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Controlled wheelchair based on brain computer interface using Neurosky Mindwave Mobile 2 FREE

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Controlled Wheelchair Based on Brain Computer Interface Using Neurosky Mindwave Mobile 2

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Abstract. Stroke diminishes someone's quality of life since post-stroke symptoms can make some limbs do not function normally -in most cases, feet- thus the stroke patients' mobility will be limited. However, the brain wave of stroke patients was observed as normal, thus in this study, the normal brainwaves were utilized to rehabilitate post-stroke patient and were expected to help their mobility through wheelchairs with brain waves control so that post-stroke patients can improve their quality of life. Brain Computer Interfaces (BCI) is a technology that allows taking action on a computer based on brain waves. Brain waves are recorded by electroencephalography so they can be processed by a computer. There have been many studies using BCI including analyzing brain waves in humans, many things that can be utilized using BCI make a lot of researchers use them to make smart wheelchairs that use brain control. and developments continue to be made to create the most optimal system. In this project we use one of the topics that is still being developed, that is Motor Imagery, where we record and analyze the brain waves while imagining motor activities such as moving hands, walking, running and so on. This record will serve as data reference to trigger the process on the computer to move the actuator. The purpose of this project is to control the wheelchair based on motor movements obtained by BCI using the Neurosky Mindwave Mobile 2 headset. This headset has one electrode where the signals from one electrode are analyzed by concentration and meditation values from the case of imagery motors, which in this project are more portable than using conventional EEG data acquisition devices that are not portable and use many channels. This headset is able to record data wirelessly via Bluetooth to a PC (Personal Computer), so the obtained signal can be processed and classified into five movement classes using the Matlab GUI, where the classes are default/motionless, move forward, move backward, turn right and turn left. The method used for the wheelchair was replacement of the default joystick in the electric wheelchair with an self-made controller module which was based on brain waves signals obtained from the headset will be processed and classified by Matlab GUI and then forwarded to Arduino Uno to control the motor in the wheelchair. The average success rates of the five classes from five trials were: the first class with a success rate of 82.22 %, the second class with a success rate of 70 %, the third class with a success rate of 73.33 %, the fourth class with a success rate of 46.67 % and the fifth class with a success rate of 17.78 %. The results of this study indicate that Neurosky Mindwave mobile 2 headset can be a possible choice for this project.

Keywords: Brain computer interface (BCI), Electroencephalography (EEG), motor imagery, controlled wheelchair, Neurosky

INTRODUCTION

Nowadays, due to the increasing percentage of senior citizens in the current population, the need for wheelchairs has increased significantly not only for people with disabilities community but also for old citizens. The use of manual wheelchairs is limited to users with leg defects or people who helps to bring sick patients. For users with some special cases, they usually use an electric wheelchair which is wheelchair system uses a joystick, switch, pedal and button to perform control tasks. However, because many diseases such as strokes deactivates the nerves or parts of the body,

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the patients can only move certain areas such as (eyes, tongue and brain) so that a system improvement is needed to make smart wheelchairs that can be used by many people from various diseases. The high number of researches on smart wheelchairs make people compete to make a better system. One of the systems that is still being researched and developed is the use of Brain Computer Interface (BCI) processing and Electroencephalography (EEG) signals as triggers for wheelchair movements, because there are many methods that can be used, research models, and various data acquisition device.

EEG is a method by which we record the electrical activity in the brain through the scalp. This method has been widely used as a tool in the medical treatment. One of them is to diagnose several diseases such as stroke, schizophrenia, compulsive disorder, depression, epilepsy, Attention-Deficit/Hyperactivity Disorder (ADHD), etc. [1]. In EEG frequencies can be divided into several types as follows:

- Delta (0.5–4 Hz),
- Theta (4–8 Hz),
- Alfa (8–13 Hz),
- Beta (13–30 Hz),
- Gamma (above 30 Hz).

Generally, gamma frequency is hardly recorded by scalp electrodes. EEG patterns are influenced by neuro-pathological conditions, metabolic disorder, and drug use [2]. Besides, stroke is one of the causes of morbidity and mortality for almost all countries in the world no matter whether it is a developed or developing country. Stroke is divided into two types, the first one ischemic stroke where it is caused by the blockage of the blood vessels in the brain and the other one is hemorrhagic stroke where the cause is rupture of blood vessels in the brain [3].

Stroke diminishes a person's quality of life because it causes patients' several limbs do not function normally or paralyzed. Ischemic stroke patients who have recovered are usually referred to as post-stroke patients [4]. Even though they have recovered, post-stroke patients have difficulties in motor movement and thus they should be rehabilitated as soon as possible to avoid the temporary paralysis gets worse to total paralysis [5]. In general, limbs that experience paralysis are feet, hands, and face. Feet are the most important factor to support human mobility, therefore paralyzed feet or immobilized feet will hamper human daily life, and thus caregiver will inevitably be needed to help them with the mobility [6]. The best solution for post-stroke patients is using wheelchair which nowadays is not limited to manual operation, but also using motor movement and joystick controller [7]. Furthermore, nowadays people compete to create automatic wheelchair design not only for elderly or people with disabilities but also for post-stroke patients [8].

BCI is a communication system which can translate humans' mind or will to control signals, so by using BCI we can develop non muscularly communication which expected to help people with motor disabilities and also rehabilitate patients with diseases such as stroke [9]. With sensors and several equipment's utilization we can develop an automatic wheelchair device by combining EEG and BCI as a brain-controlled wheelchair [10].

EXPERIMENTAL METHOD

In this project, Mindwave Mobile 2 headset was chosen as a device used to record EEG data signals is shown in Fig. 1. This device was chosen because of its lower cost compared to other common portable EEG signals recorder devices. Besides, this device was chosen because of its rich features and the simplicity of processing its output signals compared to other common devices. Several features of this device are: raw data, power spectrum (delta, theta, alpha, beta, and gamma). Moreover, we used this device because it utilizes dry electrodes so the maintenance is easier than the other portable EEG signals recorder devices which use wet electrodes.

FIGURE 1. Neurosky Mindwave Mobile 2

Several application options and programming languages can be used to process the digital signals in Neurosky Mindwave 2 headset, but in this project we used Matlab software since the software is the most commonly used to process the digital signals in this headset. Neurosky collaborated with ThinkGear to access the features in this headset, which created a library (ThinkGear etc.) so that the features in Neurosky could be accessed by external software besides software from Neurosky. The way to access the data recording features on this headset by Matlab is explained in Fig. 2 [11]. First, we had to load the library from ThinkGear so we could access the data records in the Matlab, then we had to get the connection ID on Neurosky so it could be accessed by ThinkGear. Next, ID connection was connected to "COMx" serial port, after they were connected, we could load the ThinkGear library to connect with Matlab and the headset, then we had to wait the status of data record and finally we recorded the data package read by Neurosky. In this step, we can program any features that we would like to access from Neurosky, the features are eSense (attention and meditation), raw data, delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–13 Hz) which is divided into low and high alpha, beta (13–30 Hz) which is divided into low and high beta, and gamma (30–45 Hz) which is divided into low and high gamma [12]. Data record feature displayed in Matlab will be continually recorded until we open the library from ThinkGear and unplug the connection.

In the design of this device we used the JRWD 501 electric wheelchair which previously was an electric wheelchair with joystick control. To contrive this into a brain wave controlled wheelchair, we need to change the circuit from its joystick module with microcontroller which has been programmed in such a way to move the motor in the wheelchair in accordance with the direction of the joystick depends on command sent from the Personal Computer (PC), according to the processed brain signals we have classified into the same joystick movement. The flowchart of device design is explained in Fig. 3 and an explanation of the replacement of the wheelchair controller is explained in Fig. 4.

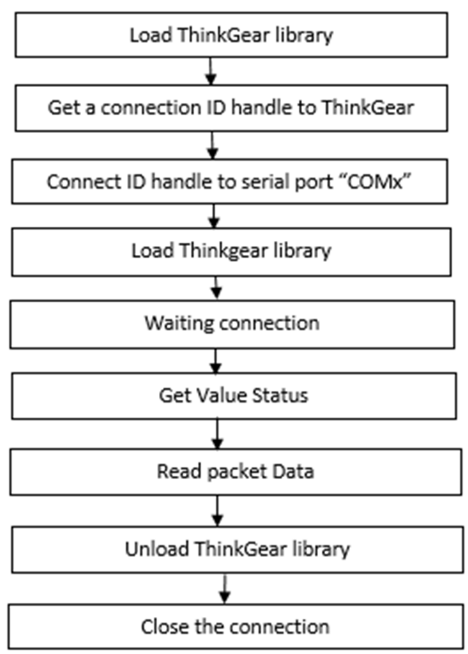

FIGURE 2. Communications steps between Matlab and Mindwave Mobile 2.

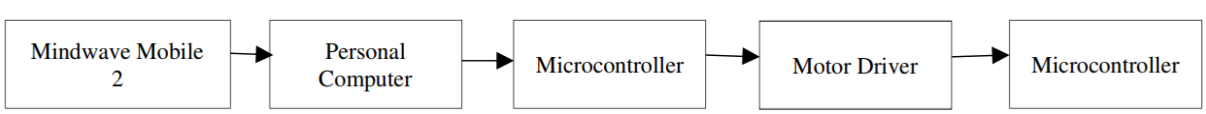

FIGURE 3. Electrical connection in Electrical Wheelchair System.

Flowchart System

In this wheelchair control system, we performed several stages of standard operation, which is shown in Fig. 5. First, we had to turn on all devices, including wheelchair, headset, and PC then we had to turn on the program from Matlab so all those three devices could communicate with each other. Second, when all had been connected, headset would record the data and sent from the headset to the computer. Third, computer processed data signals received and sent them to Matlab. Forth, Matlab read the data record by feature from Neurosky. Fifth, the data record was programmed and classified into 5 types of data which triggers other data called movements. Sixth, when movement data were triggered as mentioned in the fifth step, the data were sent from PC to Bluetooth module installed on the microcontroller, then it was transmitted from Bluetooth module to the microcontroller to move the motors on the wheelchair. The fourth to the sixth steps occurred continuously until the user stopped the program. So, the wheelchair will move according to movement data which are always sent by the computer to microcontroller.

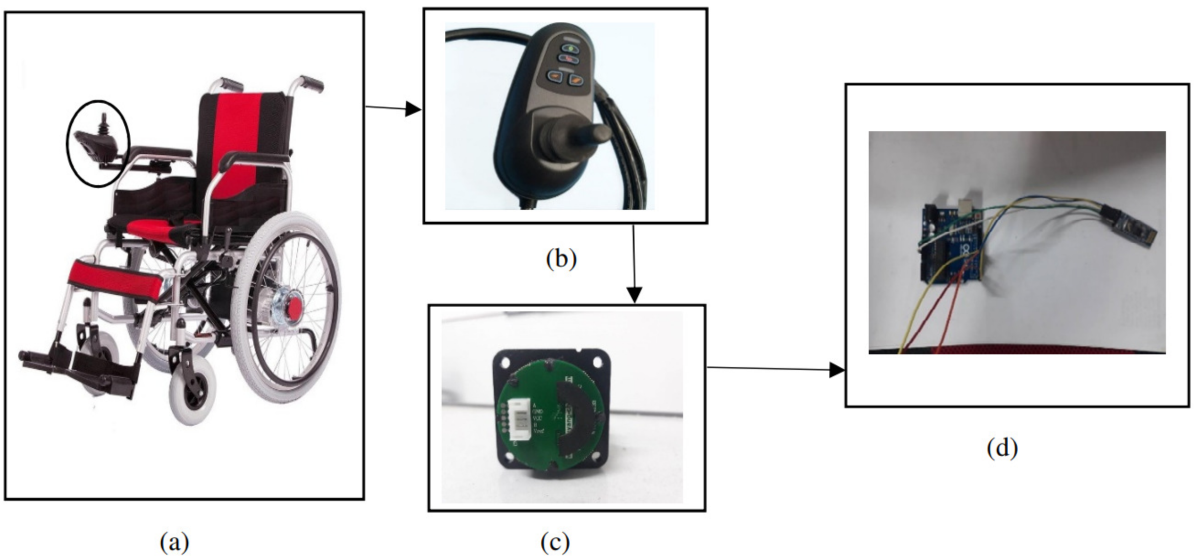

FIGURE 4. The joystick replacement circuit on the wheelchair where (a) is an electric wheelchair, (b) is a wheelchair controller, (c) is a wheelchair configuration, and (d) is a replacement microcontroller which will be installed on the wheelchair.

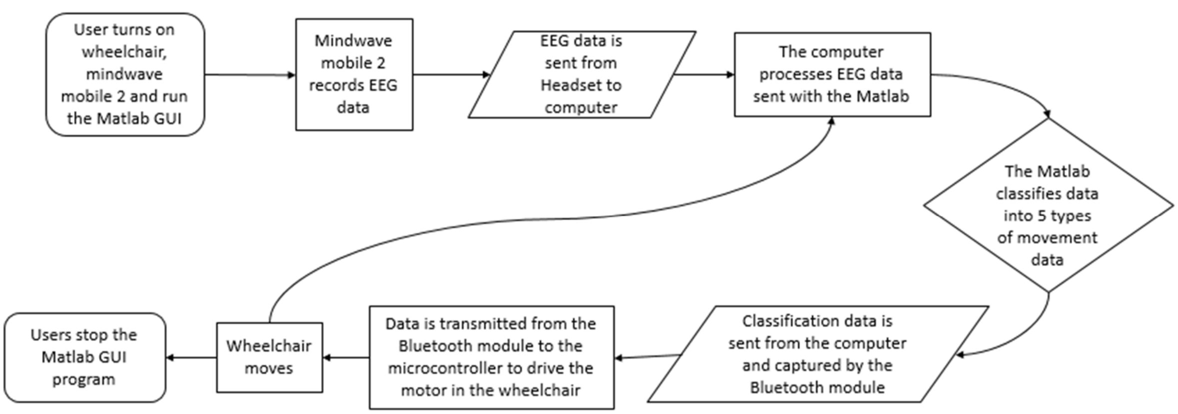

FIGURE 5. Flowchart system

Experiment Setup

To determine the wheelchair movement using headset, the easiest way is by processing eSense signal which is concentration result of attention or meditation from the subject. The processed data were classified into 5 types of movement signal consist of moving forward, moving backward, turning left, turning left, and default. In the classification of wheelchair moving data, we used imagery motor method and eye motion, for imagery motor we used features in Neurosky which was eSense, and for the eyes motion we processed high alpha signal recorded by the headset. We took eSense data for imagery motor because it was centered to the subject's concentration, thus the data results could be references for controlling. eSense feature has scale range from 1 to 100. At a normal condition the scale is between 40 to 60, and the scale can be increased up to 100 by focusing the attention and meditation concentration [13]. The classification that we have done is summarized as follows:

1. Moving forward : think moving forward
2. Moving backward : think moving backward
3. Turning left : think moving backward while continually move the eyes
4. Turning right : think moving forward while continually move the eyes
5. Default : others

Subjects for data exercise were taken from normal people since getting the post-stroke patient was quite challenging. The criteria for a good subject were not under pressure, not in pain (especially headache and under stress). This is because the concentration of the subject becomes the basic determinant so that the wheelchair can be used by everyone. In addition, for data exercise we used 3 minutes exercise duration for each classification class, and break was carried out for 5 minutes, because we did not to impose the subject's brain to keep the subject ability to concentrate well.

In our data collection for research subject, we used normal people who are classified into 3 groups as follows: the device researchers, people who rarely used the device, and people who never used the device. The aim was to ensure that the data obtained from the exercise was valid and proven that the device can be used by anyone. We present the Graphical User Interface (GUI) at Matlab in Fig. 6.

RESULTS AND DISCUSSION

Training Classification

The following data are the results of classification based on eSense score and high alpha from the exercise which were repeated for several times. The results were obtained from the calculation of the average number of total data retrieval from the imagery motor method. During the trials of motor imagery data exercise using eSense it was quite difficult to find data which were considered as true from imager motor, because eSense had 2 data types including attention and meditation, where the state of the subject used should be completely not under pressure, fatigue or stress, because the subject would have difficulty in concentrating thus the data obtained would be wrong. Data collecting

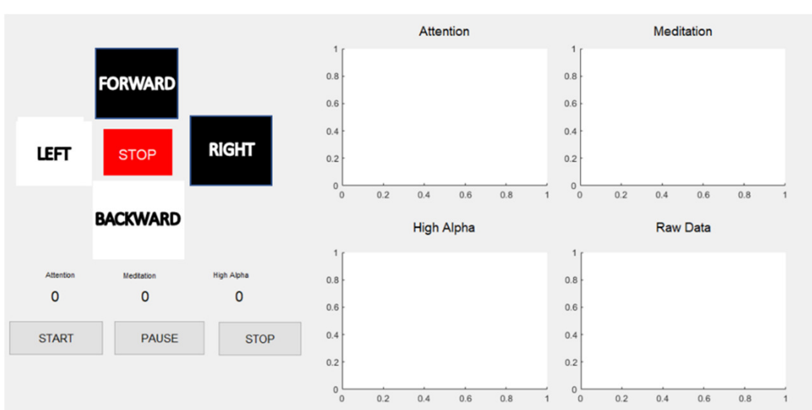

FIGURE 6. Graphical User Interface Matlab

was done in 3 minutes for each class with 5 minutes of break to avoid exhausted brain, so the data obtained would be representative. We used 3 minutes of exercise because at the previous trial it was used 5 minutes duration but because of the long classification duration, the subjects were bored and the data obtained were only optimum at the first 3–4 minutes and not optimum for the rest.

At the initial of experiment plan we were going to use only imagery motor to trigger the wheelchair movement, but when we performed data exercise and searched imagery motor variable for the movement, we found limitation because we only used one data channel so in the variable there were many similarities including the classification for moving forward and moving backward class. So that, to overcome our method limitation, we added a new variable which was considered could be a differentiator of the similar data. Because the channel was located at Fp 1 signal near the left eyebrow, we tried to use eyes motion as an additional variable to trigger movement, so that we can classify the data to 5 movement class (Table 1).

Data Results

In this section we present the data of wheelchair trial results which was carried out to 5 normal people consisted of: 1 is the researcher of this paper, 2 people who rarely used the device, and 2 more who never used the device. The trial was performed for 5 minutes and the subjects were asked to do 36 kinds of movement including 4 types of classification which were moving forward, moving backward, turning left and turning right with 9 repetitions for each, the movements were performed randomly depended on the will of the trial subjects. The results of the trial are described in Table 2.

From the data obtained, the results were relatively good for moving forward, backward, and motionless. This was because of the basic data of imagery motor itself, while for turning right and left even though they were similar with moving forward and backward but there was additional continuous eye motion needed, so the data obtained for moving forward and backward were not good. We added the eyes motion because we found the difficulty if we only used 1 EEG channel. When we only used 1 channel, it was difficult to classify the data more than 3 classifications, because when we concentrated to move a limb, if there was only 1 channel reviewed then the way we concentrated to move other limbs would be similar so it needed one more trigger to create 3 classifications. But for the eyes movement,

TABLE 1. Results of data analysis from the classification of motor imagery and eye movements from Mindwave Mobile 2.

Classification	Attention	Meditation	High Alpha
Forward	40−60	≥ 60	≤ 12000
Backward	≥ 60	≤ 55	≤ 12000
Turn Left	40−70	≥ 60	16000−38000
Turn Right	≥ 60	≤ 55	16000−38000
Default	Etc.	Etc.	Etc.

TABLE 2. Results data from participants.

Command	1	2	3	4	5	Total
Forward	6/9	9/9	7/9	8/9	7/9	82.22 %
Backward	8/9	6/9	7/9	6/9	6/9	73.33 %
Turn left	4/9	4/9	5/9	3/9	5/9	46.67 %
Turn right	2/9	1/9	1/9	2/9	2/9	17.78 %
Total	55.56 %	55.56 %	55.56 %	52.78 %	55.56 %	

there should be further optimization because when the data is a turn movement, but because the data transmission from PC to microcontroller runs continuously and eyes movement is only counted as a trigger, so when the motor wants to move the wheelchair to turn, the wheelchair has done the next command.

Similar research has also been carried out but the research used Epoc emotive data acquisition tools, which have 14 EEG channels and the study uses mental command which is a feature of Epoc which in emotive has 1 mental command that we can vary as triggers to move wheelchairs [14].

Based on the data obtained from the previous research, it has a greater success rate because tool used in the research has more possibility variable compared to ours. Limited channels did not allow us to classify more data as triggers to the wheelchairs.

CONCLUSION

The purpose of this project is to establish an automatic wheelchair which are used by the user's brain. Learning data is done by averaging the imagery of movements with the given cases. The EEG signal data we analyze is the concentration and meditation data. From the data learning we did continuously, the optimal results obtained from the range of values which could be a model of a wheelchair prototype were used in the case of imagining walking forward, walking backwards and walking forward with eye movements and walking backwards with each eye represents forward, backward, turn left, and turn right. From the results of the data obtained, we find that the method we are doing still needs to be developed because it is still difficult to classify with classifications of more than three classes so that for the fourth and fifth classifications of the data are still quite bad.

In future work, we intend to develop the methods that we do and apply the model to obtain an automatic wheelchair system that can be implemented in real wheelchairs

ACKNOWLEDGMENTS

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