INTELLIGENT CONTROL SYSTEM OF A WHEELCHAIR FOR PEOPLE WITH QUADRIPLEGIA PARALYSIS

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(Received: 14th Feb 2019; Accepted: 29th April 2019; Published on-line: 1st June 2019)

https://doi.org/10.31436/iiumej.v20i1.909

ABSTRACT: Our system proposes a wheelchair controlled by head gestures for people with quadriplegia paralysis (QP) or for those suffering from amputation of their hands and legs during the war in Iraq. The wheelchair design has an intelligent control that works with the movement of a patient‘s head in order to enable the patient to drive the wheelchair in the desired direction. The system consists of two main parts. The first is the transmitter in which sensing signals are transmitted to the second part and it consists of a 3-axes accelerometer (ADXL-345), a 433 MHz RF wireless receiver transmitter module, and Arduino UNO. The ADXL-345 sensor is placed in front of a hat that the patient wears. The system detects the direction of the patient's head movement then sends appropriate instructions to the wheelchair’s control part (receiving part). The receiving part is the wheelchair control system that consists of a 433 MHz RF wireless receiver transmitter module and an Arduino UNO. The Arduino processes the signals coming from the first part and moves the wheelchair accordingly in the desired direction. The research also provides an obstacle avoidance system with a range of 50 cm that prevents the wheelchair from colliding with objects. The head movement angles have been selected to be 40, 35 degree for vertical and horizontal movement respectively so that the QP patient feels comfortable to tilt his head in all directions and control the wheelchair easily. The system provides a very effective performance and accuracy.

ABSTRAK: Sistem ini bergantung kepada kerusi roda yang dikawal menggunakan isyarat kepala untuk mereka yang lumpuh kuadriplegia (QP) ataupun mereka yang dipotong tangan dan kaki semasa perang di Iraq. Ia merupakan reka bentuk pintar pada kerusi roda dan pesakit boleh mengawal pergerakan mereka dengan isyarat pada kepala. Sistem ini terdiri daripada dua bahagian utama iaitu yang pertama merupakan pemancar yang menghantar isyarat gerakan ke bahagian kedua dan ianya terdiri daripada 3 axis accelerometer (ADXL-345), modul penerima isyarat pemancar tanpa wayar 433 MHz RF dan Arduino UNO. Sensor ADXL-345 ini diletakkan di bahagian depan topi yang dipakai oleh pesakit. Sistem ini mengesan arah gerakan kepala pesakit dan kemudiannya arahan dihantar ke bahagian pengendali kerusi roda (bahagian penerimaan isyarat). Bahagian ini merupakan sistem pengendalian kerusi roda yang terdiri daripada modul pemancar penerimaan tanpa wayar 433 MHz RF dan Arduino UNO. Arduino memproses isyarat yang datang dari bahagian pertama bagi menggerakkan kerusi roda ke arah yang dikehendaki. Kajian ini turut menyediakan sistem mengelak halangan pada jarak 50 cm bagi menjauhi kerusi roda daripada melanggar objek. Sudut gerakan kepala telah dipilih pada 40, 35 darjah bagi gerakan menegak dan mendatar masing-masing, supaya pesakit

QP merasa selesa bagi mengerakkan kepalanya ke semua arah dan mengawal kerusi roda dengan mudah. Sistem ini juga sangat cekap dan tepat dalam mengawal arah.

KEYWORDS: *head gesture recognition; quadriplegia paralysis; wheelchair controlling*

1. INTRODUCTION

At present, many people suffer from physical disability as a result of wars and diseases; therefore, there is a need for advanced support devices with high safety to help individuals navigate easily. Intelligent wheelchairs have been developed to assist disabled and injured people. These wheelchairs are supported by some techniques to enhance performance and efficiency [1,2]. The continuity in research has led to important developments in the design of supporting devices for people who are injured, wounded, or affected by some cases of paralysis. This research includes many techniques to drive wheelchairs such as joysticks, voice recognition, hand gestures, and cameras. [3,4]. The work in this paper presents intelligent control of wheelchairs for people suffering from quadriplegia paralysis (QP) or for people who suffer from amputation of their hands and legs. The subsequent paragraphs are some research regarding the field of wheelchair control techniques.

In 2014, Warad et al. described a motorized wheelchair for handicapped humans utilizing a speech control technique and flex sensing application. The system permits a disabled person to drive the wheelchair using voice recognition including voice commands for movement (forward, backward, and stop) and for speed control of motors (maximum, medium, and minimum). The flex sensor is used to control the wheelchair direction (left and right) [5]. Chitte et al. developed a wheelchair control system for disabled persons with hand gesture sensing. The system is divided into a gesture part and a wheelchair part. Depending on the direction of the accelerometer sensor that is fixed on the hand, the ARM7 controller gives orders to move the wheelchair to the desired direction. In case of emergency, an SMS message alert is sent via GSM to the family of the person [3]. Suchitra and Brinda implemented a hand gesture system to drive and control a car utilizing a 3-axes accelerometer sensor (MEMS Sensor). The sensor is placed on the user's finger and the car moves in four directions according to the hand movement. The Arduino UNO microcontroller is used to control and monitor the comprehensive performance of the system [6].

Saharia et al. introduced a joystick control wheelchair for Disabled people. The wheelchair movement was controlled by a joystick. The command of movement was done by utilizing the joystick and then transmitting the order to the Arduino microcontroller that processes the command. After that, the controller transmits a digital signal to the motor driver circuit to control wheelchair movement [7]. Sainath et al. considered hand gestures for controlling and driving a wheelchair. The sensing circuit included an accelerometer that translates the hand tilting into pitch and roll. The system is implemented based on a microcontroller that receives the tilting data from the sensor, processes it, and then transforms it into digital signals for the motors that drive the wheelchair [8].

In some cases of disabilities, the above techniques are useless because of their limitations. A wheelchair controlled by a joystick or hand gesture does not fully achieve the requirements of individuals who are suffering from Parkinson's paralysis, quadriplegia paralysis, or weakness in their hands because they cannot properly control their wheelchairs [9]. Additionally, the wheelchair controlled by voice instructions provides services for people who cannot use hands and legs to drive the wheelchair, but it is not suitable for people who have speech difficulties [10,11].

The limitations in the previous works can be overcome using the technique used in this work, which is suitable for multiple cases of disabilities such as quadriplegia paralysis, Parkinson's paralysis, speech difficulties, amputation in hands and legs. The work includes an intelligent control technique based on head gestures. In addition, it provides an obstacle avoidance system.

2. PROPOSED SYSTEM DESIGN

The proposed system is designed to help people with quadriplegia where they can only move their head or people suffering from amputation of their hands and legs. The accelerometer sensor is placed in front of the patient's hat. It is used to detect the movement of the patient's head, then the Arduino sends appropriate instruction of digital bits via an RF-transmitter. The transmitting part of the proposed system is shown in Fig. 1.

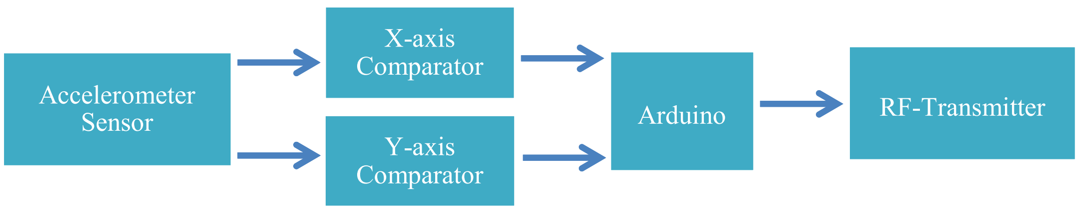

Fig. 1: Transmitter part of the proposed system (hat part).

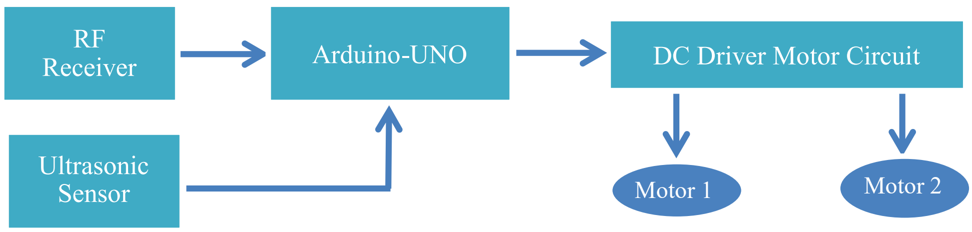

Fig. 2: Receiving part of the proposed system (wheelchair part).

The signal is received at the other end by the RF-receiver and is analyzed by the Arduino. The Arduino gives an order to the motor driver circuit to control the wheelchair motors and to move the wheelchair in the desired direction according to the direction of movement of the patient's head. Figure 2 illustrates the block diagram of the receiving part.

The patient wears the hat on his head to drive and control the wheelchair. In case of forward head motion, the wheelchair moves forward, while it moves backward when the head rotates in the back direction as in Fig. 3. When the patient moves his head to the right side, the wheelchair moves to the right and vice versa for the left direction as illustrated in Fig. 4. An ultrasound-sensor is placed in the back of the wheelchair to detect obstacles behind the wheelchair in the case of rotating the head backward. The sensor detects the obstacles on a range up to 50 cm then the Arduino holds the wheelchair back moving to avoid collision with obstacles. Figure 5 illustrates a wheelchair model pictures including the ultrasonic-sensor.

Fig. 3: Pictures show cases of patient head movement (forward and backward).

Fig. 4: Pictures show cases of patient head movement (left and right).

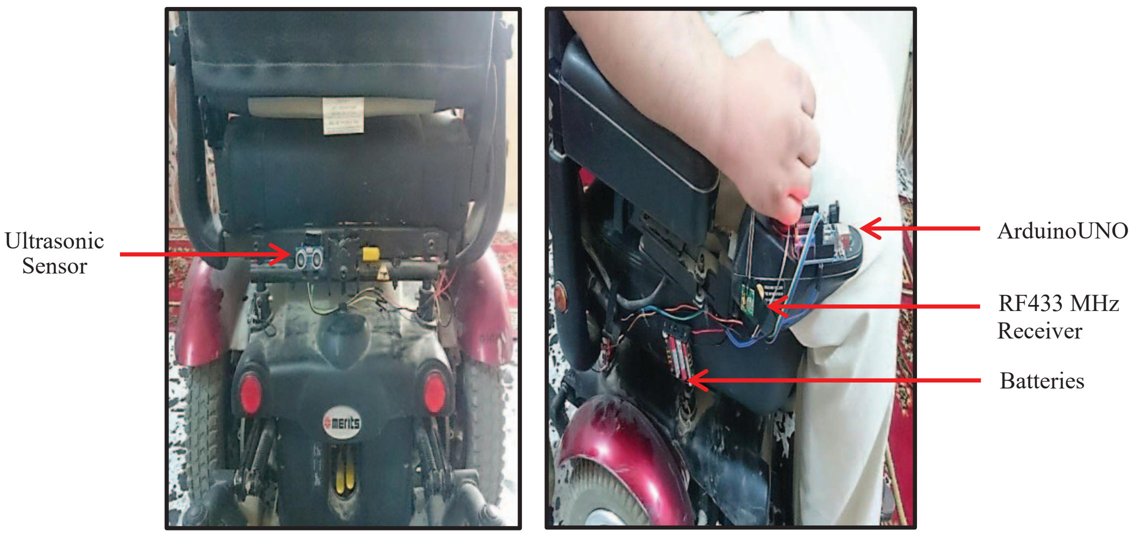

Fig. 5: Pictures of side and back of the wheelchair.

The programming code is written then uploaded to the Arduino UNO board to be programmed. Figure 6 shows the practical system of the block diagram which is explained in Fig. 3. It shows the patient's hat including accelerometer sensors (ADXL345), Arduino UNO, and RF433 MHz transmitter. Figure 7 shows the flowchart of the overall system. At first, we make a suitable configuration for the motors, accelerometer, and ultrasonic systems, then we connect them to the Arduino pins. The readings of the x and y axes of the accelerometer are monitored to choose proper angles of head movement. Then, the wheelchair moves in a direction that is compatible with the desired x and y axes values.

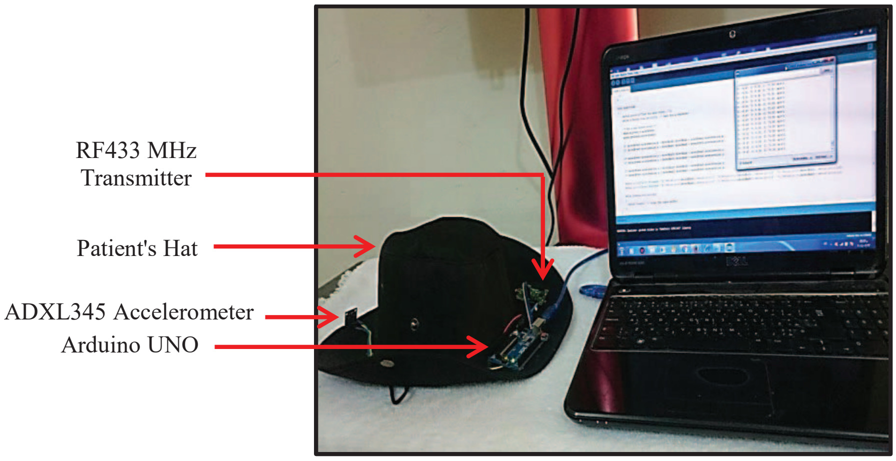

Fig. 6: Picture of practical transmitting system.

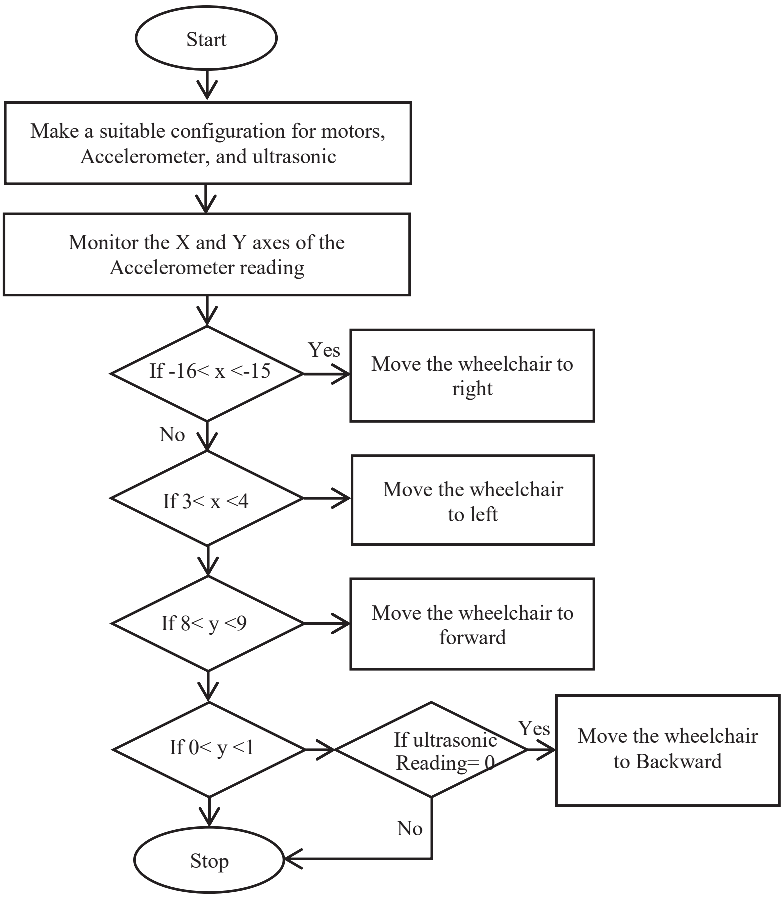

Fig. 7: Flow-chart of proposed system.

3. RESULTS AND DISCUSSION

The proposed system is based on the use of two Arduino UNO boards and an accelerometer for hardware implementation of intelligent wheelchair control by head gestures for people with QP. The software and hardware results show that the system operates very well to help the patients and gives accurate results.

The system is set and calibrated so that the QP patient can properly control the wheelchair. The patient wears the hat and moves his head in each direction to choose an appropriate angle of his head movement. The horizontal angles (right and left) have been selected to be 35 degrees, as shown in Fig. 8. These angles allow the QP patient to move his head in all directions to some extent, and provides comfortable conditions for the patient without moving the wheelchair.

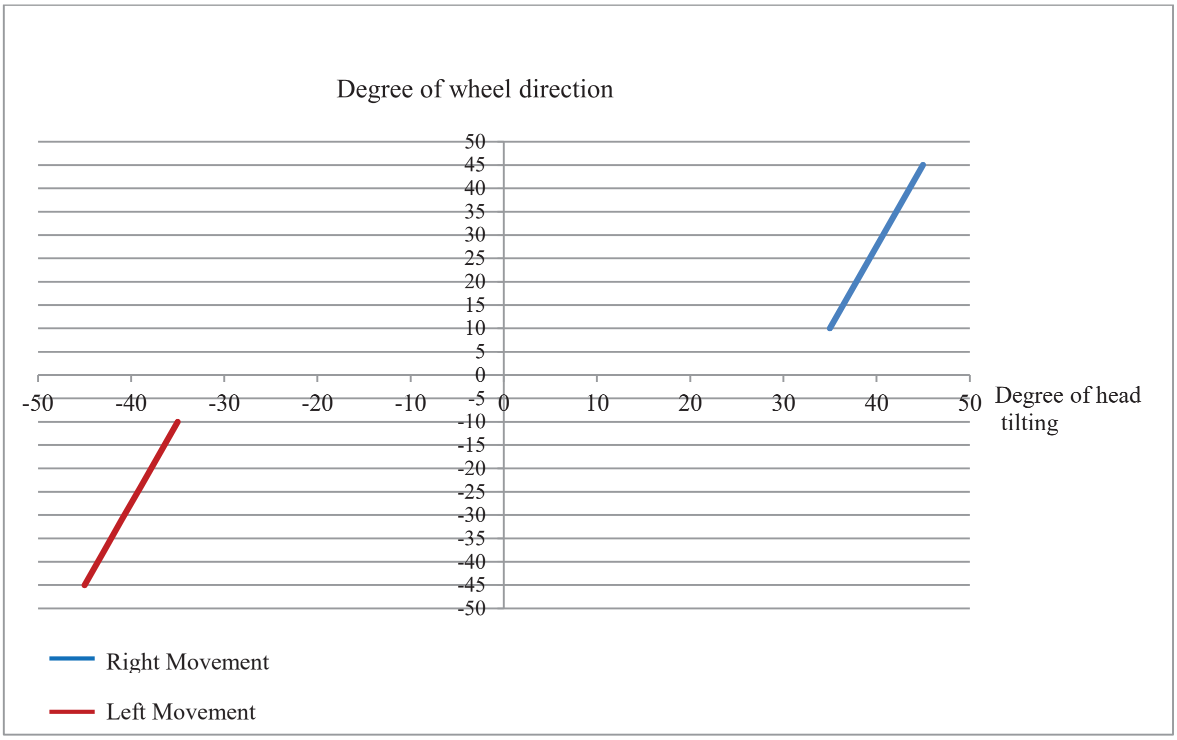

Fig. 8: Graph of degree of wheelchair direction versus horizontal head tilting degree.

The vertical angles (forward and backward) have been selected to be 40 degrees as shown in Fig. 9. The vertical and horizontal angles can be modified to be appropriate to many QP patient cases. Figure 10 illustrates the x and y axes sensor readings that represent the horizontal and the vertical head tilting respectively, where the shaded areas act the corresponding wheelchair movement. When the patient moves his head to the left or the right, then the reading of x-axis of the accelerometer sensor changed gradually and when he moves his head forward or backward, then the reading of y-axis of the accelerometer sensor changes. It is worth mentioning that when the head is in a straight position, the sensor readings are about -6 for x-axis and 4.5 for y axis.

Table 1 displays the wheelchair performance accuracy which is calculated after several trials of movement in all directions. For each direction, 50 trials were made to test the wheelchair movement; the successful movements were as described in the table. The performance accuracy was calculated by dividing the successful movements in each direction on the number of trials for the same direction. After calculating the accuracy for each direction, the average performance accuracy was calculated to be about 97.5%.

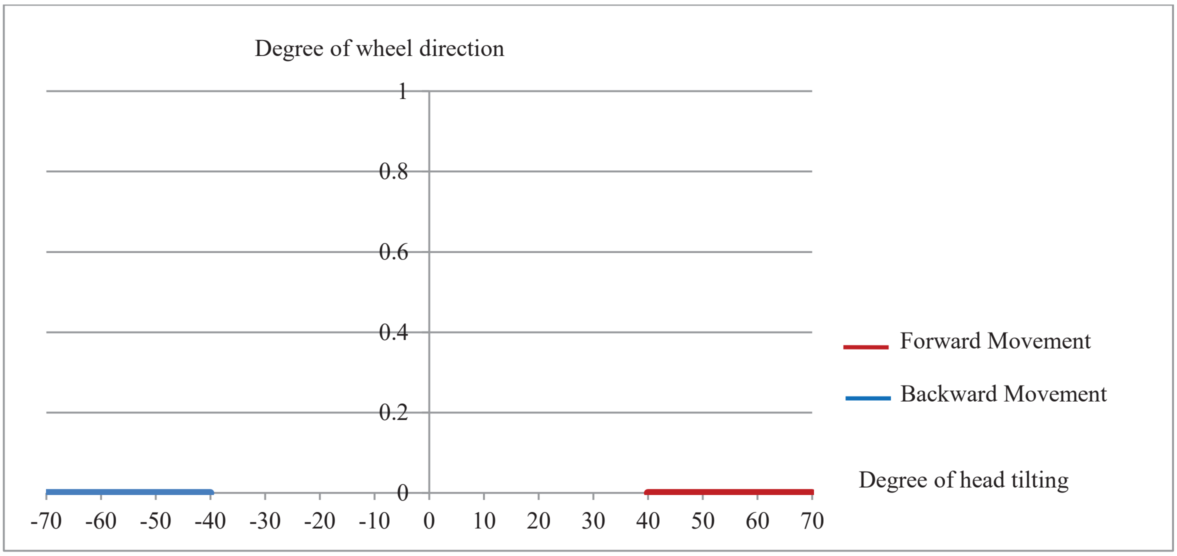

Fig. 9: Graph of degree of wheelchair direction versus vertical head tilting degree.

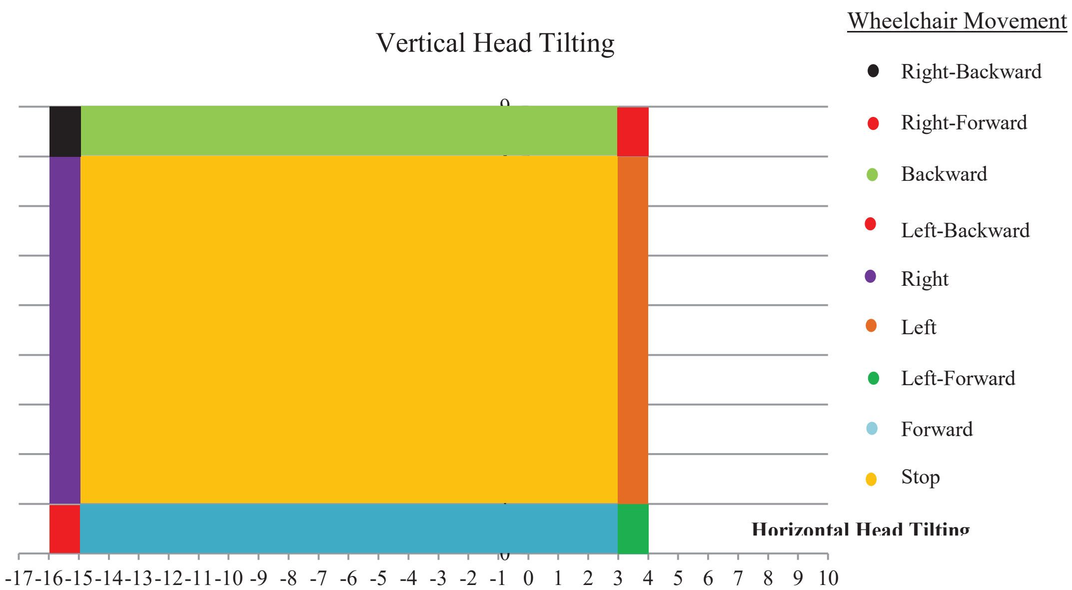

Fig. 10: Head tilting angles and their wheelchair movement response.

Table 1: system performance accuracy

Movement	Trials number	Successful Outcomes	Accuracy
Forward	50	50	100%
Backward	50	47	94%
Right	50	49	98%
Left	50	49	98%
Average accuracy : 97.5%			

4. CONCLUSION

The proposed control system has been successfully designed and implemented to move the wheelchair in four directions or to stay in same position based on a patient's head tilting. This work is useful to support people with QP or disabled people by providing alternative means to control the wheelchair by the movement of the head. The system also provides a safety mechanism to prevent collision on a range of 50 cm in case of backward movement of the wheelchair. The system has a very effective performance and high accuracy, which is about 97.5%.

ACKNOWLEDGMENTS

The researchers thank the wounded officer in the Iraqi Army (Ahmed Hamza) who drove the wheelchair easily.

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