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Brain-Wave Controlled Automated Wheelchair

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Abstract: **This project attempts to implement an Arduino robot to simulatea brainwave-controlled wheelchair for paralyzed patients with an improved controlling method. The robot should be able to move freely in anywhere under the control of the user and it is not required to predefine any map or path. An accurate and natural controlling method is provided, and the user can stop the robot any time immediately to avoid risks or danger. This project is using a low-cost brainwave-reading headset, which has only a single lead electrode (Neurosky mind wave headset) to collect the EEG signal. BCI will be developed by sending the EEG signal to the Arduino Mega and control the movement of the robot. This project used the eye blinking as the robot controlling method as the eye blinking will cause a significant pulse in the EEG signal. By using the neural network to classify the blinking signal and the noise, the user can send the command to control the robot by blinking twice in a short period of time. The robot will be evaluated by driving in different places to test whether it can follow the expected path, avoid the obstacles, and stop on a specific position.**

Index Terms- Brain computer interface, Electroencephalogram, Neural network, Neurosky sensor, Wheelchair

I. INTRODUCTION

Paralyzed patients face many difficulties in their daily life.It is hard for them to make use of motor neurons to control muscle. People suffer from motor disabilities may sometimes be very stiff and even cannot speak as they want. They need the help from others to perform daily activities. For example, fully paralyzed patients may need someone's help to control the wheelchair. In the past, many technologies have grown and become mature for disabled people to interact with physical devices, such as the electromyogram (EMG) arm, finger gesture recognition application and voice controlled wheelchair.[1] However, most of them are relying on muscles, body movements or speech commands. Obviously, they are not convenient for paralyzed people perform these actions.

Advances in the neural network and human computer interaction technologies have caused concern to brain computer interface (BCI).[2] By employing BCI technology, human can use brain wave to interact with physical devices easily.

In this project, authors will make an Arduino robot car that controlled by human brain wave using the BCI technique. Arduino Mega is chosen because it is a low-cost microcontroller and it is more powerful than an Arduino UNO.[3] The human brain wave will be captured using a low-cost Neurosky mind wave headset.[4] The techniques used in this project can be further extended to a wheelchair for paralyzed people. The objective of this work is to implement an Arduino robot to simulate a brainwave-controlled wheelchair for paralyzed patients with an improved controlling method The outcomes of this project should fulfill all the following requirements. In terms of mobility, no any map or path need to be predefined and the robot should be able to move freely in anywhere under the control of the user. In terms of accuracy, a controlling method with at least 85% of accuracy should be adopted. In terms of safety, an immediate command should be provided to stop the robot immediately to avoid risks or danger.

In terms of cost-effective, the time cost of each controlling command selection should be less than 1 second. In terms of simplicity, the robot should provide a natural controlling method that does not require left blinking or right blinking.

II. LITERATURE SURVEY

In terms of mobility, this project provided a method that no any map or path need to be predefined. Although some other systems provided a simple controlling method, the usage of the wheelchair is limited to a specific environment because the system require the predefined paths.[6] If the environment changed, a new map is required to load into the system. In this project, the robot can move anywhere like a real wheelchair. The user can blink three times or more to stop or start the robot. And blink twice to start turning or stop turning. This is a simple controlling method that allows robots to move in any direction and not to rely on any

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predefined path. However, it is important to ensure the Bluetooth connection between different devices must be established and the strength should be stable. In terms of accuracy, this project provided a robot controlling method with around 85% accuracy on average, which is an acceptable performance. During the test, we found that the accuracy is relatively high in level 1 and level 2. The accuracy can reach 100%. However, start from level 4, the accuracy becomes lower. One possible reason behind is that we need to find a good path to hit the obstacle so that we can test the obstacle avoidance function. This abnormal motion may cause some confusion to the robot controller. And this situation may not happen in the real life as we will not want to hit the obstacle by using the wheelchair. Although the accuracy is getting lower from level 4, this method still provided 85% accuracy on average. In terms of safety, this project provided an immediate command to stop the robot to avoid the risk. Also, obstacle avoidance and autonomous terrain detection are included to enhance the safety. Some other similar systems require users to select a command to stop while the command selection time may take up to 7 second. Therefore, compare to other similar system, this project has a better performance in terms of safety as it provided an immediate command to stop the robot.[9, 17, 18]

In terms of cost-effective, all the controlling command of the robot are in real time. The user does not need to wait before sending any command. Also, all the commands are just simple blinking which can be sent by the user immediately.

Some other similar systems require users to spend a longtime to select a controlling command. And the commands are difficult to perform, for example, performing the motor imagery, keeping in a high attention and performing stress blinking.[6-7] This project provided a set of simple and effective command for the user to control the robot. Blinking three times or more means start or stop the robot, blinking twice means start or stop turning. These two simple commands can perform rapidly, so that the user can control the robot in real time. Therefore, compare to other similar system, the method used in this project is more cost-effective as it provided an immediate command to stop the robot. In terms of simplicity, this project provided a natural controlling method that does not require unnatural blinking (e.g. left blinking, right blinking, strong blinking, long blinking).The user can blink twice to turn and blink three times or more to stop. Also, as autonomous obstacle avoidance and autonomous terrain detection are included, the user can send less command to avoid the jerky blinking. Some other similar systems require users to avoid the obstacles manually. Considering the daily-life situation, there must be some static and dynamic obstacle in the street, the users may need to send a lot of command if they are required to avoid the obstacles manually. Therefore, the controlling method implemented in this project has included the autonomous obstacle avoidance and autonomous terrain detection function to reduce the frequency of sending the command. Overall, all the objectives of this project are met, which is a huge success in the development of mind-wave controlled robot.

III. IMPLEMENTATION

The system is formed by a Neurosky headset (EEG reader), a computer included MATLAB, and an Arduino robot car. The EEG reader contains a TGAM1 chip that can capture the human brain signal. TGAM1 also provided the signal filter and signal amplification. After that, the EEG signal will be digitized and sent to the Bluetooth transmission module (HC-06). Finally, the EEG signal will be transmitted to the computer for further analysis.

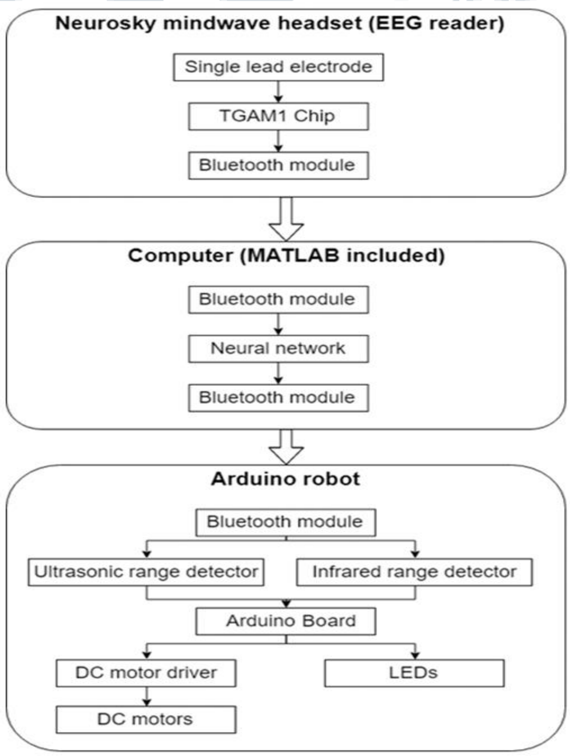

Figure 1. System architecture

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MATAB in the computer will be used for noise filtering. It will check whether the user is sending a robot controlling command, or the blinking are just natural blinking of human. If the blinking is belonging to a robot controlling command, MATLAB will also determine which command does the blinking representing. The Arduino robot car is consisting of 7 components.They are Arduino Mega, one Bluetooth HC-05 module, two DC motors, one L298N DC motor driver, five ultrasonic range detectors (SR-04), three infrared range sensors, and one LEDs board. When the Bluetooth HC-05 module received the controlling command from the computer, the Arduino board will consider the data received from the ultrasonic sensor and infrared sensor to make the final decision of the car movement. The ultrasonic sensors will detect the obstacles and avoid it automatically. The infrared sensors will detect the distance between the robot body and the ground to prevent falling from the stair. If the command from eye blinking is received, the robot will follow this command. Otherwise, maintain the motion in the last time step and run obstacle avoidance. And the LEDs will display the status of the controlling command .

Below is the flow chart showing how the system works..

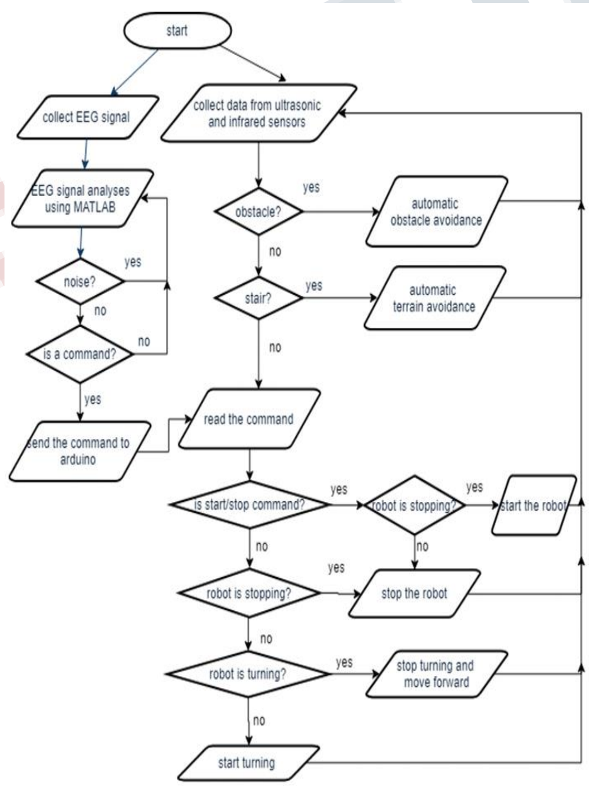

Figure 2. A descriptive flowchart

IV. EXPERIMENTAL RESULTS

Because of the safety issue, 5 ultrasonic sensors and 3 infrared sensors are added in the robot. The ultrasonic sensors in the front part of the robot will detect the obstacles. Each sensor will echo an ultrasonic wave with a time delay to avoid the wave-conflict problem. The infrared sensors are installed at the bottom part of the robot, they are used to detect the distance between the robot body and the ground to prevent falling from the stair (see Figure 3).By including autonomous obstacle avoidance, the motion can be modified and require less controlling command even the road has lots of obstacles. If the command from eye blinking is received, the robot will follow this command. Otherwise, maintain the motion in the last time step and run obstacle avoidance. In terms of performance, the car will become smoother in motion.

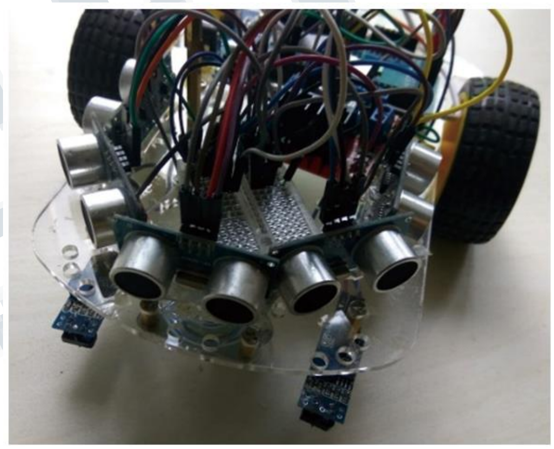

Figure 3. Ultrasonic sensors and infrared sensors

However, there are some limitations when adopting this method. First, it is impossible when user wants to get closer to the obstacle. Second, the robot will be totally out of control if one or more sensor has some unpredictable errors.Therefore, this method has been modified to enhance the performance. If the robot is moving forward, it will include the autonomous obstacle avoidance as mentioned before. However, when the robot is turning left or right, the autonomous obstacle avoidance function will not be used. By adopting the modified method, users are able to get closer to the obstacle as they may want. And users can control the robot by changing the direction even one or more sensors have an unexpected error. Therefore, both limitations are solved.

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By including autonomous terrain detection, the motion can be modified and prevent the robot falling from the stair. If the command from eye blinking is received, the robot will follow this command. Otherwise, maintain the motion in the last time step and run terrain detection.

The same method will be used as mentioned above. By adopting the modified method, users are able to get closer to the stair as they may want. And users can control the robot by changing the direction even one or more sensors have an unexpected error.

Accuracy and safety are the most important part of this project. In order to test the accuracy of the robot the following methods are used, and each method will be tested for three rounds. During the test, the number of correct command means the motion of the robot match the command sent by the user; the number of the wrong command means either: 1) The motion does not match the command. 2) The command is seen as noise. 3) Noise is seen as a command. The first test is focused on the autonomous terrain detection (see Figure 4). During the testing, the robot should detect the terrain and avoid falling from the stair. The testing criteria are to count the times of falling from the stair. In this test, a higher-level ground will be used to simulate the stair.

Figure 4. Autonomous terrain detection

The testing results are listed in Table 1.

Table 1. Testing results of autonomous terrain detection

Round	Number of times trying to fall from the high-level ground	Results	Accuracy
1	2	Both avoided	100%
2	2	Both avoided	100%
3	2	Both avoided	100%

During the test, the robot can avoid falling from stair successfully. When the sensors detected the distance between the robot body and the ground is too large, it will go back and turn to avoid falling from stairs. The next test is based on a simple rectangular map (see Figure4). During the testing, the robot should follow the rectangle drawn on the floor. The testing criteria are to count the times of incorrect command received. In this test, 5 checkpoints are labeled on the ground. The robot should reach each checkpoint in the order of: red, orange, yellow, green, and finally stop at blue.

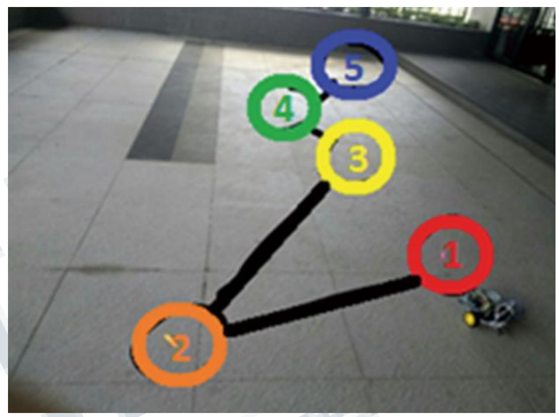

Figure 5. Test on a simple map

The testing results are listed in Table 2.

Table 2. Testing results of running on a simple map

Table 2. Testing results of running on a simple map

Round	The number of commands sent	Correct	Wrong	Accuracy
1	20	18	2	90%
2	19	18	1	94.7%
3	15	15	0	100%

During the test, the robot can pass through all the checkpoints successfully. Even sometime the robot may not recognize the user's command correctly, the user can send the command again to avoid the robot being derailed or directly stop the robot by blinking three times and more rapid. The stop command is the most sensitive and accurate command so that it can use to prevent the risk happen.

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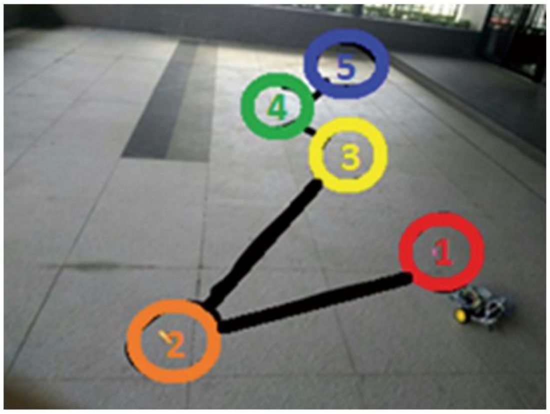

Figure 6. Test on an irregular map

The next test is based on an irregular map (see Figure 6) During the testing, the robot should follow the irregular path on the floor. The testing criteria is to count the times of incorrect command received. In this test, 5 checkpoints are labeled on the ground. The robot should reach each checkpoint in the order of: red, orange, yellow, green, and finally stop at blue.

The testing results are listed in Table 3.

Table 3. Testing results of running on an irregular map

Table 3. Testing results of running on an irregular map

Round	The number of commands sent	Correct	Wrong	Accuracy
1	22	20	2	90.9%
2	26	23	3	88.4%
3	20	18	2	90%

Same with the previous test, the robot can pass through all the checkpoints successfully. The accuracy is around 90%.

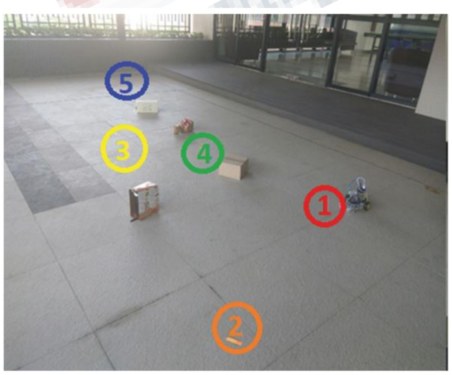

Figure 7. Static obstacle avoidance

The next test is focused on the static obstacle avoidance function

(see Figure 7). During the testing, the robot should reach all checkpoints and avoid the obstacle automatically, even the user is not sending any command. The testing criteria is to count the times of incorrect command received.

And counting the times of hitting the obstacle. In this test, 5 checkpoints are labeled on the ground. The robot should reach each checkpoint in the order of: red, orange, yellow, green, and finally stop at blue. Several static obstacles are placed on the path, the robot should avoid it automatically.

The testing results are listed in Table 4.

Table 4. Testing results of static obstacle avoidance

Table 4. Testing results of static obstacle avoidance

Round	The number of commands sent	Correct	Wrong	Accuracy	Obsta-cle hit
1	24	20	4	83.3%	0
2	25	22	3	88%	0
3	26	21	5	80.7%	0

Although the accuracy becomes lower in this test, the average accuracy can keep in around 85%, which is acceptable. One possible reason of the accuracy drop is that we need to find a good path to hit the obstacle, so we can test the obstacle avoidance function during the test. This abnormal motion may cause some confusion in terms of robot control.

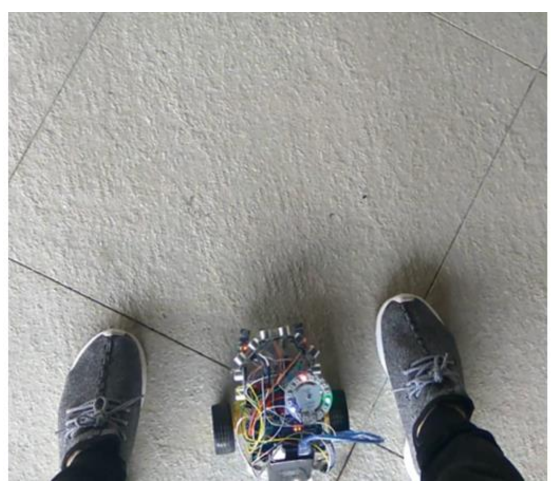

Figure 8. Dynamic obstacle avoidance

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The final testing is focused on the dynamic obstacle avoidance function (see Figure 8). During the test, the robot should avoid the dynamic obstacle automatically, even the user is not sending any command. The testing criteria is to count the times of hitting the obstacle.

The testing results are listed in Table 5.

Table 5. Testing results of dynamic obstacle avoidance

Round	Number of times of placing the obstacles	Impacted	Avoided	Accuracy
1	22	1	16	94.1%

Table 5. Testing results of dynamic obstacle avoidance During the test, the robot can avoid almost all dynamic obstacles successfully. The robot only impacted when the speed of the dynamic obstacle is faster than the speed of the robot.

V. CONCLUSION

The analysis and development of brain-controlled mobile robots have received an excellent deal of attention as a result of they'll facilitate bring quality back to folks with devastating contractile organ disorders and therefore improve their quality of life. During this paper, they tend to confer a comprehensive up-to-date review of the whole systems, key techniques, and analysis problems with brain-controlled mobile robots.

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