Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-5, 2016
ISSN: 2454-1362, http://www.onlinejournal.in

Head Movement Based Wheelchair

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Abstract: *Tremendous developments have been made in the field of wheelchair technology. However, even these significant developments couldn't aid the quadriplegics to navigate wheelchair independently. Medical devices designed to help the Paraplegic and Quadriplegic patients are very complicated, rarely available and expensive. Traditional wheelchairs though have certain limitations with the flexibility, heavy weight of the chair and limited functions. The aim is to design a simple cost effective automatic wheelchair using MEMS(Micro Electro Mechanical Sensor) technology for quadriplegics with head mobility. The control system translates the position of the users head into speed and directional control of the wheelchair. The system is divided into two main units: MEMS Sensor and programmed PIC Controller. The MEMS sensor senses the change in direction of head and accordingly the signal is given to microcontroller. Depending on the direction of the Acceleration, microcontroller controls the wheel chair directions like LEFT, RIGHT, FRONT, and BACK with the aid of DC motors.*

Keywords: *Micro-electrical mechanical sensor (MEMS) , Wheelchair, quadriplegic, gesture*

1. 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. Also, quadriplegia appears as a consequence of accidents or age. 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 [1]. There are two types of medical devices that enable independent movement to a person suffering from paraplegia. Those are exoscelets and wheelchairs. Both of these contain electronic systems to enable and improve person's movement ability both in outdoor and indoor conditions. Electronic systems, such as sensors, actuators, communication modules and signal processing units, are used to recognize the activity that the patient is trying to perform and help him carry it out in coordination with the commands given. The application of the two mentioned devices is different. Exoscelets must provide body support which makes them more complex. Also, an error in patient's command recognizing process can lead to very serious consequences – fall and, eventually, injury. Wheelchair operation is based on navigation, which, in this case, is defined as safe transport from the starting point to a given destination. The wheelchair, comparing to the exoscelet, are a more general medical device and a much simpler one. Thus, the wheelchairs are used more often [1]. Nevertheless, only patients with healthy upper extremities (paraplegics) can successfully operate standard electric wheelchairs. The patients who cannot use any of their extremities (quadriplegics) cannot operate these [2]. In such cases, when the patient is not able to use the standard control interface, other approaches are used. Through numerous research projects in this area, several different solutions have been developed, such as: SENARIO [3], VAHM [4], Rolland [5], SIAMO [6], Wheelesley [7], and omniwheeled platform [8]. Electronic systems in common for all these projects are sensors, signal processing units, software that translates user's commands into medical device actions. These solutions are dubbed robotic wheelchair. User can control the device via touchscreens [9 – 10] and voice commands [11]. Besides these, wheelchair control is also possible by eye movement and electromiographic sensors. Such interfaces are Telethesis [12] and EagleEyes [13]. Detailed overview of these researches can be found in [1]. For human-machine interaction human motion recognition is also used [14 – 20]. In this paper, a microcontroller system that enables standard electric wheelchair control by head motion is developed. A prototype of the system is implemented and experimentally tested. The prototype consists of the digital system (an accelerometer and a microcontroller) and a mechanical actuator. The accelerometer is used to gather head motion data. To process the sensor data, a novel algorithm is implemented using a microcontroller. The output of the digital system is connected with the mechanical actuator, which is used to position the wheelchair joystick in accordance with the user's command. Sensor data is processed by a novel algorithm, implemented within the microcontroller. Thus, user head motion is translated into electric wheelchair joystick position. The mechanical actuator is compatible with several different types of standard electric wheelchair. Through the performed experiment, the system's ability to correctly recognize user's command is verified. Results of the experiment are given and discussed in this paper.

Within SENARIO [3] project a wheelchair intelligent navigation system is developed. In this case, robotic wheelchair provides two modes of operation: automatic and semiautomatic. While in automatic mode, the interface accepts user's commands. Upon command reception, the wheelchair defines its current position and the destination position. Then, the route from the starting point to a destination is defined. The wheelchair follows this route until the command is successfully performed. While moving according to the route, the wheelchair avoids obstacles, using the environment information gathered through ultrasound and infrared sensors. When in semiautomatic mode, user can interfere with the performance of the activity that the wheelchair defined according to the previous user's command. In this mode, the user can directly navigate the wheelchair over a specific route. VAHM [4] project yielded autonomous wheelchair to provide independent movement to patients that are not able to control standard electric wheelchair. Software architecture is divided in three levels: physical, local and global. Human-machine interface is used to interpret user commands. The local level implements detection of walls and other obstacles. The global level enables route or object following, movement control, obstacle avoidance and route planning. The result of the project titled Bremen Autonomous Wheelchair is the robotic wheelchair Rolland [5]. This wheelchair is developed so that the help of rout planning devices is used. It is characterized by fine tuning of the movement speed and automatic passing through door. Electronic system to navigate electric wheelchair is also developed within the SIAMO [6] project. In this case, basic characteristics are: novel human machine interface, ultrasound, infrared and video sensors, and advanced control and navigation systems. The user can give commands to this robotic wheelchair by face expressions. Wheelesley [7] is developed as a general purpose medical device. As such, the wheelchair offers several different operation modes. Each of these modes gives the user different privileges while operating the wheelchair. Namely, the wheelchair can be controlled by joystick (where the function of every joystick movement can be redefined), by several mechanical switches (the combination of which represents a predefined command) and by blowing tube (where the detection of air speed is enabled). The tube is used only in the worst cases. The wheelchair is capable of avoiding obstacles and automatic passing through doors. In order to accomplish this, the information gathered through existing set of ultrasound and infrared sensors are used.

2. LITERATURE REVIEW

Usual electric wheelchair design is based on motorizing two wheels of the four. Besides this approach platforms with different number of wheels can be used. Such solution is the omniwheeled platform developed in [8]. The authors have shown that such robotic wheelchair move with ease through narrow passages. It is characterized by obstacle detection sensors and the control system based on fuzzy logic. Motion recognition is a process in which a receiver recognizes user's motion. In this context, motions are expressional movements of human body parts, such as: fingers, hands, arms, head, face, legs. The purpose of these movements can be information transfer or the interaction with the environments. Motion recognition is applicable in various fields: enabling children to interact with a computer, understanding sign language, medical devices development, navigation and manipulation of the virtual environment, tracking psychophysical condition of the driver in order to reduce the number of accidents, lie detection, etc. [15]. There are many different motion recognition approaches, of which the most common are based on hidden Markov models [16] and based on artificial intelligence (fuzzy logic and neural networks) [17]. Besides in theoretical approach, motion recognition techniques also differ in devices used for implementation.

MEMS accelerometer sensor which is a highly sensitive sensor and capable of detecting the tilt. For example if the tilt is to the right side then wheelchair moves in right direction or if the tilt is to the left side wheelchair moves in left direction. [18].The developed wheelchair is simple in operation, has good response and reasonably affordable for most of the users.

HEAD MOTION RECOGINATION ALGORITHM

Since a set of possible motions in this case is very small, the number of available commands is also very limited. Thus, the control system that we propose allows the user to give only four different commands: "forward", "backward", "left" and "right". This means that the set of motions to be recognized has only four members. The implemented algorithm relies greatly on this fact. The meaning of each of the commands is relative and depends on the present wheelchair state, Fig. 2. Namely, we define six different wheelchair states: "state of still", "moving forward – 1st gear", "moving forward – 2nd gear", "moving backward", "rotating left" and "rotating right". If the wheelchair is in the "state of still", the command "forward" will put it in the state "moving forward – 1st gear", and the command "backward" will put it in the state "moving backward". On the other hand, if the wheelchair is in the state "moving forward – 1st gear", the command "forward" will put it in the state "moving forward – 2nd gear", and the command "backward" will put it in the state "state of still", i.e. stop the wheelchair. Analogously, if the wheelchair are in the state "moving backward", the command "forward" will stop it. Head motion recognition is based on the force measurements yielded by an accelerometer attached to the head. As mentioned, there are only four members of the motion set, which represent head leaned in four possible directions. This means that the algorithm needs to estimate when the head is leaned in one of the four directions. In other words, it is sufficient to read only the accelerometer data of two axes: in this case, x and y. The position of the accelerometer and the axes are defined in Fig. 3. The thresholds are accelerometer output values that the user defined at system startup. 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 space (Fig. 4) and the algorithm operation is based on estimating the head position relative to this region.

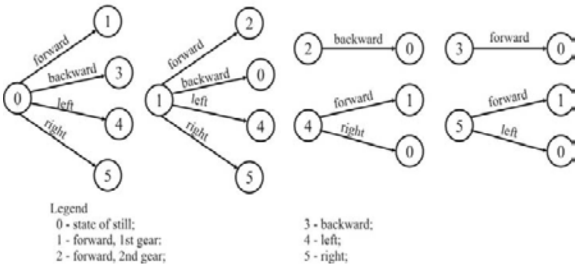


Fig. 1 – Wheelchair state diagram and relative meaning of user commands.

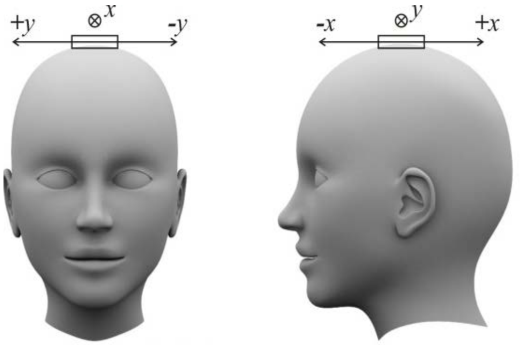


Fig. 2 – The position of the accelerometer relative to the head

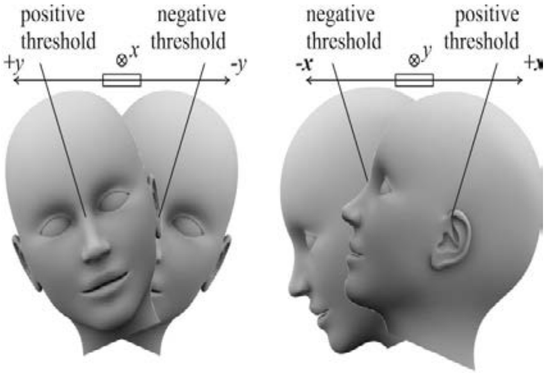


Fig. 3 – An example of threshold setting

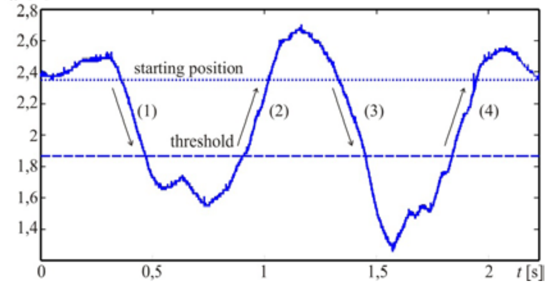
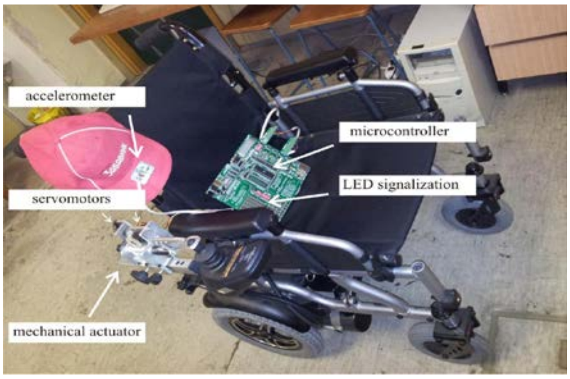


Fig. 4 – Accelerometer x axis data while issuing the command "forward".

Light signalization. In order to make the system more user friendly, enable faster learning and understanding of the system, LED indication is implemented (turning off and on of the B7 diode). The system informs the user on its current state through LED signalization. It is already mentioned that the user has to lean the head over a threshold in order to start a command. During this movement the B7 LED blinks the first time. This informs the user that the head is leaned enough over the threshold. This means that the user can start the next movement, the second part of the command. Second threshold pass, in the opposite direction (the movement marked (2) lights up the same LED second time. Now the user can start the third part of the command, the movement marked with (3). There is no light signalization during the third pass of the threshold, because then the command is finished (this implies that the threshold is passed the third time).Turning around. In this algorithm implementation, there is an intermediate step between the state of still and wheelchair rotation to any of the directions. Issuing a command "left" or "right" while in the state of still, the system goes into left rotation mode or right rotation mode, but the rotation does not start. When the wheelchair is in the left rotation mode, the rotation to the left will start when the user passes the left threshold. It lasts as long as the user keeps the head in the position below the threshold, and it stops when the user returns the head in the starting position. Analogously, for the rotation to the right. In this way, the user has the greatest possible resolution when choosing the driving direction. Both turning modes are finished and wheelchair is again in the state of still, when the user issues the opposite command, e.g. the left rotation mode is finished when the command “right” is issued. Unpredicted situations. The system recognizes unpredicted situations:falling of the head caused by unconsciousness, detachment of the sensor from the head and shaking of the head caused by a seizure. 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 another person is required. Namely, the pushbutton C2 has to be pressed.

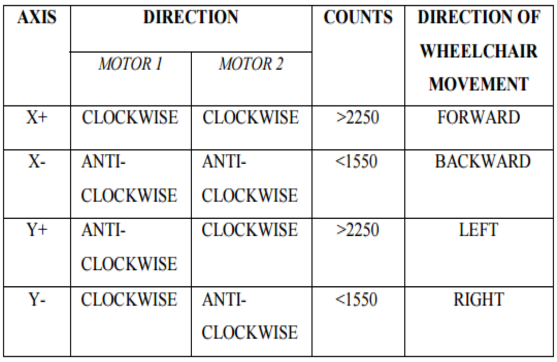
3. SYSTEM PROTOTYPE



4. EXPERIMENT

In this paper, an experiment was performed to test the designed microcontroller system. Otto Bock B400 electric wheelchair type was used. The experiment consists of two parts. In the first part, three examinees (after spending a short time adjusting the system and learning how it works) issued ten times each of the four existing commands. Thus, each examinee issued forty commands, 120 commands in total. After that, in the second part of the experiment, they performed a predefined series of ten head motions such as: look to the right, read the text in front (look down) and look up – i.e. the motions which do not have the purpose of issuing a command. This is done because it is equally important not to recognize the command where one is not intended as it is to recognize the command where one is intended. Here we considered the worst case scenario, e.g. a series that includes …down, up, down.

5. RESULT



AXIS	DIRECTION		COUNTS	DIRECTION OF WHEELCHAIR MOVEMENT
	MOTOR 1	*MOTOR 2*		
X+	CLOCKWISE	CLOCKWISE	>2250	FORWARD
X-	ANTI-CLOCKWISE	ANTI-CLOCKWISE	<1550	BACKWARD
Y+	ANTI-CLOCKWISE	CLOCKWISE	>2250	LEFT
Y-	CLOCKWISE	ANTI-CLOCKWISE	<1550	RIGHT

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