Original Article

Voice and Head Controlled Intelligent Wheelchair

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Abstract:

Introduction: *The quadriplegia patients have multiple handicaps. A novel medical device that can help them move or mobile the anywhere by themselves would give the positive quality of life for rehabilitation.* ***Objective:*** *To design a voice and head controlled electric power wheelchair (EPW) for rehabilitation. A novel medical device activates the control system for quadriplegics with voice, head and neck mobility.* ***Methods:*** *Head movement has been used as a control interface for people with motor impairments in a range of applications. Acquiring measurements from the module is simplified through a synchronous a motor. Axis measures the two directions namely x and y. At the same time, patients can control the motorized wheelchair using voice signals (forward, backward, turn left, turn right and stop) given by itself. The model of a dc motor is considered as a speed control by selection of a PID parameters using genetic algorithm.* ***Results:*** *An experimental set-up constructed, which consists of microcontroller as controller, a dc motor driven EPW and feedback elements. And this paper is tuning methods of parameter for a pulse width modulation (PWM) control system. A speed controller has been designed successfully for closed loop of the dc motor so that the motor runs very closed to the reference speed and angle.* ***Conclusion:*** *Intelligent wheelchair can be used to ensure the person's voice and head are attending the direction of travel asserted by a conventional, direction and speed control.*

Keywords: ● *Wheelchair* ● *Quadriplegia* ● *Rehabilitation* ● *Medical devices* ● *Speed control*

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นิพนธ์ต้นฉบับ

รถเข็นไฟฟ้าอัจฉริยะ ควบคุมด้วยเสียงและศีรษะ

เดชฤทธิ์ มณีธรรม
สาขาวิศวกรรมเมคคาทรอนิกส์ คณะครุศาสตร์อุตสาหกรรม มหาวิทยาลัยเทคโนโลยีราชมงคลธัญบุรี

บทคัดย่อ

บทนำ *ผู้ป่วยที่บาดเจ็บไขสันหลังระดับสูงจะไม่สามารถเคลื่อนไหวแขนและขาได้ (Quadriplegia) การที่มีอุปกรณ์สำหรับช่วยการเคลื่อนไหวโดยผู้ป่วยเป็นผู้ใช้อวัยวะส่วนที่ยังสามารถใช้การได้ควบคุมการเคลื่อนไหวด้วยตนเองจะทำให้เพิ่มผลบวกด้านการฟื้นฟูจิตใจและคุณภาพชีวิตได้* ***วัตถุประสงค์*** *คือออกแบบนวัตกรรมการควบคุมรถเข็นไฟฟ้าด้วยการออกเสียงและการควบคุมด้วยศีรษะ รถเข็นไฟฟ้า หรือ เครื่องมือแพทย์ชนิดนี้จะสามารถใช้เสียงหรือควบคุมด้วยศีรษะสำหรับผู้ป่วยพิการที่มีการบาดเจ็บของไขสันหลังระดับสูง ที่ไม่สามารถเคลื่อนไหวแขนและขาได้เลย (Quadriplegia)* ***วิธีการ*** *สำหรับการควบคุมด้วยศีรษะเป็นการควบคุมผ่านตัวผู้ป่วยเพื่อให้ดีซีมอเตอร์ (DC Motor) ทำงาน การรับการตรวจวัดจากโมดูลจะส่งผ่านดีซีมอเตอร์ให้ทำงานสัมพันธ์กัน การตรวจวัดจะวัดแนวแกนสองทิศทางคือ x และ y ในขณะเดียวกันผู้ป่วยสามารถควบคุมรถเข็นไฟฟ้าด้วยสัญญาณเสียง เช่น เดินหน้า ถอยหลัง เลี้ยวซ้าย เลี้ยวขวาและหยุด ที่สามารถกำหนดด้วยตัวเอง รูปแบบของดีซีมอเตอร์ ถือเป็นการควบคุมความเร็วโดยการเลือกพารามิเตอร์จากพีไอดี (PID) จากสมการออกอลิทึม* ***ผลการศึกษา*** *การขับเคลื่อนรถเข็นไฟฟ้านี้จะประกอบไปด้วยไมโครคอนโทรลเลอร์เป็นตัวควบคุมและส่งสัญญาณไปขับเคลื่อนดีซีมอเตอร์และในระบบจะส่งค่าสัญญาณป้อนกลับ โดยสามารถปรับค่าพารามิเตอร์ของสัญญาณกว้างของพัลส์วิทโมดูลเลชั่น (PWM) ระบบการควบคุมความเร็วได้รับการออกแบบสำหรับการควบคุมความเร็วของดีซีมอเตอร์และมุมในการเคลื่อนที่ได้* ***สรุป*** *ระบบอัจฉริยะของรถเข็นคนพิการสามารถควบคุมได้ทั้งเสียงและควบคุมด้วยศีรษะ โดยสามารถควบคุมได้ทั้งทิศทางและความเร็วของรถเข็นไฟฟ้า*

คำสำคัญ: *● รถเข็น ● ผู้ป่วยบาดเจ็บไขสันหลัง ● การฟื้นฟูสภาพร่างกาย ● เครื่องมือแพทย์ ● การควบคุมความเร็ว*

เวชสารแพทย์ทหารบก 2559;69:177-84.

Introduction

The quadriplegia patients have multiple handicaps. A novel medical device that can help them move or mobile the anywhere by themselves would give the positive quality of life for rehabilitation.

According to wheelchair, EPW give mobility to people who cannot walk. Knowing basic information about the types, accessibility, leans and safe use of wheelchairs is important[1-5]. Many prototypes of a wheelchair were developed in the research laboratories. Thus, EPW make up a significant portion of the mobility assistive devices in use today for the motor disabled and patients in recovery. The main goal of our project is to help the quadriplegic patients to move independently from one place to another by the tilt movement of their head which in turn moves his wheel chair without the assistance of another person. The head controlled wheelchair is designed such that the wheelchair moves in accordance with the movement of the patient's head. To approach the motion control problem of an EPW with a dc motor control. The direct current (DC) motor has been widely used in industry. As a result, speed control of DC motor has attracted considerable research and several methods have evolved. Proportional-integral-derivative (PID) controllers have been widely used for speed control of DC motor[6-11]. The results obtained indicate that PID techniques can be used to classify head movements sufficiently quickly and accurately to be used in a practical interface. The provision of graphical real-time feedback then benefit for particular cases and EPW can provide to the higher system also.

Some of the most significant developments in a wheelchair are in the speed control. The actual speed sometimes cannot follow the instruction speed as given from the electric wheelchair. As the same time, right or left wheel usually do not run in the same speed and angle and command also is issued by a different void and head movement, therefore head movements are needed for controlling the wheelchair. It may cause disorientation of the wheelchair[1,2,6]. The purpose of this paper is to discuss on how to achieve the best control performance of a wheelchair. In section 2, the discussion focuses on mathematical model and the conceptual design of a PID controller. In section 3, hardware design and experimental results separated by PWM, and speed control. Overall, the paper is concluded in section 4.

Figure 1 Royal Thai Army equipped with the EPW voice and head control system

I. DC Motor Mathematics Model and the Control Theory

A. DC motor mathematics model

The current in the field coil and the armature are independent of one another. As a result, these motors have excellent speed and position control. Hence DC shunt motors are typically used applications that require five or more horse power. The equations describing the dynamic behavior of the DC motor are given below.

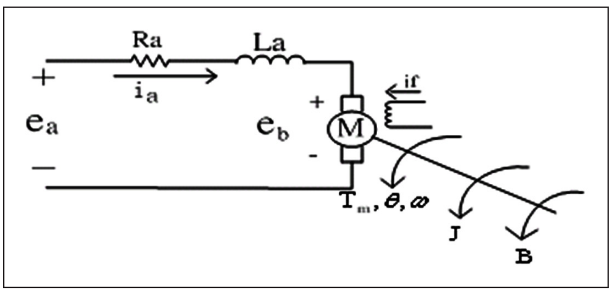


Figure 2 DC motor using the armature voltage control method

Where, R_a = the armature resistance, L_a = the armature inductance, i_a = the armature current, i_f : the field current, e_a : the input voltage, e_b : the back electromotive force (EMF), t_m : the motor torque, ω : an angular velocity of rotor, J : rotating inertial measurement of motor bearing, B : a damping coefficient. Because the back EMF is proportional to speed ω directly, then

$$e_b(t) = K_b \frac{d\theta(t)}{dt} = K_b \omega(t) \quad (1)$$

Making use of the KCL voltage law can get

$$e_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t) \quad (2)$$

From Newton law, the motor torque can obtain

$$T_m(t) = J\frac{d^2\theta(t)}{dt^2} + B\frac{d\theta}{dt} = K_T i_a(t) \quad (3)$$

Take (1), (2), and (3) into Laplace transform respectively, the equations can be formulated as follows:

$$E_a(s) = (R_a + L_a s) I_a(s) + E_b(s) \quad (4)$$

$$E_b(s) = K_b \Omega(s) \quad (5)$$

$$T_m(s) = B\Omega(s) + Js\Omega(s) = K_T I_a(s) \quad (6)$$

Figure 3 describes the dc motor armature control system function block diagram from equations (1) to (6).

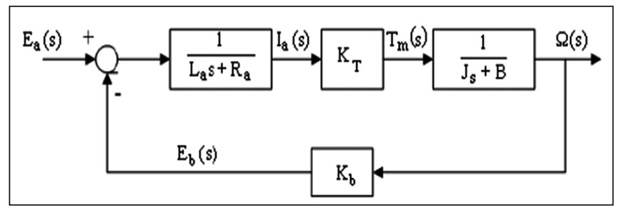


Figure 3 Function block diagram of DC motor

The transfer function of dc motor speed with respect to the input voltage can be written as follows:

$$G(s) = \frac{\Omega(s)}{E_a(s)} = \frac{K_T}{(L_a s + R_a)(Js + B) + K_b K_T} \quad (7)$$

From equation (7) the armature inductance is very small in practices, hence, the transfer function of DC motor speed to the input voltage can be simplified as follows,

$$\frac{\Omega(s)}{E_a(s)} = \frac{K_m}{\tau s + 1} \quad (8)$$

Where $K_m = \dfrac{K_T}{R_a B + K_b K_T}$ is a motor gain

$\tau = \dfrac{R_a J}{R_a B + K_b K_T}$ is the motor time constant

B. PID Control

The PID controller includes a proportional term, integral term and derivative term. The PID controller is mainly to adjust an appropriate proportional gain *KP*, integral gain *KI*, and differential gain (*KD*) to achieve the optimal control performance The relationship between the input *e*(*t*) and output *u*(*t*) can be formulated in the following,

$$u(t) = K_P.e(t) + K_I.\int_0^t e(t)dt + K_D\frac{de(t)}{dt} \quad (9)$$

The transfer function is expressed as follows,

$$C(s) = \frac{U(s)}{E(s)} = K_P + \frac{K_I}{s} + K_D s \quad (10)$$

The closed loop transfer function of DC motor speed control system expresses as follows,

$$G(s)=\frac{\Omega(s)}{R(s)}=\frac{\left(K_P+\frac{K_I}{s}K_Ds\right)\frac{K_m}{1+\tau s}}{1+\left(K_P+\frac{K_I}{s}+K_Ds\right)\frac{K_m}{1+\tau s}}$$

$$=\frac{(K_Ds^2+K_Ps+K_I)K_m}{(K_DK_m+\tau)s^2+(1+K_PK_m)s+K_IK_m} \qquad (11)$$

II. Hardware Design and Dexperimental Results

A. System Design

In this research designed the control system of an EPW for the disabled. The overall structure of the assist system that is composed of sensor design, the electronic module and the mechanical module. The Sensor design comprises of Tri-axis Accelerometer and signal conditioning unit. The electronic module has a Arduino ATmega32u4 and the mechanical module consists of a driver IC and motors. The system composes of 24 volt and 250 watt dc motor. The system design is shown in Figure 4.

B. Running experiment in the head movements

Effects of active head movements about the pitch, roll, or yaw axes. Active head movements about the pitch axis, forwards or backwards, produced significant the angle 0-5 degree suppression. Pitch forward head movements exerted the strongest effect. Active head movements about the roll axis towards the right also produced significant the angle 0-5 degree suppression. Yaw left movement after rightward drum rotation significantly enhanced with turn on and turn off but if head movements move the all angle more than 5 degree then EPW will move all direction. (Figure 5-8)

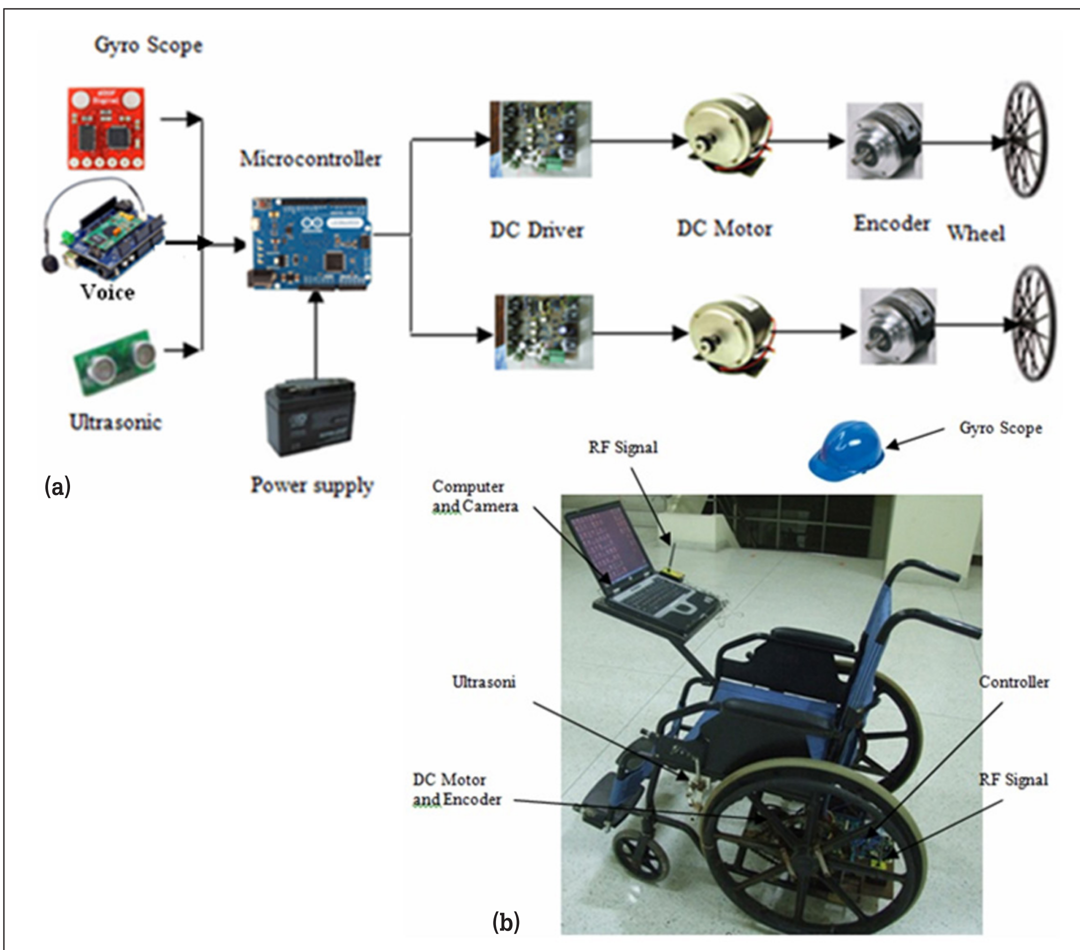
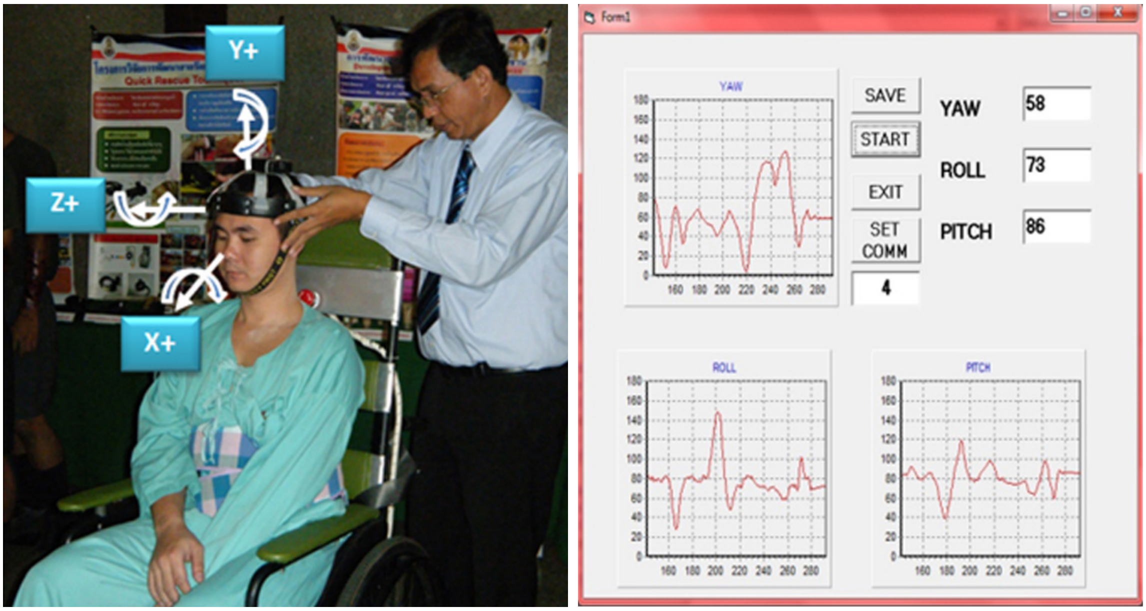


Figure 4 The system design **(a)** Schematic Diagram of EPW **(b)** Electric Power Wheelchair



(a) (b)

Figure 5 (a) Active head movements the pitch, roll, yaw axes. (b) A sensors response via visual basic program

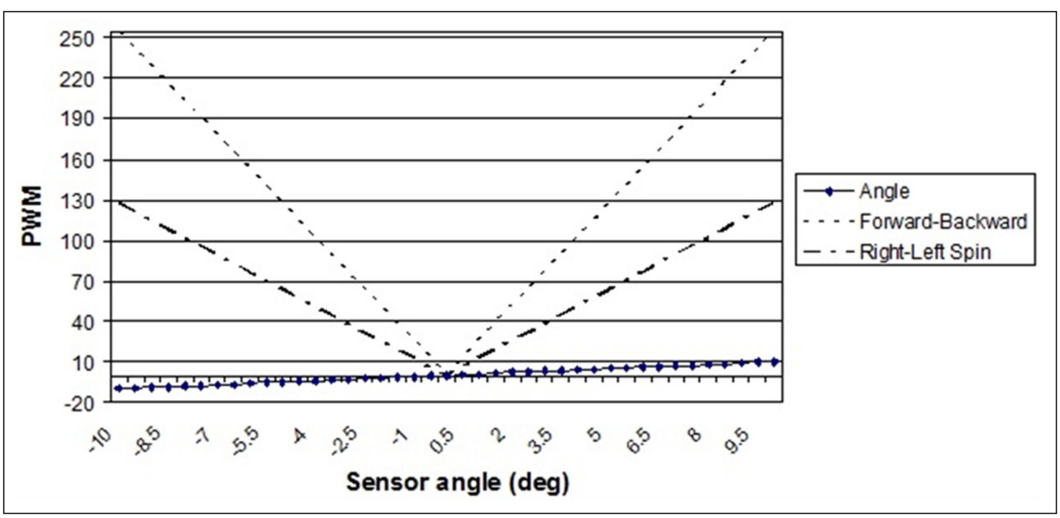


Figure 6 Gyroscope oscillations according to the head movements

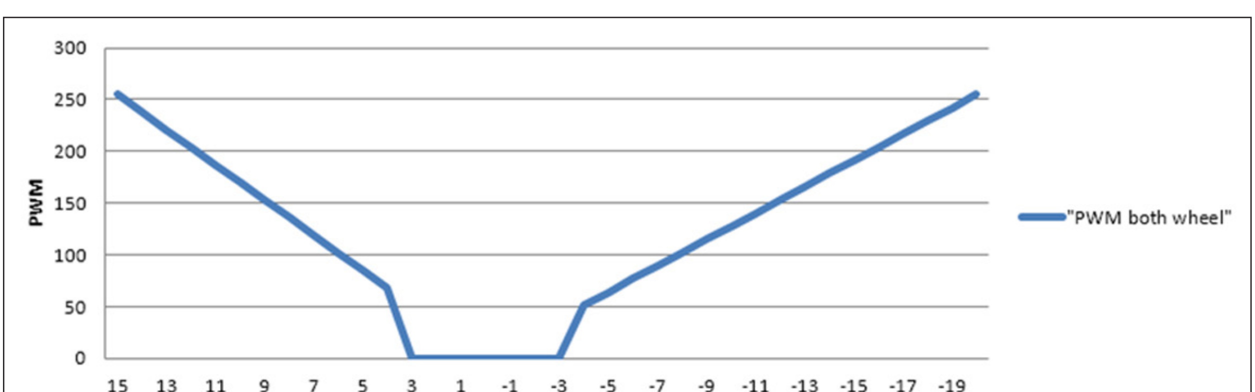


Figure 7 PWM and angle with both wheels

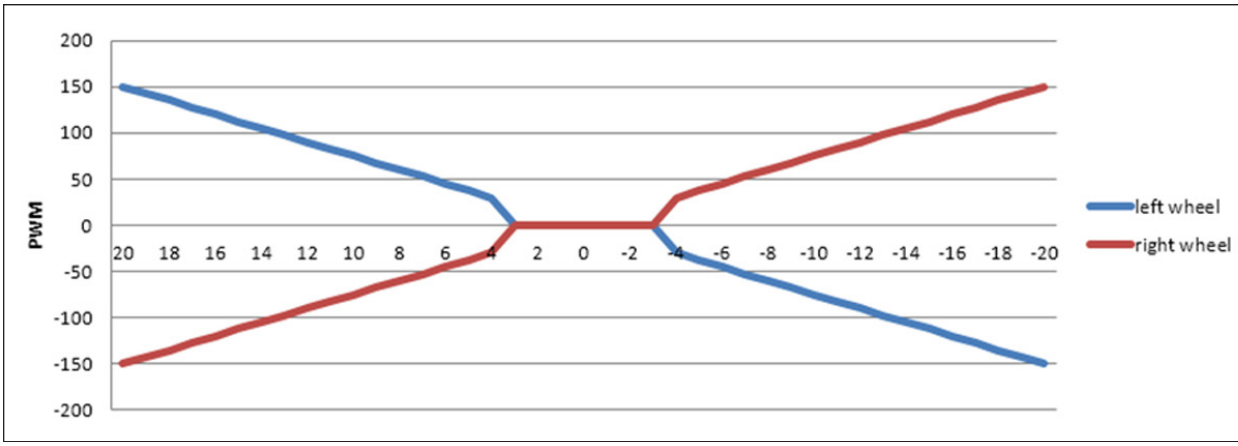


Figure 8 PWM and angle with left and right wheel

Table 1 Experiment in various environments

Commands	Noa	Nos	Pos
Room silent	20	20	100
Room with people talk (low tone)	20	14	70
Room with people talk (high tone)	20	4	20
Outdoor silent	20	20	100
Outdoor with people (low tone)	20	17	85
Outdoor with people (high tone)	20	11	55

*Noa = Number of Attempts; Nos = Number of Success; Pos = Percentage of Success

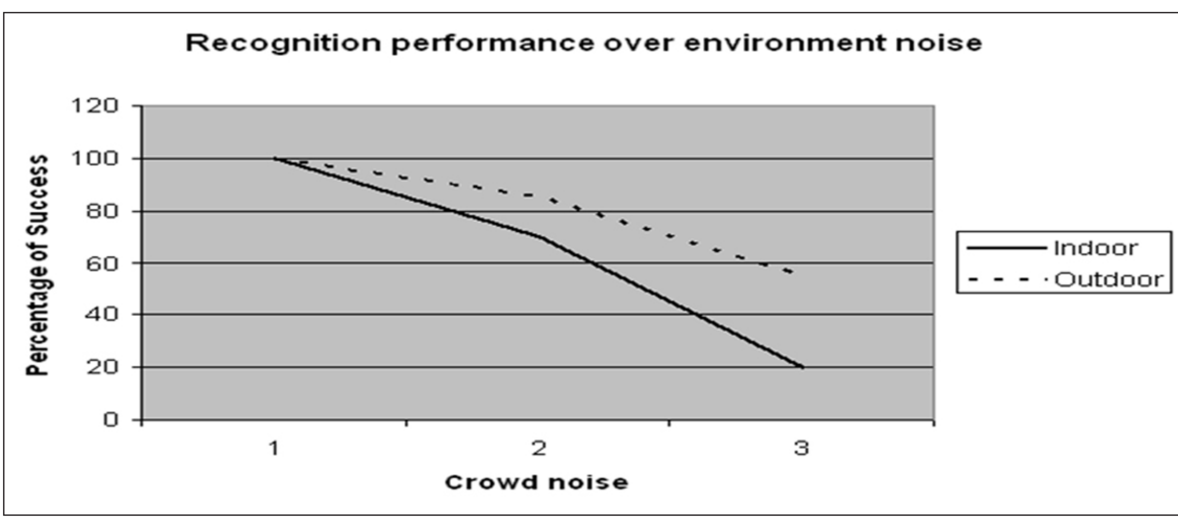


Figure 9 Recognition performance over environment noise

C. Running experiment in the voice control

The experiment speech recognition test with 20 armies and to evaluate recognition performance of voice control. The target words are five reaction commands and six verification commands as shown in table below. (Table 1) (Figure 9)

Conclusion

The searches performed in Figure 6-7. Show that the psychological condition of the patient greatly influences his ability to control and Figure 8-9 show that the PWM and angle used to classify head movements of the EPW. The turning angles of the head are determined by constants nevertheless, as shown in Figure 6, the graphical user interface of this control mode provides the facility of changing the thresholds for left, right, up and down head movements at execution time, as well as the EPW and then we can conclude that the PID controller can control the speed of an EPW well. The simulation of a dc motor was done using the software package visual basic. Figure 9 The simulator can determine exactly how to speech is necessary from the user to properly operate the system. There were some voice of the indoor and outdoor in the recording environment in the circumference. The percentage of the outdoor is better than indoor. At the results, we obtain successful recognition rates of 70% and 20% of indoor with low and high tone and percentage of indoor with low and high tone of 80% and 55%, respectively. The wheelchair used in the experiment was a dc direct drive. The wheelchair allows each user to set maximum speed. Overall, a speed controller has been designed successfully for closed loop operation of a dc motor and the motor runs very closed to the reference speed and the authors became fully confident that the wheelchair was a practical means for independent transport for the test user

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