Development of a Smart Wheelchair with Dual Functions: Real-time Control and Automated Guide

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***Abstract*—Wheelchairs are devices used for mobility by people whose walking is difficult or impossible, due to illness or disability. There are many types of wheelchairs, including basic, light-weight, folding, multi-function, special types, and so on. Each of them has its advantages and disadvantages. Development of brain-computer interface applications has become quite popular in recent year. It allows direct communication between brain and computer. One type of the communication is by imagination. By analyzing the EEG signals under imagination, different features could be calculated to transform into instructions for the control of back-end robotic device. Since brain-computer interface allows users to control the instruments without the need of physical input, it may be suitable for patients with physical defects or limb weakness. Therefore, this study aimed to design a smart wheelchair which has real-time control and automated guided functions. We based on the advantages of simple and rapid construction in LabVIEW to develop the smart wheelchair. This system was able to control our own-made wheelchair model with dual functions. In the real-time control function, our results show that the average accuracy of the imagination to the left was 70% and the average accuracy of the imagination to the right was 60%. In the automated guided function, our results tested in small-area (20m * 20m in space) shows that wheelchair could move along the pre-setting path. In the future, we want to improve the whole system and make this prototype wheelchair more practical as using a real wheelchair instead of a wheelchair model. We hope to make this functional wheelchair more humane, so that the wheelchair is not only comfortable and safe but also has multiple functions to improve patient's quality of life and reduce the burden of care from their families.**

Keywords-EEG; Emotiv; real-time control; automated guide; wheelchair

I. INTRODUCTION

Wheelchairs are for the use of mobility impaired people. Most of them apply to older people with reduced mobility, imperfect limbs, weakness, muscle atrophy, stroke, and other symptoms. Since those people cannot control their body to walk, they need a wheelchair to move. Today there are many types of wheelchairs, including basic, lightweight, folding, multi-function, special types, and so on. When talking about control types, current common wheelchairs can be divided into manual wheelchairs and electric wheelchairs. However, those traditional wheelchair and electric wheelchair are not always suitable for every requirement of limb disabilities. Manual wheelchairs have the most general control way. Their advantages are the simple structure, easy maintenance, and low price, whereas their disadvantages are not available for upper limb amputees, inefficient in the mechanical drive, difficult for common physical disabilities to use, and easily lead to accumulation of upper limb injury after prolonged use, such as shoulder pain, carpal tunnel syndrome. To overcome that issue, the electric wheelchair should be the next consideration. Joystick control dominates in that field. Although it is more convenient and easy to use, the paraplegias and upper limb disabilities may have the same problem to operate electronic devices. Hence, in addition to traditional manual wheelchairs and electric wheelchairs, developments of other control methods come in a wide variety of formats to meet the specific needs of their users. For some upper limb inconvenience and no upper limb people who cannot control the wheelchair by own hand, the brain-control approach could be an option. Therefore, this study aimed to design a smart wheelchair which has real-time control and automated guided functions. In the real-time control, wheelchair movement was controlled by imagination (i.e., to simply imagine "left" or "right" to control wheelchair movement). In the automated guide, we used GPS to locate the position of the wheelchair and let the wheelchair follow a setting path to the specific destination. In that case, patients with upper limb disorders could handle wheelchairs conveniently by themselves. They could move to somewhere by using their brain waves or automatically move to a specific destination by pre-setting path in a navigation interface with locations on the Google map. This system provided an alternative choice of method for the people whom unable to control their hands to operate the wheelchair. It would bring them at least two advantages: flexibility, to manually operate the wheelchair and convenience, saving their time and energy to operate the wheelchair. Moreover, we hope the smart system will be able to be implemented

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into other applications in the future, such as for the disabled person to control the home appliances. In that way, a smart environment which may benefit the society in many ways will be available one day.

II. METHOD

A. Signal Acquisition

We used a 14-channel dry electrode EEG Emotiv EPOC (Fig. 1(a)) to measure our subject's EEG signals. The signals went through an embedded 16 bits analog-to-digital converter with a sampling frequency of 128Hz and transferred to a computer by wireless manner (2.4GHz). Figure 1(b) shows the electrode position of Emotiv.

Before the start of each experiment, a database of individual brain waves was constructed. We then captured brainwave signals as imagining to the right / left. The system would compare these two data to determine the direction of the current imagination.

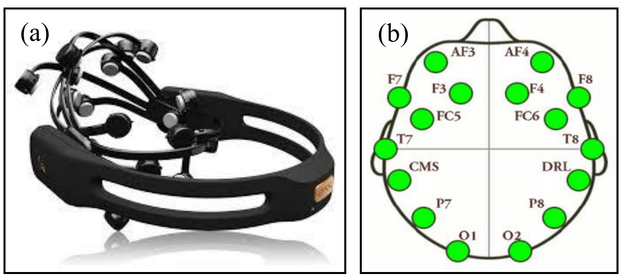

Figure 1. (a) Outward of the Emotiv EPOC EEG
(b) Emotiv electrode positions in the 10-20 system.

B. Experiment Procedure

Fig. 2 is our experimental flow chart. The process begins at the Home page. There were three items, real-time control, automated guide, and end, to be chosen (Fig. 3). After choosing real-time control or automated guide, steps must go back to the home page to end the program.

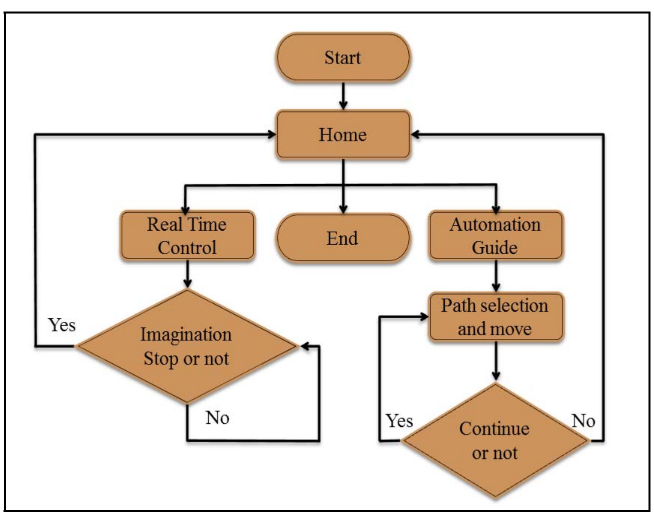

Figure.2 Experimental Flow Chart

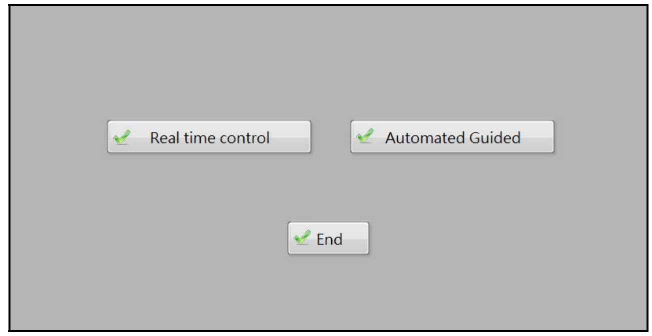

Figure 3. User interface of Home page

- Real-time control mode

When selecting the real-time control mode, the user could use his mind to change the orientation of wheelchair. The wheelchair was designed to go straight with a constant speed of 40 centimeters per second. That means even though the user did not think anything (i.e., left or right), the wheelchair would still go forward. Figure 4 shows the imaginary user interface. The first panel is in the neutral state. The second and third ones are imagination of left and right, respectively. Because of individual differences, we collected EEG signals from the presetting using EPOC. Firstly, the user wore Emotiv and relaxed, not to think anything for eight seconds. Then he imagined left and right each eight seconds, and rested thirty seconds between each record. It total lasted 84 seconds. After that, the user would be asked to take advantage of gyroscopes in Emotiv to control the mouse cursor, with a blink of a second as a click on the button.

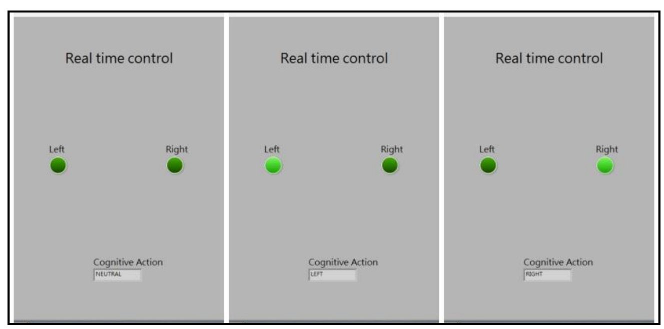

Figure 4. User Interface in imagination

- Automated guided mode

When selecting the automated guided mode, detail steps were described as followings: (1) Automated guided interface (Fig. 5(a)) appeared after selecting this mode. User's current location on the Google map was automatically searched by GPS. (2) By clicking one of the three buttons marked with pre-planning destinations, the map would show the identified path and the destination (Fig. 5(b)). Then the wheelchair started to move along the path. (3) When the wheelchair arrived at the destination, a dialog would pop-up and asks whether to continue the automated guide (Fig. 5(c)). If the user chose "yes", he could click one of the three buttons marked with pre-planning destinations (Fig. 5(d)); otherwise, it would go back to the home page. The selectable place name of destinations would be changed which was depended on the current location.

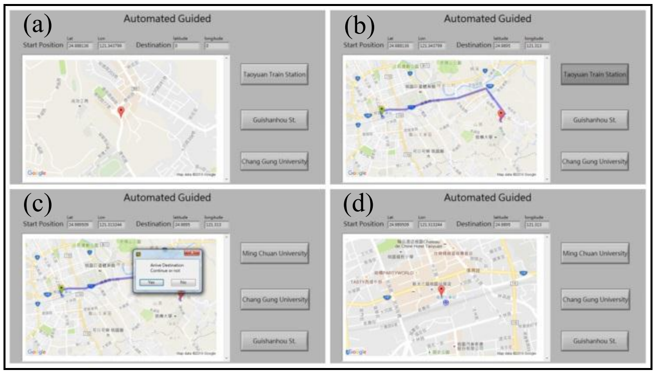

Figure 5. Automated Guided user interface

No matter choosing which function, during the movement, the user could click on ‘Home’ button or grit the teeth to stop the wheelchair immediately.

C. Wheelchair model

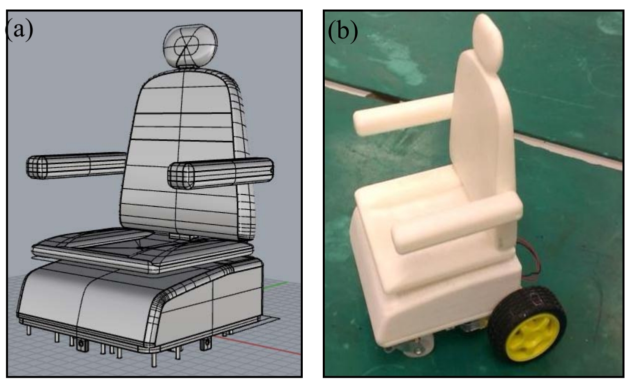

Figure 6. (a) 3D Wheelchair design (b) Wheelchair model

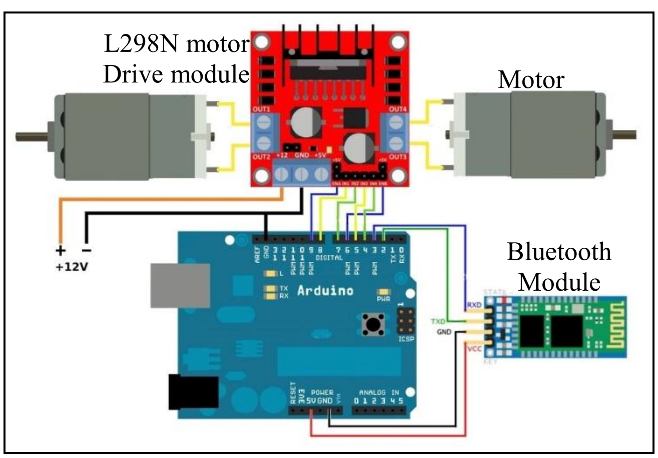

Figure 7. Drive system

In order to test the feasibility of our smart system, we made a small wheelchair. Wheelchair production was based on the rhinoceros program to draw 3D prints (Fig. 6(a)). We used the 3D printing technique to make a wheelchair model (Fig. 6(b)) and put the drive system (Fig. 7) in the bottom of the wheelchair box. LabVIEW program connected to Arduino in the drive system with Bluetooth. Through the instruction output by LabVIEW, the L298N module drove the motor to rotate the wheels for steering control and automatic guidance.

III. Result and Discussion

We have developed a smart wheelchair with dual functions based on the advantages of simple and rapid construction in LabVIEW. The real-time control function could use a simple imagination to control the wheelchair for left or right movements (Fig. 8). The automated guide function could set a destination and move the wheelchair to approach it by automatic driving. At present, this system was able to control our own-made wheelchair model. Test results were described as followings:

- Real-time control:

Each subject was tested for ten times. The results show that the average accuracy of the imagination to the left was 70% and the average accuracy of the imagination to the right was 60%. They all did not reach the expected target 80%. The reasons may be due to the lack of concentration during single training (i.e., construction of the database) and the poor electrode-skin contact of Emotiv. Those cause impure and interfered brainwave signals. In the future, we consider several times of imaginary training and re-check the status of the electrodes before testing in order to improve the accuracy.

- Automated guide:

The results in small-area test (20m * 20m in space) show that wheelchair could move along the pre-setting path. Test with GPS was still in process. Because the positioning of GPS has a certain error range (about 10 to 15 meters), we may need a larger space to practice actually. In the future, additional protections will be added on the wheelchair (e.g., placing ultrasonic radar). When an obstacle is detected within a limited range (e.g., 5 to 10 cm), the wheelchair will slow down and stop. A warning sound will be emitted until the obstacle is removed. Further, in the case of an emergency, the user can immediately take over the control priority to make sure of his security.

The purpose of this study was to construct a prototype of smart wheelchair system. In the future, we hope to make this functional wheelchair more humane, so that the wheelchair is not only comfortable and safe but also has multiple functions to improve patient’s quality of life and reduce the burden of care from their families.

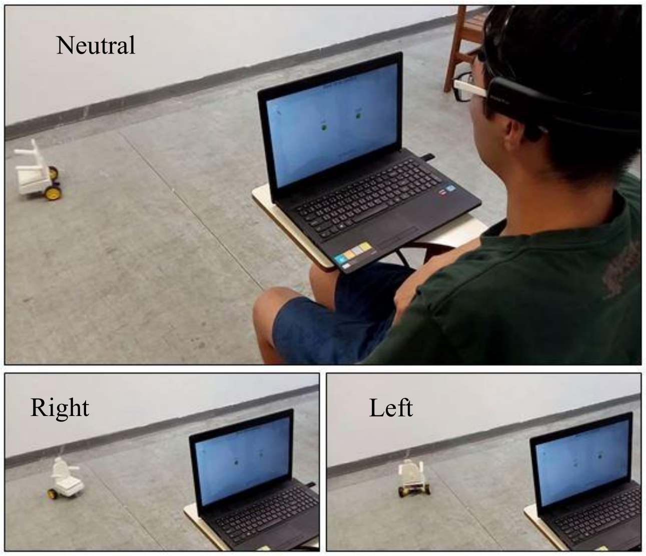

Figure 8. Real-time control wheelchair

ACKNOWLEDGEMENTS

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