ICIC Express Letters
Volume **12**, Number **11**, November **2018**
ICIC International ©2018 ISSN 1881-803X
pp. **1171–1175**

DESIGN AND ALGORITHM FOR ELECTRIC WHEELCHAIR USING VOICE RECOGNITION AND JOYSTICK

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Received April 2018; accepted July 2018

Abstract. *The incorporation of suitable technologies became an increasingly important element of wheelchair design. This paper proposes an innovative technology and design which enables patient to control electric wheelchair's movement using voice recognition and joystick. In this paper, we described the design of low-cost and robust wheelchair and then presented the evaluation of the system. Voice recognition module can control the wheelchair to move forward, left, right and stop, and in addition, there is the reverse mode in the joystick module. Next, the speaker dependent module is applied to wheelchair control systems by training the voice recognition module. The controller system is based on Arduino and combined with high current driver motor with gearbox and two batteries for power systems. The accuracy of the detection using speaker independent (SI) pre-programmed commands is 72.5% and user-defined speaker dependent is 85%. Furthermore, the accuracy using joystick is 100%.*

Keywords: Wheelchair, Voice recognition, Joystick, Disabled person

1. **Introduction.** More than one billion persons in the world have some form of disability that needs assistive robotics technology for solving it. Recently, assistive devices can be found in many human environment, both in public and private environment. Wheelchairs are an essential assistive device for many individuals with injury or disability. Manual wheelchairs provide a relatively low-cost solution for the individual mobility needs. Manual wheelchair mostly moved by turning both rear wheels back and forth depending on the direction. This type of wheelchair is exhaustive for its users and cannot be used for those with impaired hands. While the needs of many individuals with disabilities can be satisfied with manual wheelchairs, a segment of the disabled community finds that it is difficult or impossible to use manual wheelchairs independently [1]. To solve this problem, there is electric wheelchair, which includes one of the assistive robotics technologies. There are complex wheelchairs, which use robotic technologies to extend the capabilities of manual wheelchairs by introducing control and navigational intelligence [2]. Nevertheless, the complex wheelchairs are not suitable for many disabled people, because of the complexity of its use and their higher price. In this research, we would like to design the low-cost and robust controller to control the electric wheelchairs.

Children with physical disabilities may not be able to move independently and thus can delay their development of cognitive and psychosocial skills. Tefft et al. [3] have shown that the children can benefit substantially from access to an independent mobility facility especially with a wheelchair. Furthermore, many people with mobility impairments need an appropriate manual wheelchair, but in case of aged persons and children with quadriplegia, spinal cord injuries (SCI) and amputation, it requires electric wheelchair

DOI: 10.24507/icicel.12.11.1171

rather than the manual wheelchair. To solve the different needs of disabled persons, there are many ideas focusing on advanced technologies in the literature. Yayan et al. [4] built location-based applications based on Android platform for indoor navigation. The applications can guide the disabled person to move only in indoor environments. Another study [5] developed a multimodal control strategy based on 3D joystick and EMG bio signals to make the wheelchair more convenient and easy to use. The EMG based controller is not robust and relatively expensive to be implemented in real use. On the other hand, Avutu et al. [6] focus on developing low-cost electric-powered wheelchair by employing mechanical lever and gear box system.

Our research would like to combine the two approaches in order to develop low-cost, but robust electric wheelchair. Robust, in here, means the controller can deal with uncertain parameters or disturbances. In this paper, we present our research that successfully builds an electric wheelchair based on modification of the manual wheelchair by adding controller and motor, but its manual function is still maintained. Similar to [5], our design used a multimodal control strategy based on joystick and voice recognition, instead of EMG-based controller. Figure 1 shows our wheelchair named as Ratanggalih. It was low-cost because the cost of modification from the manual wheelchair is not more than $500.

Figure 1. Electric wheelchair named as Ratanggalih

The remainder of this paper is composed as follows. First we discuss the problem statement in Section 2, then followed by the proposed method, in Section 3. In Section 4, we discuss the main result in our experiments. Finally, we summarize our work with notes on future research in Section 5.

2. **Problem Statement and Preliminaries.** Manual wheelchair is difficult to be handled; thus, electric wheelchair is a good solution for disabled person. One of the promising solutions is the use of electric wheelchair. There are many controller types of electric wheelchair such as an advanced one by using EEG [7-9]. Nevertheless, there is main weakness of this controller, that is, it is not robust to signal disturbances. In our previous research, we successfully developed the EEG-based wheelchair [10] and the problem is the same, the controller is not robust to the noise of the signal. In here, we would like to design the low-cost, but robust controller based on joystick and voice recognition for our wheelchair. It should have speech recognition capability, and as addition, a joystick for manual operation. Thus, our systems are designed with a module of voice recognition and one joystick as shown in Figure 1. Speech recognition is divided into two processing categories: speaker dependent and speaker independent. In order to achieve

a smooth movement, we control the speed of wheelchair using pulse width modulation (PWM). PWM is a great method of controlling the amount of power delivered to DC motor without dissipating any wasted power.

3. **Proposed Method.** We modify our previous research [6] by changing EEG with combination between joystick and voice recognition systems as shown in Figure 2. We use two batteries as a DC motor power source of wheelchair capable of handling patients with long-term use. Based on block diagram of the system, we proposed an efficient and simple algorithm for the electric wheelchair as shown in Algorithm 1. First, program will detect the mode (voice or joystick) and then detect the obstacle in front of the wheelchair. The distance sensor is able to measure distance between 3-300 cm. If there is no obstacle, then wheelchair may move forward or move based on the patients' commands.

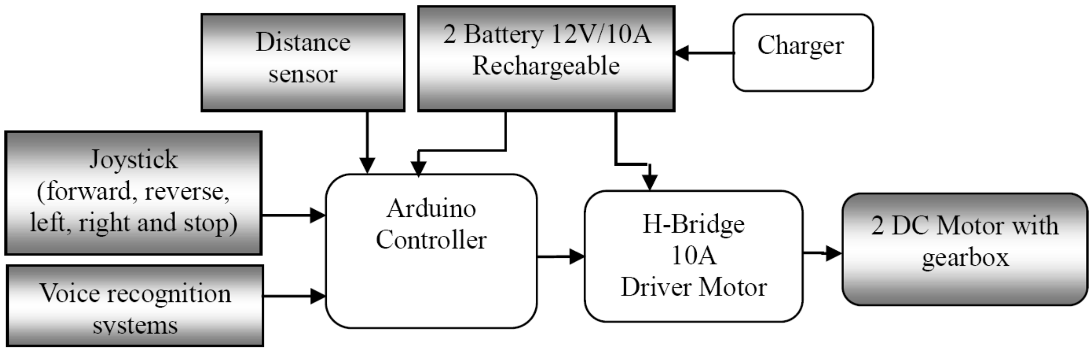

FIGURE 2. Block diagram of electric wheelchair

Algorithm 1. Algorithm of the electric wheelchair using joystick and voice recognition systems

```
declare variables
setup serial connection
forward(PWM value)
left(PWM value)
right(PWM value)
reverse(PWM value)
do
    input mode
    if mode=joystick then
    read joystick (analog x, analog y)
    if distance>20cm then
        if (x>400 && y>400) then
            motorStop()                  //standby
        if (x>900 && y>400) then
            forward(value)               //forward
        if (x>400 && y>900) then
            right(value)                 //turn right
        if (yPosition==0 && xPosition>400) then
            left(value)                  //turn left
        if (xPosition==0 && yPosition>400)
            reverse(value)               //reverse
        if (buttonState==0)
            motorStop()                  //stop
    else
    motorStop()                          /stop
```

```
    end if
  if mode==voice then
  accept input
  if distance>20cm then
      if (input=stop) then
          motorStop()                  //standby
      if (input=forward) then
          forward(value)               //forward
      if (input==right) then
          right(value)                 //turn right
      if (input==left) then
          left(value)                  //turn left
    else
    motorStop()                        //stop
    end if
  loop
```

4. **Main Results.** The comparative experiment with users that attempt ten times for each command based on speaker independent and dependent and using joystick. The average result of the experiments is shown in Table 1. Speaker dependent systems are trained by the user's voice that will use in the recognizer system. These systems can achieve a high accuracy for word recognition comparing the speaker independent system. From Table 1, we can conclude that the distance between user and the microphone is very important, with the best result being about 10 cm. In our experiments, controlling wheelchair using joystick is very robust to any disturbances. This is the most common approach employed in most applications. The demo video of the Ratanggalih electric wheelchair can be seen at [11].

Table 1. Accuracy between voice and joystick

Action	**Voice Recognition Systems**				**Joystick**
	Speaker Independent		**Speaker Dependent**		
	10cm	***20cm***	***10cm***	***20cm***	
Forward	70%	70%	90%	70%	100%
Left	70%	70%	90%	80%	100%
Right	80%	80%	80%	80%	100%
Reverse	–	–	–	–	100%
Stop	70%	60%	80%	70%	100%
Average	**72.5%**	**70%**	**85%**	**75%**	**100%**

5. **Conclusions.** Based on the experimental result, controlling wheelchair using voice and joystick is easy and applicable. The accuracy of the detection using speaker independent (SI) pre-programmed commands is about 72.5% and user-defined speaker dependent is 85%. Furthermore, the accuracy using joystick is 100%. We had extensive testing performed to ensure design integrity. Wheelchairs have the potential to provide increased freedom to disabled persons in real applications. Possible further research would also include using advanced machine learning algorithm to increase accuracy of voice recognition.

Acknowledgment. This work is fully supported by Bina Nusantara University.

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