Control Of Wheel Chair For Quadriplegia Patients: Design A Bioremotecontrol

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Abstract

This project includes the design procedures of remote-controlled system which appeals to quadriplegics who cannot move the parts below their neck due to the damage of spinal cord injuries. There is a big increase in the number of patients with spinal cord injuries nowadays. This kind of injuries can cause permanent handicaps. Paraplegic patients with spinal cord injuries can remote their wheeled-chairs with their hands but it is not the same for quadriplegics. They cannot move only their lower parts but also their upper ones and that is why they cannot get out of bed and move from one place to another one. They will be able to move their wheeled-chairs to the forward or back, right or left due to the design which is formed with the corporation of doctor and engineer .They will be able to remote their chairs with their head movements and their life will be conformed both physically and psychologically. In this project head movement is detected with micromachined accelometer. The numeric data gained is analyzed with the help of microcontroller. Commands are transformed in the form of wireless RF communication system. The performance practice of the project is designed with an electric motor vehicle, which is prepared as a prototype.

1. Introduction

Spinal cord injury (SCI) increases day by day. Quadriplegia, hemiplegia, or paraplegia emerges as a result of SCI. Patients has to use wheelchair when they have SCIs. There are a lot of types of wheelchair that are used in cases of hemiplegia and paraplegia. Patients having these diseases are capable of steering the wheelchair by using their hands and thus can mostly use the wheelchair without the need for an attendant. However, patients with quadriplegia cannot move the part of their body that is below the neck. As a result, they cannot use a vehicle on their own. That affects patients negatively in psychological terms [1].

It is difficult to heal SCIs by their very nature. They are really challenging with their functional and social results. Statistics indicate that 12,000 new SCI cases occur in the USA every year. SCIs are common among young adults, and the average age for it is 31 (40.2 to 28.7) [2]. In the injuries, the distribution of phenomena is as follows: 30.1% for incomplete tetraplegia; 25.6% for complete paraplegia; 20.4% for complete tetraplegia; and 18.5% for incomplete paraplegia [2]. Research shows that neuropathic pain frequency is 64 to 83% among patients with SCI [2].

Patients describe their pain experience as severe pain (11-94%) and excruciating pain (18-63%) [2].

Pain emerging after SCI is classified as pain over the injury level (musculoskeletal), pain at the injury level (neuropathic), and pain below the injury level (neuropathic).

Research indicates that among patients, 83.2% of pain is below the injury level, and 50% is at the injury level [3]. In terms of pain and symptom profile, there are 3 types of pain: aching and throbbing pain; penetrating pain; and burning pain, electric shock, and tingling pain [4].

A study dealing with the social and medical problems confronted by SCI patients discharged from hospital demonstrates that while the percentage of patients in the labor was 63% before the injury, it went down to 5% after the injury [5]. A research carried out in Japan found the percentage of adaptation to the working life after the injury to be 30% [6]. Job is as important as physical, social, and psychological well-being for people with SCI just like healthy individuals [7].

A study exploring the life quality of patients with SCI in Sweden shows that 80% of patients ae engaged in a good job and education after the injury [8]. A study conducted in the USA indicates that majority of the patients with SCI complete their education after the injury and return to their gainful jobs [9]. A study done in Italy reports that patients with SCI are negatively affected in terms of professional status and income [10]. A study exploring the social situation of 173 patients with SCI in Romania reveals that 60% of patients spend most of their time in bed, and only a small amount of individuals with SCI have a chance to make a change in their lives. Another study reports that 55% of quadriplegic patients and 64% of paraplegic patients complain about upper extremity pain [11]. Research shows that 27% of patients complain about high anxiety, fractiousness, aggression, and angriness [5]. Another study demonstrates that the percentage of depression symptoms is 37.1% [12]. As it is clear from statistical data, hemiplegia, quadriplegia, and paraplegia, which emerge as a result of spinal cord injuries, are very serious diseases that have a negative effect on quality of life. Also, they negatively affect the psychology of patients.

There are tongue, jaw, and head movement-controlled devices for patients with quadriplegia in the world, and a lot of academic and sectoral research has been conducted in this field.

Taylor and Nguyen (2003) focused on the performance of head movement interface for wheelchair [13]. Another study on the steering of wheelchair by head movements was carried out by Ramirez et al. (2012) [14].

In 2013, Kim et al. completed their design of a tongue-controlled wheelchair for SCI patients [15]. Odle et al. (2011) introduced their work on the development of OpenSim™ shoulder model in the control of wheelchair for tetraplegic patients [16]. Menon et al. (2013) developed a tongue-controlled wheelchair system [17]. However, it is thought that tongue-controlled devices lead to oral infections in the long term. Also, these devices are not preferred as they constrain such functions of patients while using the vehicle as speaking and attention. Jaw-controlled systems constrain the fields of view of patients and cause arthritis in the long term [18]. Head-controlled devices currently available in the sector are quite expensive.

Given the features and costs of the devices available in the sector, it is aimed to design a more cost-effective biocontrol system. This design provides quadriplegic patients with a lot of technological conveniences. The patients using this system will be able to go to the places they want on their own and will not depend on an attendant continuously.

The living standards of patients who cannot use their neck and the part of their body below the neck will be raised thanks to the economical and innovative biocontrol wheelchair that is steered by head movements. They will no longer need an attendant to accompany them. As distinct from the existing systems in this field, the system can detect head movements through accelerometer technology and generate a response swiftly. Thus, a system which is similar to the systems controlling the wheelchair manually but can be controlled fast is introduced.

2. Material and Methods

When devices produced for quadriplegic patients are considered, it is seen that jaw-controlled devices lead to arthritis; tongue-controlled devices bring about oral infections; and voice-controlled devices involve problems about receiving commands in noisy environments. Therefore, use of head movements in giving commands was deemed appropriate in this study. The basic operating logic of the system must be understood for circuit to be designed. For that reason, basic working principle was determined before circuit algorithm was formed (Figure 1).

An accelerometer sensor to detect head movements was selected for the designed system. Head location information received from the selected analog accelerator sensor is digitalized through analog/digital converter unit in microcontroller, and prototype vehicle is directed based on such location information.

RF Receiver/Transmitter unit was used in the system for patients to control their vehicles more easily. Another feature of the system is that the patient has the option of activating or deactivating his/her vehicle. As a result, while the patient is using his/her vehicle in activated status, s/he can deactivate it whenever s/he wants. In this way, s/he will not have to limit his/her head movements. Furthermore, a calibration unit was designed which will take the present head position of the patient as long as s/he does not have arthritis, kyphosis, and non-flat head position as a reference and sense commands based on such position.

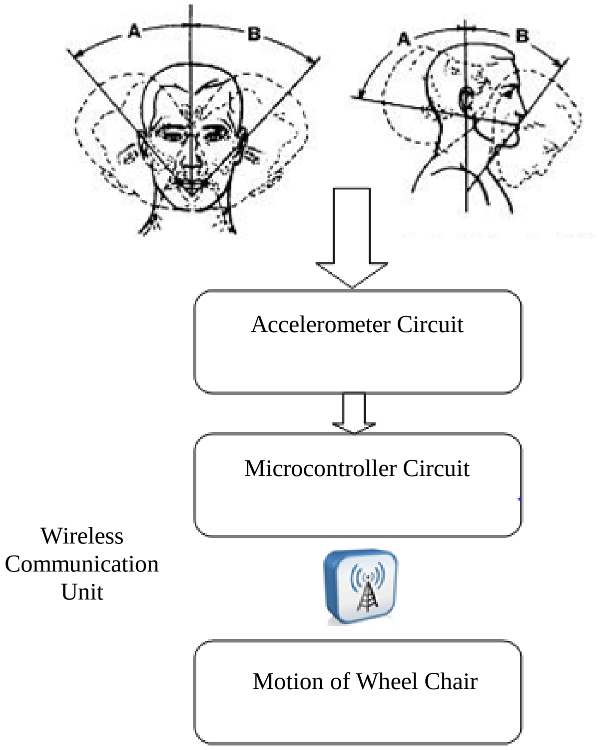

Fig. 1. Block Diagram of System

RF Receiver/Transmitter Unit: Wireless universal asynchronous receiver transmitter (UART) communication was conducted by use of digital ATX-34 Transmitter Module and NRX-34 Receiver Module in the system. These modules were designed in accordance with the section of the Regulation on Fundamental Standards and Principles and Procedures on Installation and Use of Short-Range Access Radio Devices (TGM-STK-001) related to 433-434MHz ISM band. These modules were preferred because they are appropriate for use in the biomedical field and comply with biomedical standards.

Calibration Method: The designed system involves a calibration button on the prototype vehicle. The function of this button is to accept the value sent by the sensor at a specific moment as the reference value. In addition, it helps to sense commands even when the patient does not have an upright position (laying back on the chair and the head being forward). Some patients may have arthritis, kyphosis, or incapability of being upright. In such cases, the circuit will not work properly unless the point of reference is changed. This problem is solved by the added button. After the attendant puts the patient in the wheelchair, s/he presses the button once and calibrates the circuit based on the position of the patient at that specific moment.

Accelerometer and Electronic Design: Accelerometers are sensors that sense the movement based on gravity. Movements in the x-y-z axes are sensed by accelerometers. Literature contains a lot of engineering studies involving the use of accelerometer. Srivastava et al. (2014) designed a system that can be controlled by voice and gestures by use of an accelerometer [19]. Sung et al. (2008) designed a gyro-accelerometer [20]. This is an important example of the use of accelerometer involving swift response. Troiano et al. (2008) focused on the measurement of physical activity through accelerometer sensor [21]. Hyde et al. (2008) dealt with upper extremity orientation by use of a simple accelerometer and gyroscopes [22]. Lau and Tong (2008) used accelerometer and gyro-sensors to analyze gait disorders [23]. Accelerometer sensor was used to sense head movements in the designed system. The sensor was used because it is capable of getting head tilt information. In this way, information is transferred to microcontroller, and the vehicle is directed through various software controls.

Mechanical Design: Mechanical design was prepared for a system acting simply based on tank logic. Four motors are attached under the box through screwing with small retaining clamps. Driving electronic card is inside the designed prototype vehicle. Figure 2 illustrates the prototype vehicle model that can be steered based on head movements.

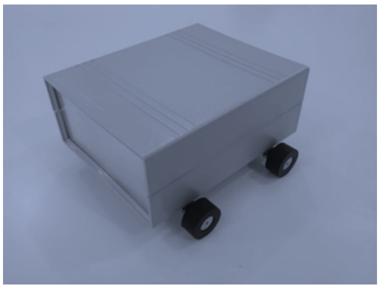

Fig. 2. Designed Prototype

The prototype vehicle was designed based on wheelchair model in order to test command management based on head movements more quickly. DC step motors are controlled via microcontroller. To turn right and left, right and left wheels move in different directions via the same torque. Torque is controlled via microcontroller in accordance with the technical scheme of step motors. When the vehicle moves forward or rearward, four wheels move in the same direction. As the movements indicated in Figure 1 are performed, the system will receive commands accordingly and move the prototype vehicle.

3. Conclusion and Discussion

Mechanical Design: Performance trials were carried out thanks to the designed prototype vehicle. When the system is activated by the patient, a forward angle of 15 degrees is sensed by the sensor, and the vehicle is moved forward. When a rearward angle of 15 degrees is made, the vehicle goes rearward. When angles of 15 degrees are made rightward or leftward, the vehicle goes right or left. When the patient wants to deactivate the system, s/he moves his/her head firstly forward, then rearward, and then forward again, which is the special movement required. In this way, the designed prototype vehicle stops.

RF Receiver/Transmitter Unit: Basically, the transmitter module reads the values from the sensor and digitalizes them and sends UART data to the RF module. This process is repeated as long as the system is active. Figure 3 illustrates the algorithm of the system belonging to the transmitter module.

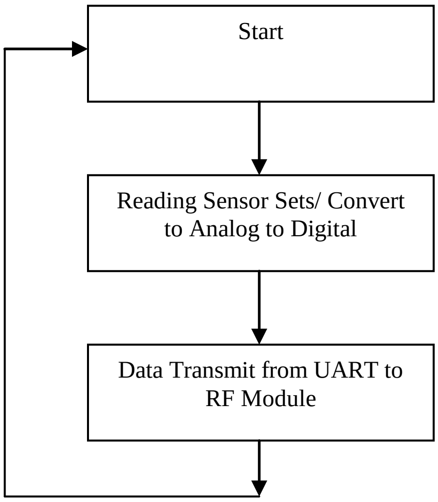

Fig. 3. Designed Prototype

According to the technical specifications indicated in Table 1 for ATX-34, the module has quite high data transmission speed (2.4 Kbit/s). This module was preferred because it has low supply voltage, consumes little current, and has a working frequency compliant with biomedical standards.

Table 1. ATX-34 Transmitter Module Technical Specification

	Min.	**Type**	**Max.**	**Unit**
Supply Voltage	5	-	12	Vcc
Frequency		433.920		MHz
Data Speed	0.3		2.4	Kbit/s
Current Value		6.5		mA

Figure 4 illustrates RF transmitter unit. Since placement of the transmitter on head was not deemed appropriate, it was separated from the sensor block via ribbon type cable and moved in such a way that it would be in the backrest of the wheelchair. It was designed in this way because it was thought that sending RF signals directly over the head may lead to electromagnetic damages in the long term. The transmitter module in this unit transmits the sensor information it receives to the receiver module in the prototype vehicle wirelessly.

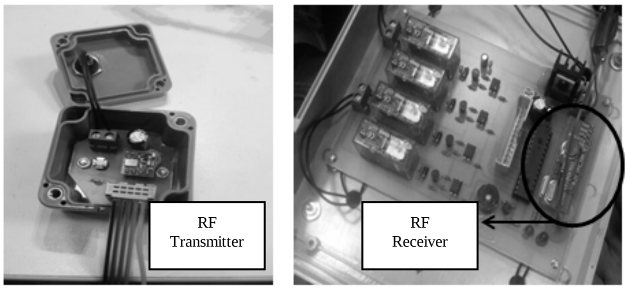

Fig. 4. Designed Prototype

Figure 5 illustrates the head piece whereby the designed accelerometer circuit will be positioned on the patient's head. The head movements of the patient can be sensed through the accelerometer circuit in the upper section of the head piece. All of the sensed movement functions are brought to the RF transmitter unit via cable. From there, signal is transmitted to the receiver unit based on the wireless communication protocol.

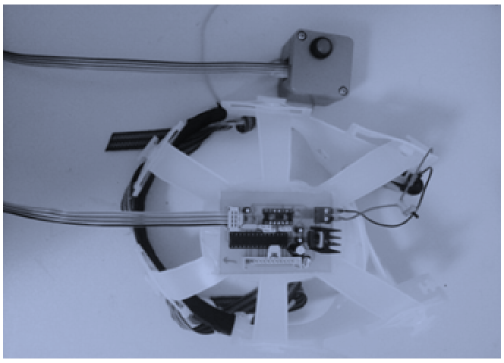

Fig. 5. Designed Prototype with RF Receiver and Transmitter System

NRX-34 receiver module is inside the motor control unit in the prototype vehicle. The receiver module transmits the information received from the sensor to the microcontroller and checks whether or not the patient has given activate command or deactivate command in a cycle. Figure 6 illustrates the designed algorithm of the receiver module.

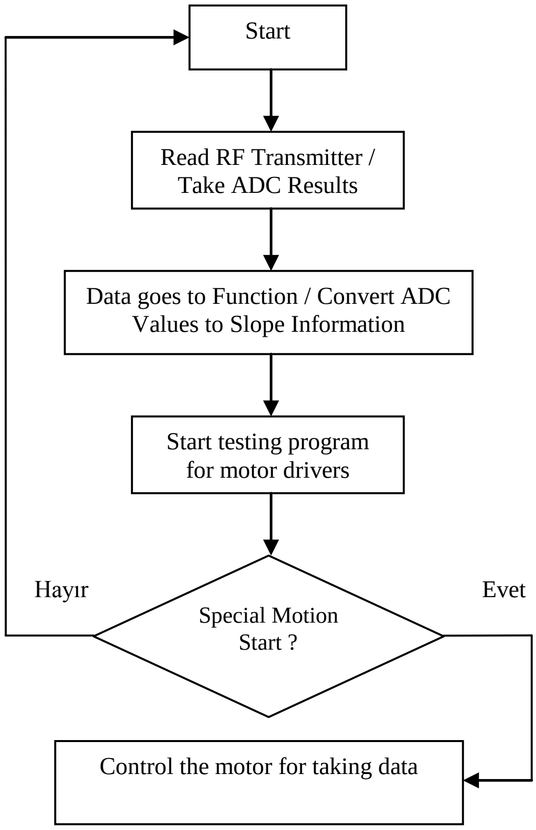

Fig. 6. Receiver Module Algorithm

5 V regulator was used for providing the supply voltage of the module in the motor control unit based on the supply voltage values indicated in the Table 2. 12 V supply was applied to the main motor control unit to drive the motors.

Table 2. NRX-34 Receiver Module Technical Specification

	Min.	Type	MAx.	Unit
Supply Voltage	4.5	-	5.5	Vcc
Frequency		433.920		Mhz
Data Speed	0.2		4.8	Kbit/s
Sensitivity		-117		dBm

Accelerometer and Electronic Design: FreeScale^{TM} MMA model accelerometer sensor used in the system is an analog sensor with a precision of +/- 1.5 G. The sensor is capable of sensing the movements in X-Y-Z axes. Since the patient cannot move his/her body in the designed system, there is no need to use the z axis. Figure 7 illustrates the pin connections of the sensor used in the circuit [24].

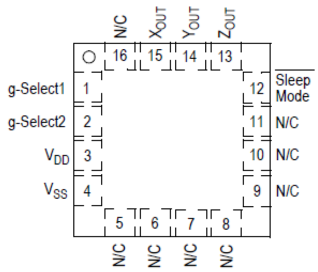

Fig. 7. Pin Connections of the Sensor

A filter system was designed for absorbing the noises likely to emerge in the sensor output. The sensor can be supplied with a low supply voltage between 2.2 V and +3.6 V. After the trials, it was deemed appropriate to supply the sensor used in the circuit with 3.3 V. Thus, a 3.3 V regulator was added to the circuit.

The designed system involves a sensor card in a helmet to be put on head. Head tilt information received from the sensor card is transmitted to the wireless communication card. By this means, such information is wirelessly delivered to the relay card inside the mechanical design. Tilt information is tested through various algorithms, and the prototype vehicle is moved based on such information.

Figure 8 illustrates the printed circuit of the entire electronic system. The control card seen in the figure is positioned inside the designed vehicle. Thanks to this card, relays drive motors, which set the vehicle in desired motion. These relays are 4 in number, double contact, and electromechanical. They are supplied with a voltage of 12 V DC. While 2 relays control stopping or starting of the motor, the other 2 relays control forward-going or rearward-going of the motor. In the design, relays are driven by npn transistors.

DC motors used in the design are capable of revolving 120 times per minute. The drive wheel has a torque of 0.5 N/m. The movement of the vehicle is simply based on tank logic. According to this logic, the vehicle rotates its right motors forward and rotates its left motors rearward to turn. The sensor card indicated in Figure 8 is mounted on helmet on the head.

Wireless communication and sensor were not designed on the same card. This is because; UART communication over the patient's head is not appropriate. This card was positioned in a place close to the patient and the cables to come out of the helmet.

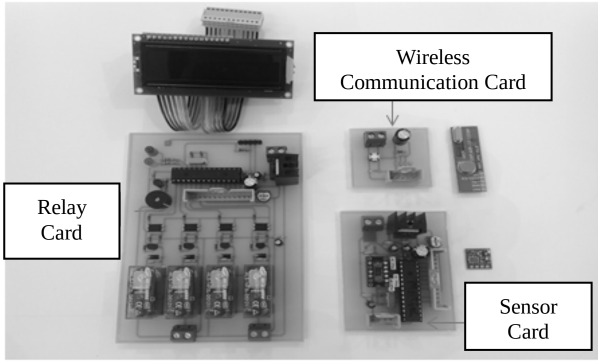

Fig. 8. Designed and Constructed System Parts

In this study, a prototype vehicle which quadriplegic patients who cannot user their upper and lower extremities can use through head movements was designed. Head movements are sensed thanks to the helmet put on the patient's head, and thus the wireless prototype vehicle is set in motion. Wireless system is preferred so that patients are not disturbed by unnecessary cables. The project also involves a calibration button by considering that there may be patients with neck arthritis or kyphosis. In this way, when the button is pressed by someone else for once, the position of the patient's head at that specific moment is sensed, and commands are perceived accordingly.

The patient can start the vehicle with the activate button or stop with the deactivate button. These features make the patient more independent and make them feel psychologically well. The prototype vehicle described in this paper lights the way for new works. A real battery-operated vehicle may be tested through works on the vehicle designed as a prototype.

4. References

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