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Management of Quadriplegic Patients Using Head Movement Controlled Wheelchair: A Case Report

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Abstract--The health service sector has been continuously trying to improve the services given to the people in need of mobility assistance. As a result, more developers have been directed towards robotic wheelchairs. A robotic wheelchair is an intelligent wheelchair that has capabilities of navigating, detecting obstacles and moving automatically by utilizing sensors and artificial intelligence. Electric wheelchairs are designed to aid quadriplegic patients. These can be used by persons with higher degree of impairment, i.e. persons that, due to age or illness, can not move any of the body parts, except of the head. Medical devices designed to help them are very complicated, rare and expensive. In the following case report, a male quadriplegic patient had reported and was unable to move due to loss of sensation in his arms and legs. A head movement controlled wheelchair was designed to ease and enhance the quality of life.

Keywords--artificial intelligence, medical devices, mobility assistance, quadriplegics.

Introduction

Quadriplegics are persons who are not able to use any of the extremities. The reasons for such decreased motion possibilities can be different: stroke, arthritis, high blood pressure, degenerative diseases of bones and joints and cases of paralysis and birth defects. Quadriplegia is a spinal cord injury that causes paralysis after an accident¹. Other causes include tumours or spinal cord diseases. The injury may cause partial or total limb paralysis (arms and legs). There are five different types of spinal cord injuries:

- Complete spinal cord injury A: this is the most severe type. The patient has no sensation or motor function below the injury.

- Incomplete spinal cord injury B: patient has some sensation. Motor function is limited below the injury.
- Incomplete spinal cord injury C: patient has some sensation and muscle control, but the muscles are weak and non-functional.
- Incomplete spinal cord injury D: muscles are 75% functional.
- Incomplete spinal cord injury E: minor injury. The patient has almost normal sensation and strength.

Conditions that could cause quadriplegia include; transverse myelitis, multiple sclerosis and Guillain-Barré syndrome². The injuries may occur in children, before, during, or after birth. The most common cause is lack of oxygen in the brain due to poor oxygen supply.

Also, quadriplegia appears as age. The first thing that needs to be assessed is the injury location. Injuries higher up in the spinal cord tend to cause more paralysis issues. The most obvious symptom is limb deterioration, which can also affect torso function. This can cause the loss of control of several autonomic functions, including: Bladder and bowel, Loss of movement, Loss or change in sensitivity. The general sense of feeling may be impaired in the affected areas, with symptoms including numbness, loss of sensitivity, or burning neuropathic pain. The patients with such severe disabilities are not able to perform their everyday actions, such as: feeding, toilette usage and movement through space. Depending on the severity of the disability, a patient can retain freedom of movement to a certain level by using different medical devices.³

There are two types of medical devices that enable independent movement to a person suffering from quadriplegia. Those are exoscelets and wheelchairs. The need of this report is to ensure that the patient can drive this wheelchair on his own and can lead an independent and satisfied life and can carry his day to day tasks with full efficiency. This can enhance his quality of life and help him gain confidence.

Case Report

A 40 year old male patient reported to the Department with the chief complaint of inability to move his extremities and inability of locomotion. On the external appearance, patient presented with presence of arms and legs but inability to move them. Patient also reported with symptoms of loss of sensation in arms and legs and inability to intentionally move arms and legs. On examination, diagnosis was made and treatment planning was done. An automated head movement control wheelchair was designed for this patient to ease and enhance the quality of life of this patient. The following case report discusses the fabrication , function and patient satisfaction of this wheelchair.(figure 1)



Figure 1. Quadriplegic patient settled on the head movement controlled wheelchair

A head movement of controlled wheelchair was planned for this quadriplegic patient. This head movement controlled wheelchair contains electronic systems which enables and improves a person's movement ability both in outdoor and indoor conditions⁴. Electronic systems such as sensors, actuators, communication modules and signal processing units, were used to recognize the activity that the patient was trying to perform and help him carry it out in coordination with the commands given by head movement. Head movement is a natural form of pointing and can be used to control this wheelchair which helps in movement⁵. (figure 2 and figure 3)

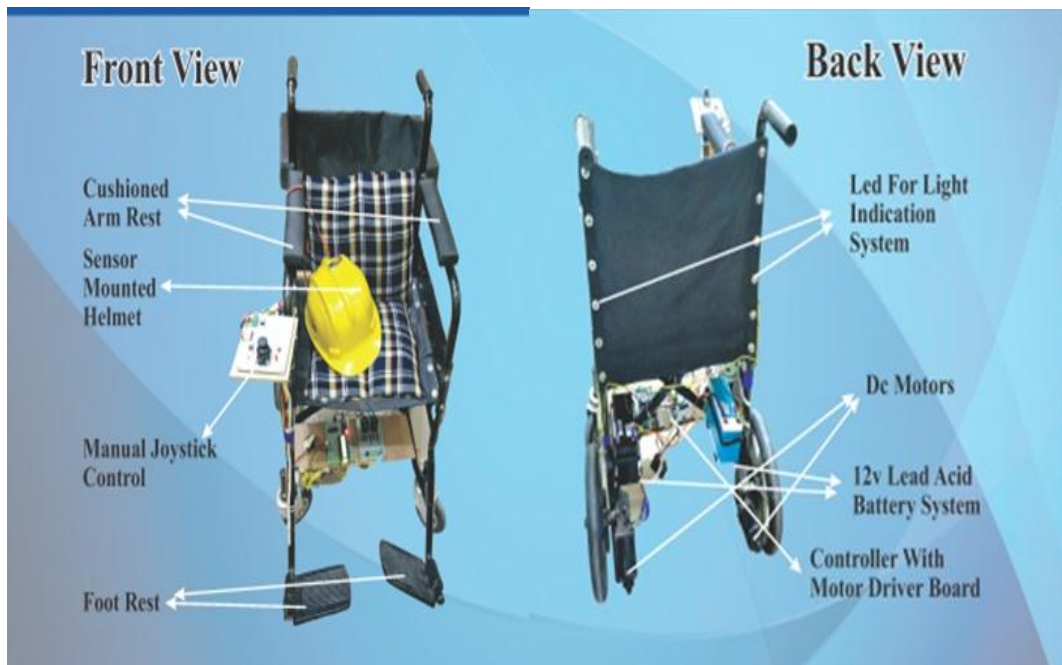


Figure 2. Front and back view of the head movement controlled wheelchair



Figure 3. Runner up position in project presentation at synergy at SGT university

This head movement controlled wheelchair had secured the Runner Up position in Project Presentation at Synergy 2017 at SGT University. Synergy is a carnival of student's innovation. The primary aim of this event is to give a platform for inter-disciplinary research to solve various problems in the world and to overcome challenges that go beyond the framework of research in industry, government and academia. SYNERGY is the accurate platform for students to showcase their talent.

Wheelchair operation is based on navigation, which, in this case, is defined as safe transport from the starting point to a given destination.⁶ For human-machine interaction human motion recognition is also used.⁷⁻⁹ In such a situation we had prepared a system where patient can wear the helmet with attached head

movement device. The movement of the head controls the wheel chair direction. Microelectric mechanical sensor will translate the head movement into computer Interpreted signals. It then passes on data to the microcontroller. (FIGURE 4)The microcontroller transfer signal to motor driven circuit which then control the wheel chair direction. ¹⁰

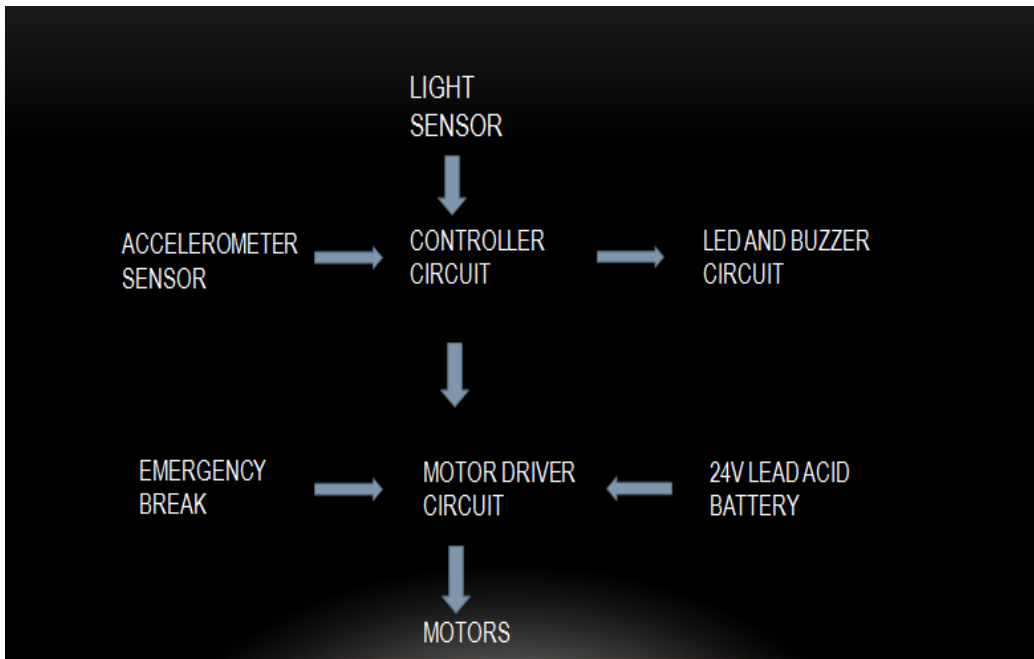


Figure 4. Microcontroller system block diagram

Head motion recognition algorithm

Since a set of possible motions in this case is very small, the number of available commands is also very limited. Therefore, the control system that has been designed in such a way that allows the user to give the following commands: "At Rest ", "Forward", "Left" and "Right". Motion recognition is usually a very intuitive way to interact with electronic devices, but there are technical difficulties.¹¹ The meaning of each of the commands is relative and depends on the present wheelchair state.(figure 5)

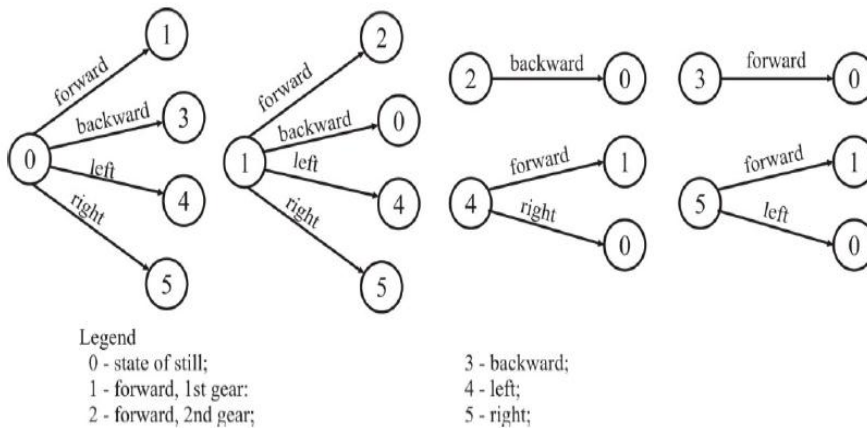


Figure 5. Wheelchair state diagram and relative meaning of user commands diagram

Ranges of motion has been defined as "At Rest- zero position", "Rotating Left", "Rotating Right" and "Moving Forward". If the wheelchair is in the state of still, which means At Rest or Zero Position, the wheelchair will be static at that point. Infact, after a certain degree of movement to the left right or forward direction, if the patient brings back his head to the zero position, the wheelchair will stop moving and will standstill at that specific angulation¹². (figure 6)



Figure 6. Quadriplegic patient "at rest-zero position"

Further, a small degree of inclination of head towards the right or left direction will move the head movement controlled wheelchair in that particular direction, respectively. As shown below, the patient moves his head with a slight degree of tilt towards right and left direction. As per the command given, the wheelchair moves in the considered direction respectively¹³.(figure 7)



Figure 7. Quadriplegic patient "at right and left position respectively"

As the patient wishes to move forward, command of head movement towards the forward direction with slight degree of inclination towards the front will be given¹⁴.(figure 8)



Figure 8. Quadriplegic patient "at forward position"

And finally, if the patient wishes to stop the movement in the desired direction, the patient has to bring his head at the Zero Position or At Rest Position. The algorithm needs to estimate when the head is leaned in one of the four directions. It is sufficient to read only the accelerometer data of two axes: in this case, x and y ¹⁵.(figure 9)

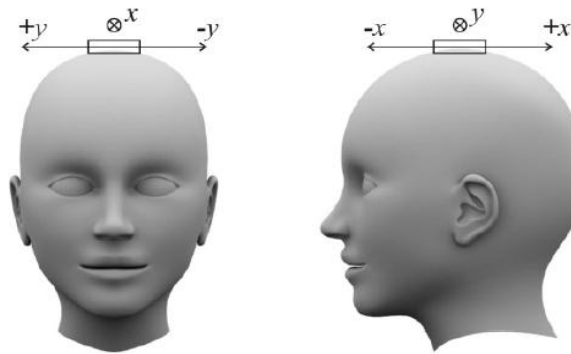


Figure 9. The position of the accelerometer relative to the head and the definition of the space axes and their directions

The thresholds are accelerometer output values that the user defined at system startup¹⁶. These represent the angles in all four directions by which the head needs to be leaned in order to issue a command to the system. These thresholds define borders of a region in three-dimensional space⁸.(figure 10)

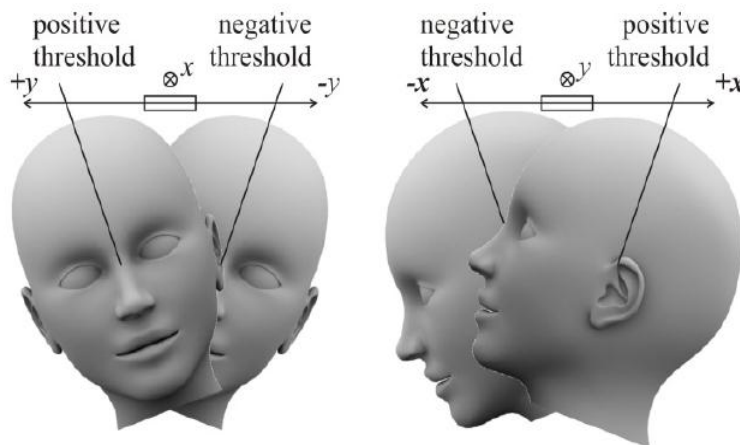


Figure 10. An example of threshold setting

The algorithm is implemented through several steps of operation. The motion data processing is done, i.e. the command is estimated while the user moves the head. On startup, the gravity is measured. Because of this, it is required that the patient remains calm for the first period after turning on the system¹⁷. The end of this period is signaled by the diode B5. Then, after every measurement, that amount is subtracted from the accelerometer output signal. Thus, the

gravitational component of acceleration is eliminated in correspondence the position and attitude of the control unit attached to the patient’s head.

Output voltage changes, which appear as a result of head motion not intended to issue a command lead to errors. As, this is a system has been intended for the Quadriplegic patient who had reported in our Department with severe disabilities, it has to be as adjustable¹⁸. Because of this, the threshold setting according to patient’s possibilities is enabled. The thresholds are set up upon start-up. After corresponding signalization, the patient moves the head first in +x direction, and then in +y direction. Axes and directions are defined relative to the position and attitude of the control unit attached to the head of the patient¹⁹. (figure 11)

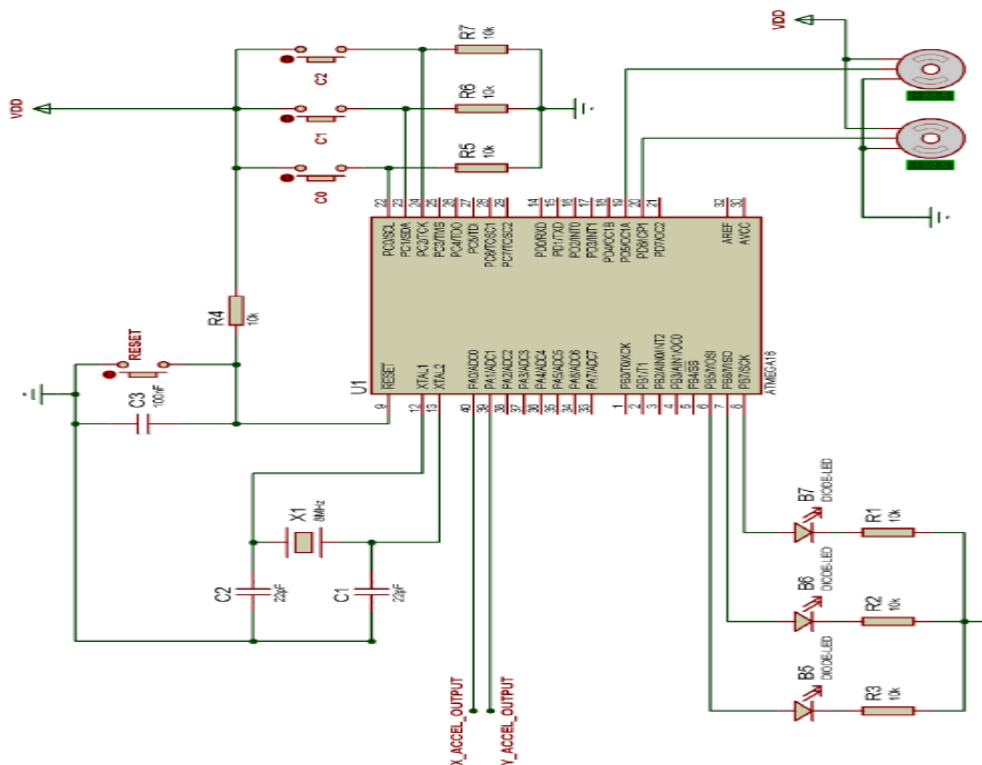


Figure 11. The prototype schematic

Every command consists of three consecutive motions. In order to issue one of four available commands, the user needs to: (1) lean the head over a threshold; (2) return the head to the starting position; (3) repeat the movement (1) ²⁰.(figure 12,figure13)

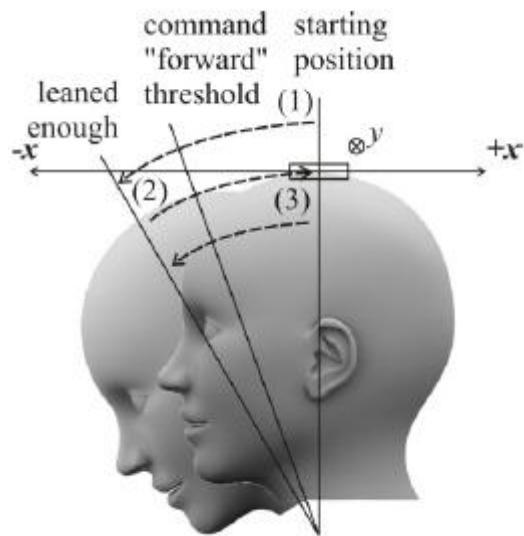


Figure 12. An example of issuing a command – “forward”

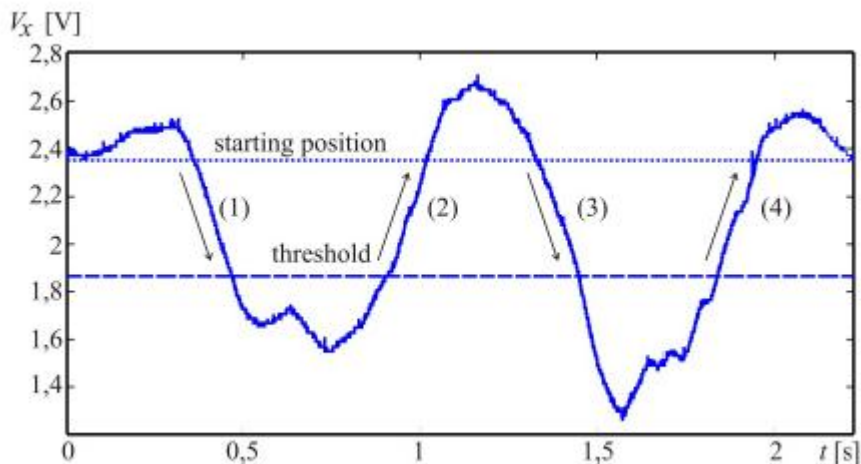


Figure 13. Accelerometer x axis data while issuing the command “forward”

In order to make the system more user friendly, we have enabled an LED indicator on the wheelchair. In case of unpredicted situation, The system recognizes these conditions such as falling of the head caused by unconsciousness, detachment of the sensor from the head and shaking of the head caused by a seizure²¹. This wheelchair has also been enabled with Manual Joystick Control. In case of detection of any of these situations, the system stops the wheelchair putting them in the state of still and blocks command issuing. In order to unblock the system, to continue normal operation, the help of a personal attendant is required and can manage through the Manual Joystick Control panel.

Discussion

Quadriplegic patients complaint of loss of sensation of inability to move their extremities. The foremost thing that has to be assessed is the site of injury causing loss of sensation of extremities. One such case has been discussed in this case report. As this patient had reported, he was in a state of helplessness. This patient could not move his extremities and there was loss of sensation in the extremities. He was upset that he could not carry out daily tasks and had to be dependant on the attendants for the same. The quality of his life had been deteriorating and was guilty about it. A head movement controlled wheelchair had been fabricated as discussed in this case report to fulfill the needs of helplessness. Slight angulation of head leads to the movement of the wheelchair in forward, left and right direction. When the head is held straight and still, the wheelchair comes back to the zero position and stops in the desired direction. An LED indicator has also been installed in this wheelchair for the patient's convenience. A manual joystick control has also been installed in this wheelchair. When the patient falls or becomes unconscious, this manual control unit can be immediately operated by the attendant to stop the wheelchair. This wheelchair provides an ease for the patient as well as the operator to operate this head movement controlled wheelchair. The patient was recalled every 3 months to check the efficiency of the chair and repair any parts if needed. The patient was happy and stated that it has enhanced his quality of life and can carry out everyday tasks independently.

Conclusion

The novel technique of head motion recognition is used to enable wheelchair is valuable for the patients who cannot move independently like amputees - missing legs and/or arms, or patients with weak or no upper body movement and paralyzed children. The automated wheelchair can be used to help quadriplegic individuals lead their life without extra assistance. The technique is implemented as an algorithm of microcontroller system. The tailored made threshold is made for patient's convenience. Moreover, the low cost of the assembly parts of this wheelchair can enhance its affordability.

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