	8-12 Hz	Creativity, relaxation, visualization i. Very cons compared to the situation where a state of relaxation that I encourage the flow of energy and creativity and fresh feeling healthy. ii. Alpha brain waves are ideal conditions for reflection, problem-solving and visualization to act as a gateway to our creativity.
Beta (β)	12-27 Hz	Beware, concentration i. To always keep our mind sharp and focused. ii. In the beta state, our brain will easily do the analysis and preparation of the information and generate solutions and new ideas. iii. Beta is very beneficial for work productivity, study for exams or other activities that require high concentration and alertness.
Gamma (γ)	> 27 Hz	Regional learning, memory and language processing and ideation i. Gamma waves are shown away from the brain signals for anesthesia caused a deep sleep [10], [11].

Table 1 shows the classification of brain waves by the types of the wave like delta, theta, alpha, beta, and gamma. The frequency range and also the description of the criteria for each type of wave are specified and keeping it specific.

D. Emotions

Emotion is a communication method for describing inner feelings through the physical and real world in the form of body language involves facial expressions and body movement. The emotion was synonymous to all mankind. However, emotions have been interpreted in different fields [12].

Through this theory suggest that the field of physiology, emotions was the result of the reaction of the body. While in theory the field of neurological state, activity in the brain is the source that generates the emotional response. Meanwhile, in the field of the cognitive theory states that mental activity is a very important role in the formation of emotion.

According to [13] Model explains, there are 5 elements of stimuli that affect the behavior of an individual to master the academic skills of an information and new or difficult. One is the emotional element involved (motivation, persistence, responsibility and structure). This combination will result in an indication in the realization of one's emotions at a certain time.

The stimulus can evoke emotions involving visual or auditory, or both at the same time [14]. Different emotions involve different areas in the brain [15].

Emotions can generally be categorized into three major classifications: Basic (happy, sad, fear, anger, surprise, and disgust), motivation (thirst, hunger, pain, and mood) and the conscious self/social (shame, dignity and guilt) [16]. Human emotions can be said and equated in meaning in the same way through a combination of mixed primary colours (red, yellow and blue) to produce secondary colours (orange, green and violet). The combination of basic emotions or early stages can result in more complex emotions.

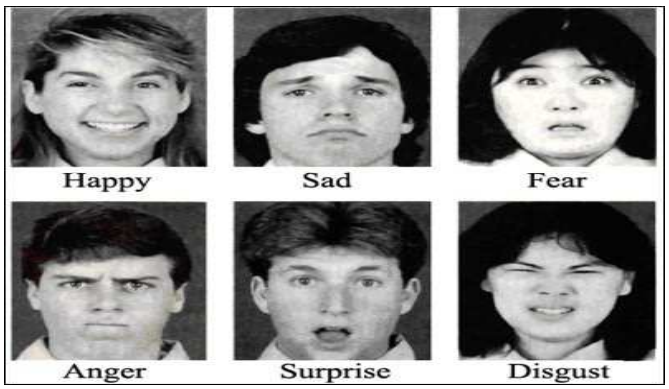


Fig. 1 Basic through emotional reaction interface [17]

In Fig. 1, we can see a variety of facial expression that represents any kind of emotion that occurs in human beings. Reactions face or facial expression that results show the human emotional responses produced at that time. It happens automatically without being forced. However, this change can be masked and it can be overcome with observations of brain waves in the studies undertaken.

Emotions are describing two-dimensional space, the molecular bond between the atoms in the horizontal axis and the vertical axis is on the rise. Emotional quality provided by different molecular bonds of the pleasant surprises. Fig. 2 shows the model of emotion in 2D space.

Fig. 2 Model emotions 2D space (modified from the study)

Fig. 2 shows the type of emotion that occurs in every human being. Emotions are divided into two parts. Negative emotions (left side) and positive emotions (the right side) fig. Negative (-) emotions consisting of fright of emotion, disappointment and sad while positive (+) emotions are consisted of emotion excited, joy and tranquil emotion. This model also shows clearly the negative (-) movement of the molecular bonds (left side) to the positive (+) molecular bonds (right side) and a low feeling lines (bottom) to feeling high (top).

II. MATERIALS AND METHODS

The methodology for this research is divided into four; (i) both visually and EEG data is used to extract the date at the same time from the respondent, (ii) the recording process for the complete data include image capture with the camera and electrical reconstruction using EEG, (iii) pre-processing, feature extraction and classification is performed at the same time and (iv) the extracted features are classified using artificial intelligence techniques to emotional faces.

Information obtained from the brain to study produced by the electrical activity of large quantity neuron networks simultaneously. Electrical activity that occurs simultaneously throughout the brain produces waves like an EEG signal. EEG signals were full of information on the activity of the brain usually between 0.5 to 100µV in amplitude when measured from peak to peak voltage as shown in Fig. 3.

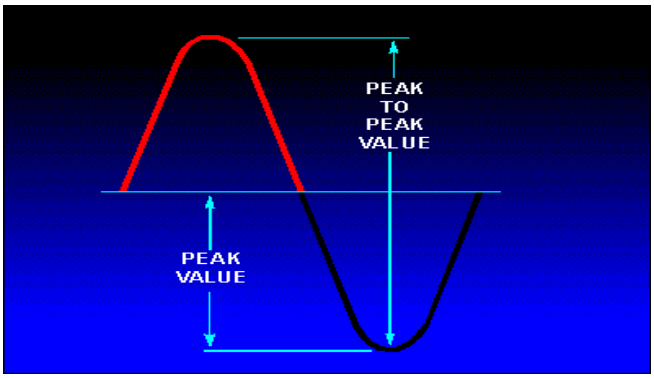


Fig. 3 Peak to peak value [18]

As such, the EEG equipment will endeavor to strengthen the signal. However, when the EEG signal is very weak, the existence and the movement disorder which causes unnecessary information signals EEG important right and there was a wave that is generated. Preprocessing needs to

be done. The system will need to extract and filter out the noise and movement to get key data that contains information about emotion, through pre-processing features extraction and classification. Extracted features are classified using artificial intelligence techniques using neural networks.

The electrodes were placed according to the 10/20 system or international system is an internationally recognized method to describe the accurate location of scalp electrodes. The number of 10 and 20 means the fact that the distances between one electrode with another electrode are either 10%-20%. This rule covered total front to back or right to left a distance of the human skull.

This research is using the electrodes was labelled as FP1-A1, FP2-A2, F3-A1, F4-A2, C3-A1, C4-A2, P3-A1, P4-A2, O1-A1, O2-A2, F7-A1, F8-A2, T7-A1, T8-A2, P7-A1, P8-A2, Fz-AV, Pz-AV and Cz-AV.

Subjects were advised to arrive at the lab earlier before the session so that he or she can rest for a while. The subjects came to the lab with their hair washed without using any additive like a hair gel, baby oil, shampoo, and conditioner and so on. This item can give effect significantly to the impendence level.

All the equipment for the experiment such as monitor screen, computer, EEG machine, and camera need to prepare early at least 30 minutes prior to the session of data collecting. To ensure the respondents in a comfortable mood, room temperature also must be maintained with an air conditioner and the respondents must be seated 80cm away in front of a computer screen.

To take readings and measurements of EEG signals, this process involves the use of research equipment as follows:

1) Software Installation Process:

- CD Installer software installed on the computer. It aims to control the process next well using EEG applications. Without CD installer, the software cannot function.

Fig. 4 Safenet microdog [19]

- Safenet microdog
  This software is used every time the process of data collection on respondents. Reading and data analysis cannot be performed if Microdog is not used in a computing device. EEG also cannot function properly. It also can be used only by one computer at a time.

2) Hardware Installation Process:

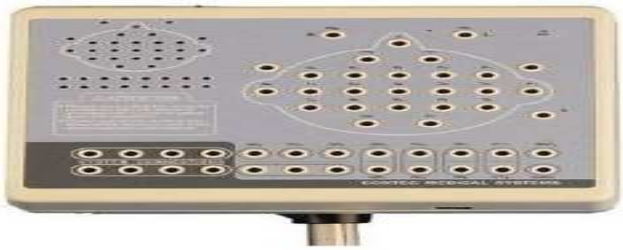


Fig. 5 CONTEC KT88-3200 EEG [20]

- CONTEC KT88-3200 EEG
  These measurements will be performed using this equipment. EEG signals are an important part of the whole process should be done carefully to avoid locations corresponding electrodes on the subject as well as harassment and interfering with the movement of the main signal EEG readings. CONTEC KT88 3200 will be able to supply up to 32 channels of EEG under the international standard system for electrode placement.

Fig. 6 Gel EEG [21]

- Gel EEG
  EEG gel used to support the placement of electrodes will be placed and then he swept to connect properly on the head with this place some gel flow between electrodes and skin.

3) Data Recording Process:

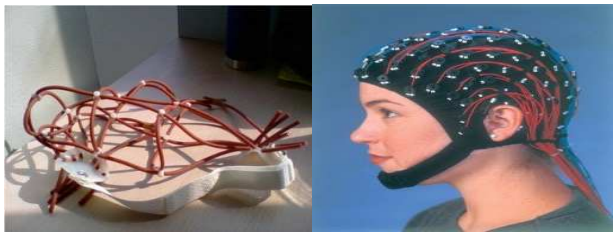


Fig. 7 Hat/Cap EEG [22]

- Hat/Cap EEG
  EEG cap placed on the head of respondents and is connected to the main system. Respondents were asked to act naturally and ordered them to stay in a comfortable and relaxing for a good reading with minimal disturbance and movement. Interrogation sessions and recording of EEG signal is carried out at the same time. EEG signals obtained through the production of waves on a computer screen.

Fig. 8 Cameras [23]

- Cameras
  Video cameras are used to capture facial expressions and reactions of respondents during the data collection process are run. The camera is used to facilitate researchers to investigate the relationship between the expressions on the face of respondents with data.

4) Pre-processing: This process is to eliminate unwanted signals of EEG to read and reconstruct the signal as close as possible to the original activity of the brain. EEG signal containing brain activity, noise and reference activities. This process is considered as:

- Disorders and movement
  Raw EEG signal contains much noise and movement derived from static electricity or electromagnetic fields. The interruption came from reactions around the device. It produced by body movements such as eye movements generate waves in the EEG signal. Process low-pass filter and the high filter process are performed to remove the respective frequency below 2Hz and above 40Hz. Thus, unwanted noise and movement will be eliminated as quickly as possible.

- Reference
  Measurement electrodes must represent electrical activity in a particular place. Voltage is a measure of the relative while the last recorded measurement will refer to the reference point.

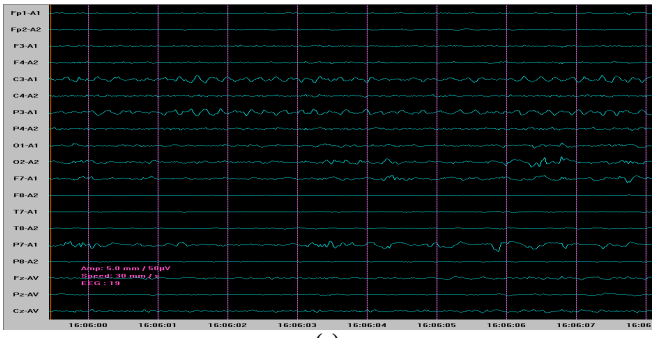
5) Feature Extraction: The results obtained from the data pre-processing, this section will obtain important information. By doing so, the EEG signals can distinguish between each other or different emotions. EEG signals recorded the readings over time are right, with the situation existing rhythmic lines are consistent with the reaction of emotion during the recording made. As mentioned in the introduction, rhythmic activities of different paths reveal information about brain activity.

Respondents were asked to look at the video. Time allocated for each video is about 2 minutes. Each respondent should see 4 different types of video included anger, sad, happy and surprise emotions. On the computer screen will appear readings of brain waves.

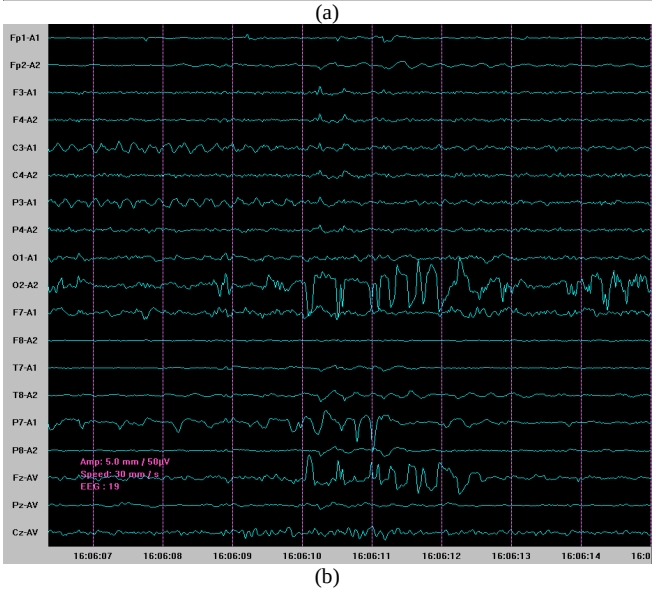
III. RESULTS AND DISCUSSION

A. The Findings of The Initial Study (Raw Data)

Researchers expect the following results; (i) to study brain waves for the purpose of emotions, (ii) to associate facial studies human emotion and brain waves, (iii) it is very useful to your doctor in a hospital and the police criminal investigation department, and (iv) help develop software packages based on the study. Following are the results of successful brain waves produced about and this is the raw data that has not been classified:



(a)



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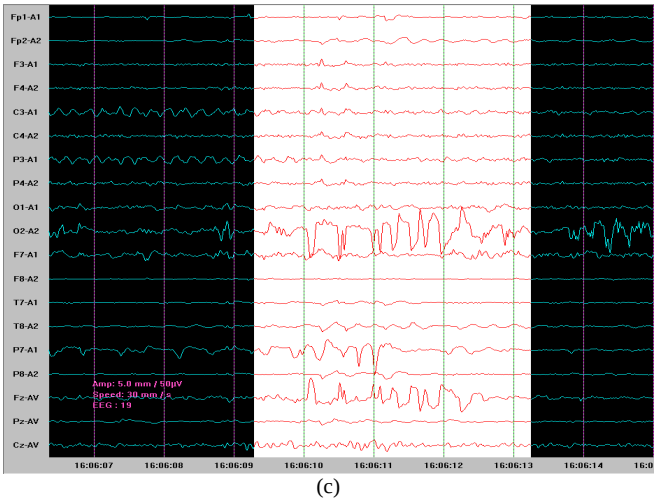
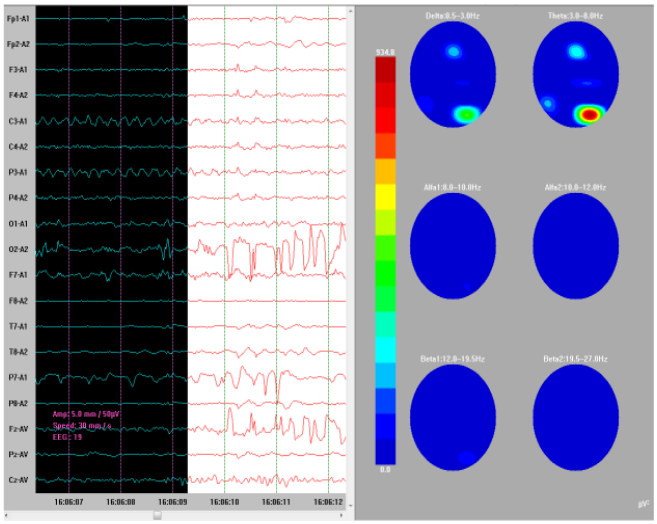


(c)



(d)

Fig. 9 Raw data of brain waves

Fig. 9 (a) shows how the initial wave of success recorded during the process of detecting emotions run. From the figure can be seen brainwave researchers still did not show significant changes. While Fig. 9 (b) shows changes in brain wave patterns that indicate the occurrence of an emotional response to the wave. Fig. 9 (c) shows the waveform of interest to determine whether this is related to the wave of emotional facial reactions recorded during these waves of change appear or otherwise. Fig. 9 (d) shows the reading of brain wave frequencies that are at a certain level in the classification of types of waves such as delta, theta, alpha, beta, and gamma.

B. The Findings and Analysis of Every Emotion Under Review

This is results of the study and analysis of results for each study involving emotional emotions of anger, sadness, happy and emotional surprised. The data analysis showed differences in brain waves produced and successfully recorded for each emotion that has been declared. Frequency and the type of wave involved are also described.

C. The Findings and Analysis of The Emotional Anger

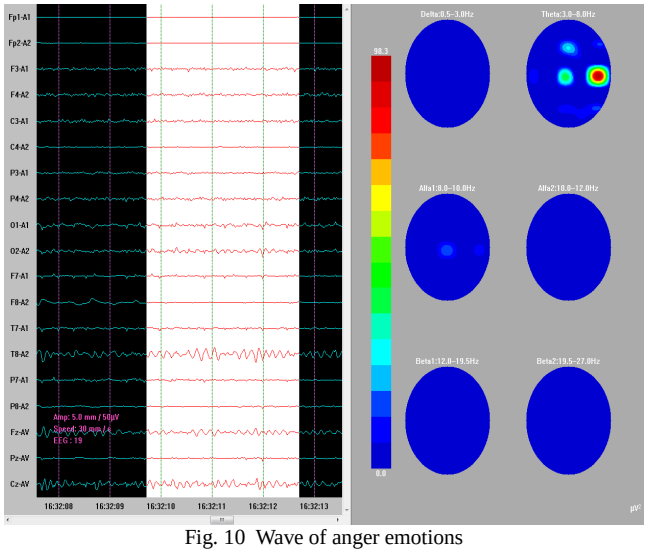


Fig. 10 Wave of anger emotions

Brainwave study showed angry emotional reactions are very clear on the right side of the brain involving this type of Theta waves. Theta waves mean of deep relaxation and stress relief or linked to pressure on human emotions. Thus, Theta wave is visible when the emotion of anger occurs.

D. The Findings and Analysis of The Emotional Sad

When the waves of emotion sad are recorded, there are several effects or reactions to the right side of the back of the brain. There were two waves delta and theta reaction. The reaction at the delta waves was insignificant when compared to the waves of theta at emotional sad. However, delta still shows the answers where the waves are often associated with men who have a sense of empathy and intuition. Theta waves at sad emotions related to the old memory. Due to the high response occurred in waves of theta.

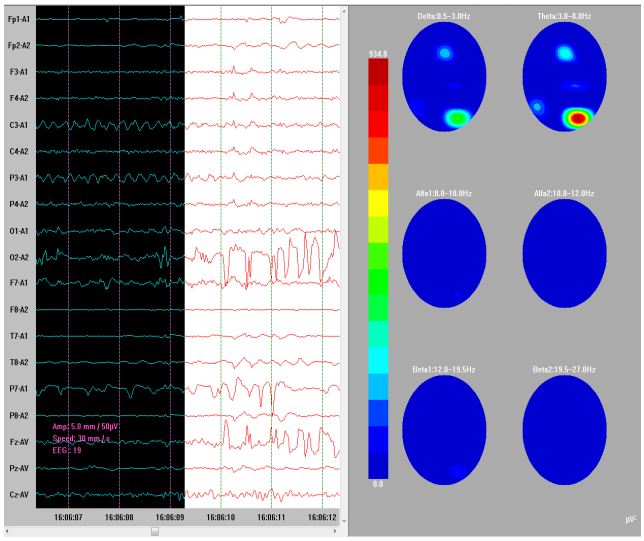


Fig. 11 Wave of emotion sad

E. The Findings and Analysis of Emotions Happy

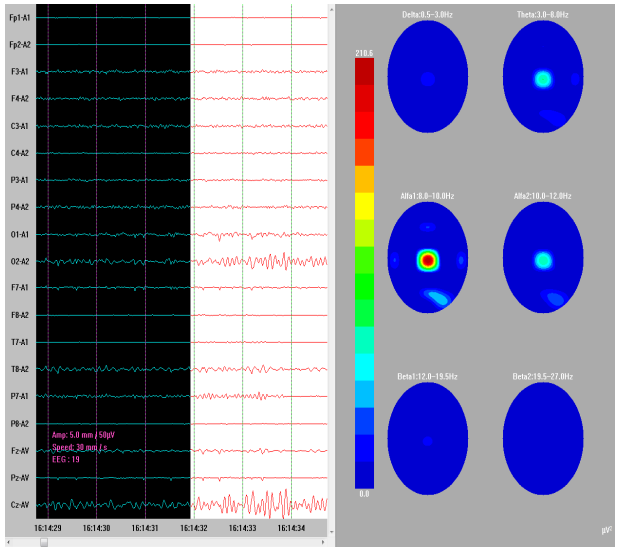


Fig. 12 A wave of emotions happy

When the wave of emotion which thrilled recorded, there are changes in the wave of emotion that show at the event

response respondent view or live video joy. Reactions that occur in the brain wave activity that shows a very noticeable in the middle part of the brain that are on alpha waves. Alpha wave refers to activities related to rest and quiet. Thus, the wave of emotions those are very happy in the alpha wave which involves the flow of energy and creativity and fresh feel.

F. The Findings and Analysis of The Emotional Surprised

The results and analysis of emotional shock waves showed the occurrence of many events or reactions in the brain. Almost every type of wave shows the reactions. The most obvious answer can be seen is in the delta and theta waves. The various frequencies in the range of Delta are accompanied by emission from (human growth hormone), which is useful in healing. While theta shows frequency associated with stress or high stress. Due to the many reactions that occur in delta and theta waves on this emotion.

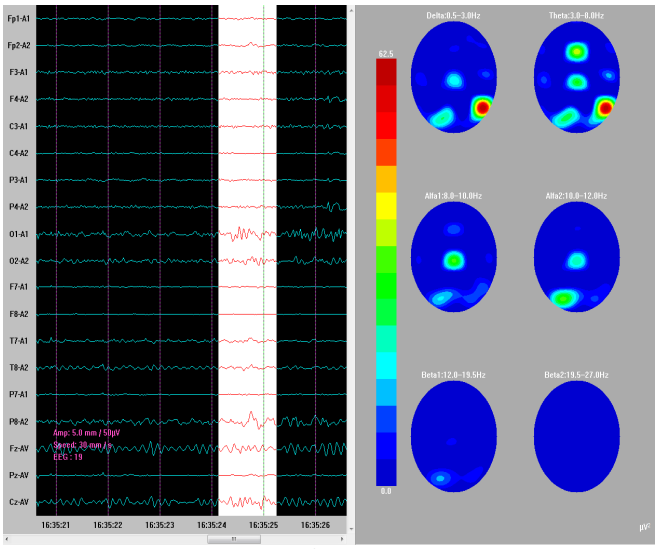


Fig. 13 Wave of emotions surprised

IV. CONCLUSIONS

The results of this study can be used by hospitals and police departments to detect the emotions of patients and offenders. Ease of interpreting the information during interrogation allows certain parties who can reveal human emotions.

The detailed of information about the basic human emotions was discussed at the beginning of the study. Correlation properties for EEG pattern for all the emotions that exist can be distinguished on the basis of previous studies. The emotional face can be identified using video sequences for expression. Data can be related to the relationship between the data with others. Identification of emotions can be linked to the findings of the previous objectives. Thus, data can contribute to a doctor at the hospital and the police department of this study.

Based on the findings obtained through a process carried out revealed that facial reaction alone cannot describe or reveal the real emotional person. But with this brain wave analysis, we will be able to know the true emotions of a respondent, although it is trying to hide.

The results for all processes in the method of research have been done. Using the data obtained, the expected results and the final results can contribute to developing a software package to identify human emotion through (facial expression for the human-machine interface).

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