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DEVELOPMENT OF AUTOMATIC WHEELCHAIR FOR ALL PHYSICAL DISABILITIES

EDWARD ALEX

ABSTRACT

The Development of an Automatic Wheelchair for all Physical Disability Types is a mechanical device designed and developed compatible with most physical disabilities that is self-mobile with the aid of the user's command. This project will benefit the user especially the physically challenged who is suffering from paralysis by controlling the motion of the wheelchair with the elementary movement of their hand, feet, or head. The project is composed of four major control systems: the head gear control system, the armrest control system, the footrest control system, and the wireless control system. The headgear, which has a transmitter employing an accelerometer which is responsible for transmitting control signals to the motor driver following the movement of the head. This will be an advantage for the person who is paralyzed from the neck down. The armrest is set-upped with a joystick to control the motion and direction of the wheelchair. The armrest is also comprised of push-button switches which serve as a back-up control system if another control system may fail. This will be an advantage for the person who can only move his hand. The footrest is also integrated with joystick to control the movement and direction of the wheelchair using the foot. With the aid of an ultrasonic sensor placed in the footrest, the chance of for collision is eliminated. This will an advantage for the person who is paralyzed from the leg up. The wireless control system can be done by the use of a mobile application with Bluetooth connection to control the movement of the wheelchair.

INTRODUCTION

Quadriplegia, also known as Tetraplegia, is defined as the "four-limb paralysis" and is caused by illness or accident, or injury that has resulted to the total or partial loss of ability to use the torso and limbs. The common cause of this is spinal cord injury. [1] Spinal Cord Injury or SCI primarily occurs amongst young to middle-aged people who obtained a traumatic injury, or non-traumatic medical condition that resulted in a disability that carries lifetime consequences. Each year in New Zealand, roughly 80–130 people are diagnosed with a Spinal Cord Injury. Most of these cases lead to partial or full paralysis. [2]. The figure below shows the causes of paralysis by percentage. It can be seen that the major cause of paralysis is stroke followed by spinal cord injury.

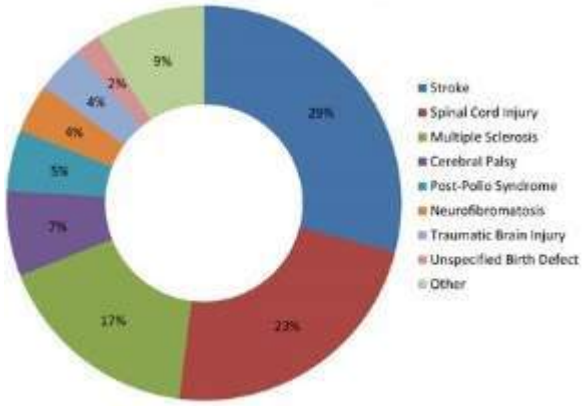

Figure 1: Cause of Paralysis [3]

One of the existing systems for a wheelchair which uses the head movement is the movement through voice recognition. Through voice commands, the user can control the wheelchair such as saying "susume" to navigate forward the wheelchair. It means "run forward" in Japanese. This is a grammar-based recognition system the researcher named "Julian". There were three types of commands that are given: short moving command, basic reaction command, and verification command. The speech recognition system was experimented and resulted in 98.3% successful recognition rate for the movement command and 97.0% successful recognition rate for the verification command. Figure 1 below shows the block diagram of the system while figure 2 below shows one of the running experiment that was carried out. [4]

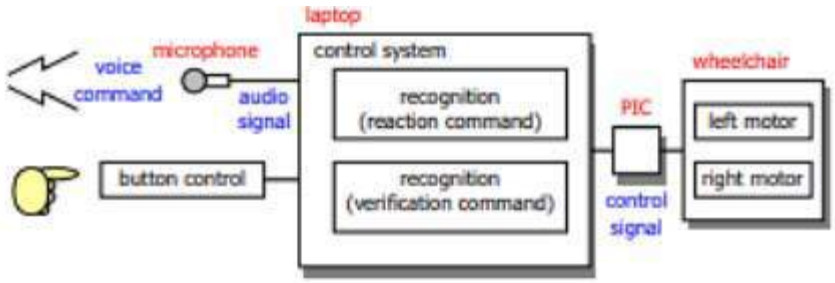

Figure 2: Voice recognition block diagram

Figure 3: Running Scene using a laptop

Another existing system uses facial recognition to give the command to the wheelchair. The user – with the initial help of another person or caregiver – could assign as to what facial expression is linked to a specific wheelchair movement. This was made possible through the use of facial recognition software, and a mounted Intel 3D RealSense Depth Camera, The computer captures a 3D map of the face and makes use of AI algorithms to process data in real-time to navigate the wheelchair. The system not only works on bright light but also on a dim light, and is incompatible with most of the motorized wheelchairs available on the market. [5]

Figure 4: Facial Expression Recognition

A similar paper proposed a system that assists the person with a disability to control the motion of the wheelchair wirelessly through hand gestures. The proposed system may be mounted on the principal functioning body part – like the hand to control the wheelchair movement. The system consisted of a transmitter that acts as a wireless remote that was mounted on the hand. The transmitter end consisted of a microcontroller using MEMS accelerometer which senses the tilt of the platform it is mounted on such as the upper side of the hand. Figures 4 and 5 below show the hand movement that will determine the motion of the wheelchair and the sensor used in the project. [6]

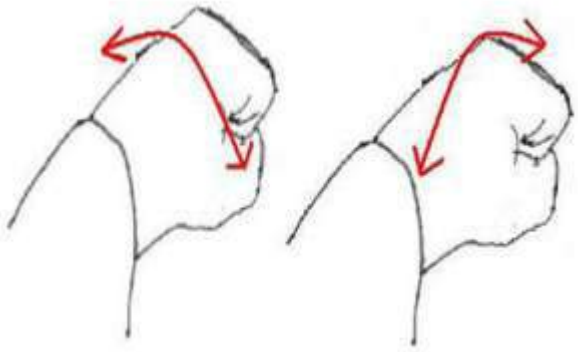

Figure 5: Hand movement for controlling

Figure 6: Accelerometer Sensor

Bluetooth is a wireless technology that is primarily designed for communication over a short range of distance at about 10m or 30ft. Electronic devices that use this technology have built-in radio antennas called receivers and transmitters that can simultaneously send and receive wireless signals to other devices with Bluetooth. It is often used for transferring photos from a digital camera to a personal computer, connecting wireless mouse to a laptop, hands-free headset to a mobile phone especially on cars while driving. These devices automatically connect to one

another and up to 8 devices and do not interfere with each other because each pair uses different channels out of the available 79 channels. [7] The figure below show Bluetooth device connectivity.

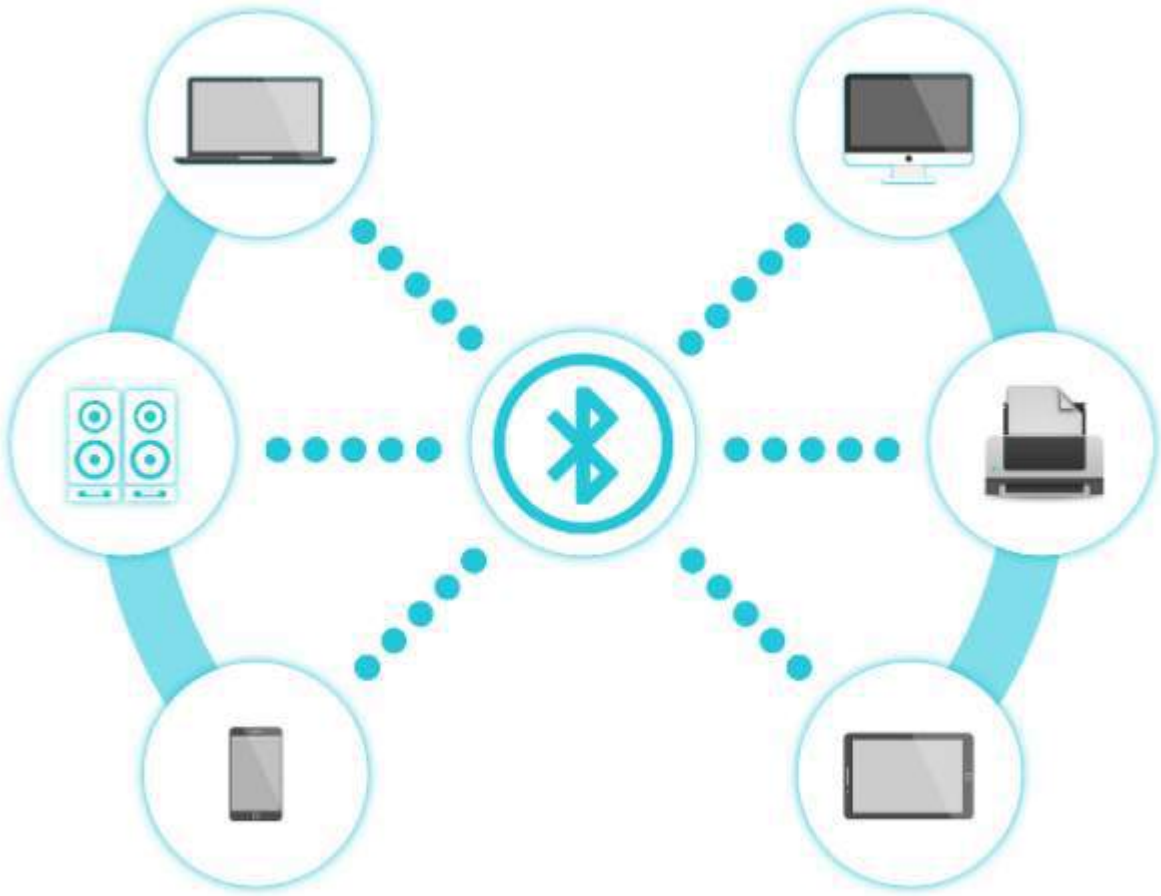

Figure 7: Bluetooth Device Connectivity

Another similar research was about controlling a robot using an android application with the aid of Bluetooth connection. The Android OS if not the largest, is one of the largest numbers of operating systems used in Smartphone's that is very rampant nowadays due to research, entertainment, and social media. The objective of this paper is to be able to devise an Android application or program than can control a robot powered by an Arduino microcontroller with the use of a Bluetooth module and motor driver. Since Arduino and Android are open sources, it is an advantage for this research to obtain information about the different aspects of programming involved in the project. The result of this project is a concoction of embedded programming and computing. It was concluded on this project that it is not hard to implement Arduino with Android. The following figures below show the system block diagram and the prototype of the robot. [8]

The Robot Prototype

The primary structure for supporting most external loads and maintaining the stiffness of the structure of the wheelchair is the frame. The frame can always be made stronger by increasing its size or adding reinforcements but the weight should also be considered and must be limited. This is to improve the moving performance of the wheelchair hence, must be reduced. For this reason, it is important to adopt light-weight materials for the making or designing of the wheelchair frame. Yet, the strength and stiffness should also be maintained. One study suggests using the fiber-reinforced composite material because of its high stiffness-to-weight and strength-to-weight ratios.

Plastics matrix and reinforced fibers compose the reinforced fiber composite materials. Fatigue life and density are low, stiffness and strength are high, corrosion and wear-resistant, and environmentally stable are the advantages of this material over monolithic materials. These composite materials that are laminated reinforced fibers are usually made out of polyester/glass or epoxy/carbon that are broadly utilized in military, automotive, aerospace, aircraft, sports structures, and marine. With the use of these epoxy/carbon materials, the weight of the wheelchair can be effectively reduced. Figure 10 below shows the reinforced carbon-fiber (epoxy/carbon) composite laminates. The different color implies the regions of connection and tubular frames which are made of 26-ply and 16-ply, respectively. Each ply has a thickness of 0.2mm. To reduce stress concentration, thicker structures are used in connection regions.

The use of solid mechanics is a strong tool for designing a project. With the help of finite element and analytical calculations, stiffness, strength, and stress areas of the wheelchair structure can be easily predicted and identified and can instantly be modified to achieve an optimal design. Using these tools, the behavior of material for structural and design of wheels, frames, and impact-absorbing structure in the wheelchair have been analyzed. Figure 11 below shows the loading and boundary conditions of the wheelchair frame.

Figures 12 to 14 below show the FEM model of the wheelchair frame used in the ANSYS software. Elastic property and static structural analysis were done on this FEM model. Using the thick shell theory to simulate this epoxy/carbon composite laminates, the SHELL91 that is 8-noded high-order shell elements with multi-plies were used. Furthermore, it is assumed in the finite element analysis that there is perfect bonding between plie. To deliberate the effects on the magnitude of stress, the directions of fiber for all plies may be changed. The boundary

conditions were set on specific nodes for the finite element model. The external nodes on the frame are set to many nodes.

Figure 15 below shows the global deformation of the wheelchair frame system associated with $[0/45_4/-45_4/90_4]_s$ under the upward loading test. For the same case, figure 16 below shows the distribution of the normal stress (σ_1) along the fiber direction on the outer surface of the tubular frame. The stress concentration can be noticed around the connection region. [7]

Another study simulated four wheelchair frames using different materials. It was Aluminium 1060 alloy, Gray Cast Iron, Stainless Steel, Mild Steel, and numerical analysis was done on it through Solidworks. This simulation was done with 980N (Above average weight of a person). The stress analysis on Aluminum, Cast Iron, Stainless, Mild steel is shown in figures 17 to 20.

From the simulation result, it is showed that Mild steel can sustain higher stress and its Strain & displacement is very low than other material. Due to the good simulation result, low market cost and availability Mild steel have been selected for frame material.

Von Mises stress analysis is used to find the yielding criteria of isotropic or ductile materials under complex load. According to Von Mises yield criterion, it is independent of first stress invariant. But the ductile materials will exceed yield point when the second deviatory stress invariant will reach a critical value. The stress analysis of the wheelchair frame is given in figure 21 below [9]

PROBLEM STATEMENT

A handicapped person with a locomotive disability needs a wheelchair in order to move around. One can do so manually by forcing the wheels by hand. However, types of physical disabilities vary from one handicapped to another. Hence, it is desirable to provide them with an automatic wheelchair that can be controlled by the head, hands, and feet that will be compatible for all types of physical disability – may it be a person cannot move his upper body but can move his head or the other way around. Since it is motorized and can move at a fair speed, it is important that it is able to avoid obstacles automatically at an instant. All this should be achieved at a cost that is reasonable. With these requirements in mind, the researchers propose an automatic wheelchair for all physical disability types.

OBJECTIVES

General:

- To design and fabricate an automatic wheelchair for all physical disability types.
- To integrate appropriate sensor and actuators and use contemporary software on the automatic wheelchair for all physical disability types.
- To define mechanical properties, mechatronics properties, and control system of the automatic wheelchair for all physical disability types.

Individual:

- To design and fabricate the headgear of the developed prototype of an automatic wheelchair and integrate wireless connection.
- To develop the program of the accelerometer and Bluetooth module to control the wheelchair through the headgear and mobile device.
- To analyze and determine the external and internal forces, moments, axial, shear, and bending stresses, modulus, and strain, and failures involve in the framing of the wheelchair and identify stress concentration areas using ANSYS.

SCOPE OF THE PROJECT

This project is about the design and fabrication of an automatic wheelchair that will be suitable for all types of physical disability. This was made possible with the use of appropriate sensors, actuators, and microcontroller. This paper is focused more on two of the four control systems of the wheelchair which are the headgear and the Bluetooth module. The rest of the control systems are discussed on different papers. Also, this paper is focused more on the behavior of the wheelchair frame upon loading conditions apply. This has been done through simulation with the use of finite element analysis using the software ANSYS and some useful mathematical equations.

WORK BREAKDOWN STRUCTURE

The figure below shows the Work Breakdown Structure for the Development of an Automatic Wheelchair for all Physical Disability Types. It shows the five main phases of the project and the sub-activities under each activity.

METHODOLOGY

The project was carried out through the use of sensors, actuators, and microcontroller. The project was divided into four control systems. The control system on the headgear, armrest, and footrest, and wireless control. The headgear is composed of an accelerometer sensor that will send voltage output signal that ranges from 2-3.6V, the input signal to the microcontroller, that allows the wheelchair to move forward if the headgear is tilted forward; move backward if the headgear is titled backward; and the same concept applies if the headgear is titled both left and right sideward. The armrest is composed of a joystick module that allows the wheelchair to move on four directions along with its output signal. Pushbutton switches are also integrated into the armest – one for each direction – that will serve as a backup control if other sensors may fail. The footrest has also composed a joystick. Also, the footrest is integrated with an ultrasonic sensor that serves as a safety device that stops the vehicle if there is chance of collision.

The figure below shows the block diagram for the whole system of the Automatic Wheelchair for all Physical Disability Types that is divided into four control systems but are connected together in 2 microcontrollers. Two

microcontrollers were used for the reason that the ultrasonic sensor created errors on the system and needs to be isolated from other sensors.

Block Diagram of the Whole System

The figure below shows the flowchart of the control system of the headgear with the use of accelerometer. The 0.6V output signal from the accelerometer was set as the parameter that serves as the input signal for the microcontroller that determines the direction of the movement of the wheelchair. It was decided to be 0.6V output set that would allow the wheelchair to run smoothly after series of trials and test were done after sensitivity issues were observed.

Flowchart for the Accelerometer

The figure below shows the flowchart of the wireless control system which is the mobile device that is connected to the wheelchair using Bluetooth connectivity. It uses a low cost and low power transmitters, with a range of 10-30 meters for class 2 devices that are common to mobile devices. Incoming Bytes declared in the codes are read by the module that signifies which command the Bluetooth module will follow that allows the wheelchair to move on a specific direction.

COMPONENTS

The following figures below show the major hardware components that were used as discussed above.

Software:

The figures below show the software programs that were used for finite element analysis for the wheelchair frame and the designing of the finite element model. ANSYS student version was used in the simulation of the wheelchair frame while Solidworks was used in making the 3D STEP model for the wheelchair frame. On the other hand, Arduino IDE software was used in compiling the programming codes with the use of C language for the Arduino Uno microcontrollers while Proteus was used in making the schematic diagram for the components.

RESULTS AND DISCUSSION

After a series of trials and tests, the group has come up with the prototype of the Development of an Automatic Wheelchair for all Physical Disability Types. Figure 45 below shows the prototype of the project with all the components installed. The prototype and all its components are in good working condition. All components are connected together in the main board located below the seat just at the back of the footrest as shown in Figure 46.

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