FACULTY OF ELECTRICAL ENGINEERING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FINAL YEAR PROJECT

DEVELOPMENT AND ANALYSIS OF HEAD TRACKING SYSTEM FOR ROBOTIC WHEELCHAIR CONTROL

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Bachelor of Electrical Engineering (Control, Instrumentation & Automation)

2016

“I hereby declare that I have read through this report entitle “Development and Analysis of Head Tracking System in Robotic Wheelchair Control” and found that it has been comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation).

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DEVELOPMENT AND ANALYSIS OF HEAD TRACKING SYSTEM FOR ROBOTIC WHEELCHAIR CONTROL

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

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2016

I declare that this report entitle "Development and Analysis of Head Tracking System for Robotic Wheelchair Control" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Dedicated to my lovely father, mother and sister

ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my project supervisor Mr. Tarmizi Bin Ahmad Izzuddin for the continuous support of my final year project and related research, for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better supervisor for final year project.

Besides my supervisor, I would like to thank both of my FYP panels: Dr. Saifulza Bin Alwi and Madam Nur Asmiza Binti Selamat, for their insightful comments and encouragement, but also for the challenging question which incented me to widen my research from various perspectives.

I thank my fellow course mates for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last three years. Also I thank all my lecturers and friends in Universiti Teknikal Malaysia Melaka that helped and assisted me in any form during my days in the varsity.

Last but not the least, I would like to thank my family: my parents and to my sister for supporting me spiritually throughout writing this thesis and my life in general.

ABSTRACT

Quadriplegia patients have restricted limb movements due to injuries in spinal cord or brain. Most of them only able to move their eyes and head partially depends on the level of damages. This project is aimed to develop a hands-free motorized wheelchair controlled by head movement of users to assist the patients for daily movement without the help from others. An Inertial Measurement Unit (IMU) will be attached on user's head to sense and track user's head orientation. Inertial Measurement Unit is an electronic device that normally consists of an accelerometer and gyroscope. Different head orientation represents different command such as accelerate, stop, turn right, turn left, and reverse. NI myRIO will be used as controller while LabView software will use to program NI myRIO in this project. Inertial Measurement Unit will be connected to NI myRIO for signal processing before sending command to the wheelchair motors. Algorithm for this project is a signal processing filter named Complementary Filter to process raw signals obtained from Inertial Measurement Unit into a less noisy and more precise data. Signals obtained from the devices will be further analyzed, compared and discussed.

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CHAPTER 1

INTRODUCTION

1.1 Background

Statistics revealed that approximately 11,000 new spinal cord injuries occur each year in United States. Among them, 52% of spinal cord injured individuals are considered paraplegic and 47% quadriplegic [1]. Quadriplegia is a disease that cause major losses of human's limbs mainly shoulder and below by spinal cord and brain damages. There are a few levels of spinal cord injuries such as from C1-C7 that leads to quadriplegia. The loss is usually sensory and motor, which means that both sensation and control are lost [2]. Great people like Stephen Hawking and Max Brito have been suffering from this crippling phenomenon [3]. Thus, people who suffers from quadriplegia have very restricted movement in their daily living.

1.2 Motivation

A wheelchair is very crucial for quadriplegics as they relies on it to move around in their entire life. They can choose to use a normal wheelchair with the help of another person, or a motorized electric wheelchair that does not require hand control due to restricted hand movement. The price of a hands-free motorized wheelchair is high and not affordable for normal families. In past few years, there are plenty of new technologies applied to develop a hands-free motorized wheelchair by controlling the movement of wheelchair using head part of quadriplegics. For example, eye-tracking method – by using number of eye blink and eyeball movement to control wheelchair [19], EEG method – by using brain attention level to move a wheelchair [5], Head orientation method – by using a camera to capture and differentiate user's head position. [8] By considering the limitations of other wheelchair systems, this project will be proposing a head tracking system by using an Inertial Measurement Unit emphasizing low cost, more robust and higher stability to assist quadriplegics for their daily movement.

1.3 Problem Statement

Conventional motorized wheelchairs are usually controlled by users using a joystick. However, it is not suitable for Quadriplegia patients who have restricted limb movements that only able move their eyes and head partially. Recently, there are plenty of new technologies being invented to design a wheelchair system mainly for quadriplegics. For instance, eye-blinking detection and head movement detection by using image processing technologies, or EEG headset by detecting brain signals.

There are a few disadvantages by using image processing method in detecting eye-blink or head movement, such as a camera need to be placed in front or behind the user to capture eye and head movement. This makes the system become bulky. Another disadvantage is that a camera could not capture user's image properly in a low light and dark condition. It causes the wheelchair unstable and fail to move smoothly in such environment. A better resolution or large sensor camera with an infrared might improve the system but it also increases the cost. [8][19]

On the other hand, an EEG headset that detects brain signal also leads to some disadvantages. For example, the signal from the headset is not as stable as image processing method. Human's brain signal fluctuates a lot and it cannot be detected accurately by an EEG headset. To control the wheelchair, users have to focus on something to increase the attention level detected by EEG headset. This will causes some problem because human tends to think or focus on something unintentionally. [5]

Thus, head orientation tracking by using an Inertial Measurement Unit (IMU) is proposed in this project. Data received from IMU will be processed by NI myRIO and send an ‘Accelerate’, ‘Stop’ , ‘Reverse’ and direction command to the wheelchair motor to replace conventional joystick navigation. Inertial Measurement Unit consists of accelerometer and gyroscope. However, accelerometer is sensitive to vibration that even small force working on the object will disturb its measurement completely. A low-pass filter is needed to filter out unwanted signals to minimize disturbance. [20] While a gyroscope outputs angular rate instead of absolute measurement. It is likely to drift and gives a value other than zero even though the object is in rest.

Hence, a filter is needed to correct the error that produced by both accelerometer and gyroscope. Complementary Filter is proposed in this project to overcome this problem so that a smooth signal can be obtained in NI myRIO to process and command a motorized wheelchair. The wheelchair is aimed to be implemented in a cost effective way which reduces the complexity in the design, and to be used as a human-friendly interface for a quadriplegia patient.

1.4 Objectives

1. To replace joystick control with head movement control in motorized wheelchair for quadriplegics.
2. To detect patient’s head orientation with a 5 DOF Inertial Measurement Unit (IMU).
3. To implement Complementary Filter to process data obtained from Inertial Measurement Unit (IMU).
4. To use National Instruments myRIO to implement and analyze the processed data.

1.5 Scope of Work

This project will be focus on the head part of human body to control a motorized wheelchair. Head orientation of user will be used command the wheelchair such as ‘accelerate’, ‘stop’, ‘turn left’, turn right’, and ‘reverse’. A 5 Degree of Freedom Inertial Measurement Unit (with 3 axes accelerometer and 2 axes gyroscope) is the only sensor proposed in this project to track user’s head orientation. Signals and data obtained in the Inertial Measurement Unit will be sent to NI myRIO for signal processing. Complementary Filter will be implemented in this project by using LabView software and NI myRIO. Analysis and calibration of signals will be done to ensure safety and reliability in the operation of the proposed motorized wheelchair.

1.6 Thesis Outline

This thesis consists of 5 chapters which are organized as follows:

Chapter 1 presents the background, problem statement and motivation of the proposed technique. The objectives of this project are also presented followed by the outline of thesis.

Chapter 2 gives some overview of quadriplegia, reasons that causes quadriplegia and its categories. It also explains about modern motorized wheelchair and some of the method to control it, for example eye-blinking method, EEG method, image processing method and so on. Besides that, it focuses on the usage of hardware such as Inertial Measurement Unit (IMU) and the components inside, such as accelerometer and gyroscope.

Chapter 3 presents the methodology of the proposed head tracking system in motorized wheelchair. The proposed head tracking system uses an Inertial Measurement Unit (IMU) to distinguish the head orientation of users such as turning left, right, tilting forward and backward. This chapter also presents the algorithm used to filter signals obtained from Inertial Measurement Unit (IMU) to be processed by NI myRIO controller. Besides that, the parameters of components used in LabView software and are also presented.

Chapter 4 presents the results for the proposed head tracking system. Data obtained from Inertial Measurement Unit and the filtered data are analyzed and discussed. Several tests are conducted to determine the accuracy of the proposed system.

C**hapter 5** concludes the thesis by summarizing the project outcome and presents possible future works for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Quadriplegia

Quadriplegia, or Tetraplegia in Europe, is a disease caused by disruption to the spinal cord in cervical part of human body that results in partial or total loss in sensory and motor of their body limbs. It leads to the loss of body movement and sensation to their arms, body and legs. The difference of quadriplegia and paraplegia is that paraplegic still retaining the movement of arms. Other than that, quadriplegics will still able to move their head and depending on muscle strength and spinal cord injury levels. Spinal injuries are divided into a few levels and sections. For quadriplegics, their spinal injury level usually falls in section C1-C8. For section C1-C3, patients will only have limited head movement, while C4-C8 will retain full head and neck movement with good muscle strength in C5-C8 [4].

2.2 Motorized Wheelchair

A conventional motorized wheelchair usually consists of a pair of motors, battery, joystick and motor driver as shown in Figure 2.1. Joystick will act as a control unit to let users maneuver the wheelchair with ease. Signals from joystick will be send to a motor driver (usually under the joystick) to control the speed of the 2 motors so that the wheelchair can be moved and turn around [5]. Studies revealed that 81% of all motorized electric wheelchairs are controlled by joysticks. Among the users, 32% of them having problem in using the joystick while 9% of them could not operate the wheelchair without any assistance. On the other hand, 18% of new patients who wish to use a motorized wheelchairs are having difficulties in operating the joystick due to lack of muscle strength and skills. [6] Joystick controls should be replaced with other methods for patients that have limited strength and movement, such as head movement control or eye-blinking control [7].

Figure 2.1: A motorized wheelchair [6]

2.3 Methods in Controlling Motorized Wheelchair using Human Head

There are a few methods in controlling the movement of a motorized electric wheelchair. For instants, it can be a joystick control, head movement control, eye blinking control, brain signal control and etc. In this project, we will be focusing in using the head part of human to control and send command to a motorized wheelchair. By using human head, a few methods can be used as following:

1) EEG Headset to detect brain attention level

   Electroencephalogram (EEG) is a method to detect electrical activity in a brain. It uses metal electrodes to place along the scalp to capture and record electrical impulses that transmitted through brain cells. When a person focus on something, there will be some increase in attention level that will be detected by the EEG headset [8]. A consumer EEG headset such as NeuroSky MindWave EEG as shown in Figure 2.2 is suggested to control acceleration and brake of wheelchair by detecting attention level of brain. Brain-computer interface (BCI) is a system that able to convert brain activity signal obtained by EEG into control signals to control a wheelchair. If focusing level exceeds certain amount, controller will send an 'accelerate' or 'stop' command to the wheelchair [7].

Figure 2.2: A Neurosky MindWave EEG Headset [22]

2) Eye-tracking method

Patients who suffers quadriplegia level C1-C3 are unable to move their head flexibly. So, eye-tracking detection method is suggest to be used to control the movement of a motorized wheelchair. There are a few method to detect eye blink, for example using a camera to capture eye movement, or using an EEG headset that includes eye-blink detection such as NeuroSky MindWave EEG headset [39]. Eye-blinking technique can be combined with EEG signal to increase safety as human eye could accidently blink more than usual. Some of the eye blinking frequency or eye ball position could be used as a different command as shown in Table 2.1 [9]:

Table 2.1: Eye-blinking commands [9]

Wheelchair Status	Eye activities	Accuracy (%)
Forward	Blink 3 times	90
Reverse	Blink 4 times	90
Stop	Blink 2 times	90
Turn Left	Glancing Left	95
Turn Right	Glancing Right	86

3) Detect Head orientation using camera and image processing

   A small camera such as high-definition webcam is placed in front or behind the user to capture their head orientation and movement. This could be done by using image processing techniques such as pixels mapping to analyze different head orientation [10]. When camera images is first captured and send to computer, depth thresholding will be done by separating user's head from background. Pixels of top, left and right of the head will be lock-on so that when user tilts their head, the target pixels will follow and thus it detects movement of the head to a certain different area. The pattern of head movement will then be mapped into a preset pattern such as left, right, front, back. It user's head movement matches one of the preset pattern, the wheelchair will respond in terms of the command given such as turn left, right or go straight [11].

4) Detect Head orientation using an Inertial Measurement Unit

   The principle of head orientation control using an Inertial Measurement Unit (IMU) is similar with using camera image processing technique. Users are required to tilt their head to certain angle to operate a motorized wheelchair. Key difference between these two methods is the way it obtain and analyze data [11]. An Inertial Measurement Unit will use an accelerometer and gyroscope to measure head position and detect head movement, while a camera will be using image processing that runs in a computer to sense head orientation. Details of an Inertial Measurement Unit will be discussed in the next section.

The few methods are summarized and categorized as Table 2.2 below shows comparison between the methods in developing a hands-free motorized wheelchair:

Table 2.2: Comparison of different motorized wheelchair control method [5][8][19][20]

No.	Method	Advantage	Disadvantage
1	EEG Headset to detect brain signal	- Does not require user to have any body movement	- High cost for most EEG headset - Brain signal differ from users and not stable. - Requires training and practice before the wheelchair can be controlled smoothly. - Tiring for users who need to focus all the time to move the wheelchair. - Multi-channel EEG headset is bulky and uncomfortable for user.
2	Eye-tracking	- Easy to learn and use	- Not stable since human eye blinks frequently by its own. - Users unable to move their eyeball freely since it will move the wheelchair.
3	Detect Head orientation using camera and image processing	- Easy to control	- Unable to detect user's head

			orientation in low light or dark condition. - Requires high quality camera to increase stability.
4	Detect Head orientation using an Inertial Measurement Unit	- Easy to control - Can operate in dark - Low cost - System less complex compared to EEG or image processing method.	- Users required to attach an Inertial Measurement Unit on their head all the time.

2.4 Inertial Measurement Unit (IMU)

Inertial measurement Unit, also known as IMU, is an electronic device that consist of accelerometers and gyroscopes, while some also includes magnetometer and barometer. An IMU is capable of measuring linear acceleration and angular velocity with the aid of accelerometers and gyroscopes. It is often used in obtaining position, speed, altitude for navigation system in an aircraft, space shuttle, ships and etc [12]. Types of Inertial Measurement Unit is normally categorized by its Degree of Freedom (DOF). A standard Inertial Measurement Unit requires 6 axis (also known as 6 Degree of Freedom) to utterly sense a complete motion and position. 6 DOF Inertial measurement unit will consist of a 3 axis accelerometer (X, Y, Z axis) and a 3 axis gyroscope (Roll, Pitch, Yaw). To increase in calibration against orientation drift, a magnetometer will be added to an Inertial Measurement