Faculty of Electrical Engineering

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**DEVELOPMENT OF SYSTEM CONTROLLER AND
VOICE-CONTROLLED MOBILE APPLICATION TO CONTROL
AN OMNI-WHEELED MOBILE ROBOT**

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Bachelor of Mechatronics Engineering

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor Degree of Mechatronic Engineering.

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DEVELOPMENT OF SYSTEM CONTROLLER AND VOICE-CONTROLLED MOBILE APPLICATION TO CONTROL AN OMNI-WHEELED MOBILE ROBOT

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A report is submitted in partial fulfilment of requirements for the
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DECLARATION

I declare that this thesis entitle "DEVELOPMENT OF SYSTEM CONTROLLER AND VOICE-CONTROLLED MOBILE APPLICATION TO CONTROL AN OMNI-WHEELED MOBILE ROBOT" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………………

Name : ………………………………………

Date : ………………………………………

DEDICATION

To my beloved

supervisor

and family

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I would like to gratefully acknowledge this people for the success of this project.

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who directly, indirectly and unconditionally guide me towards the accomplishment of this project.

ABSTRACT

The main purpose of a mobile robot is to perform high maneuverability and accurate positioning, but indoor environment often fails the performance of the mobile robot. This is because indoor environment is compact and has limited space for movement. Besides that, unlike global positioning system (GPS), indoor positioning with high resolution is not easy to achieved. Hence, this project emphasizes on improving the movement precision and controllability of a indoor mobile robot. The objective of this project is to develop an omni-directional mobile robot that can achieve high maneuverability and accuracy. A mobile application is designed and developed too to control the mobile robot by using speech recognition. To achieve precise movement, dead-reckoning method is applied on the mobile robot to create a closed-loop system. One PS/2 protocol fastball mouse is used to attain two degree-of-freedom and coordinate-based precision and navigation. MIT App Inventor 2 is used to create an Android mobile application in which its functionality is controlled by using speech. Algorithm-based libraries are created and compiled so that the speech spoken can be in English, Malay language or Chinese langauge. A HC-05 Bluetooth module is connected to an Arduino Mega 2560 on the mobile robot to serve the purpose of establishing communcation with the mobile application. A system controller, in this case a Proportional (P) controller, will be implemented and tuned by using Ziegler-Nichols tuning method, then followed by improving the controller by using gain-scheduling method. Analysis is conducted on the performance of the system controller with and without gain-scheduling enhancement. At the end of this project, a speech-controlled Omni-wheeled mobile robot with precision of ± 0.10cm is developed.

ABSTRAK

Tujuan utama robot jenis mudah alih adalah untuk mencapai cara pergerakan bertingkas dan kedudukan yang tepat, tetapi, kawasan tertutup seringkali menyebabkan prestasi robot jenis mudah alih mengecewakan. Hal ini berlaku kerana kawasan tertutup mempunyai kawasan pergerakkan yang padat dan hal ini menyebabkan prestasi robot jenis mudah alih digagalkan atau ditewaskan. Projek ini bermatlamat untuk menghasilkan satu robot jenis mudah alih yang dilengkapi dengan tayar-omni dan robot tersebut akan dikawal oleh aplikasi telefon bimbit pintar melalui teknik pengenalan dan pentaksiran ucapan manusia. Bagi mencapai ketepatan yang tinggi bagi pergerakkan robot tersebut, cara perhitungan akan diaplikasi bagi mewujudkan satu sistem tertutup dan berkitar. Satu PS/2 protokol tetikus bola akan digunakan bagi mencapai dua paksi darjah kebebasan dan pergerakan yang tepat melalui koordinasi. MIT App Inventor akan digunakan untuk mencipta satu aplikasi Android bagi telefon pintar di mana aplikasi tersebut dikawal melalui ucapan manusia. Pusat sumber yang dalam format algoritma akan ditubuhkan agar aplikasi telefon bimbit pintar tersebut boleh memproses ucapan manusia dalam bahasa Inggeris, bahasa Malaysia dan bahasa Cina. Modul Bluetooth HC-05 akan disambung kepada Arduino Mega 2560 di atas casis robot dengan tujuan menubuhkan komunikasi antara robot dengan telefon pintar. Satu pengawal akan dilaksanakan dengan menggunakan cara Zigler-Nichols. Seterusnya, pengawal tersebut akan ditingkatkan kuailitinya dengan melaksanakan cara pendapatan berjadual. Pada akhir projek ini, satu mudah alih robot beroda Omni-roda yang dapat mencapai ketepatan $\pm 0.10cm$ dan dikawal melalui ucapan manusia telah dihasilkan.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Indoor environment is often congested and limited. Its arrangement and pattern changes from time to time due to active human activity. Hence, any changes of this will affect and limit the movement and navigation of the mobile robot, eventually causing the robot to be outdated. Several studies and developments that were done on omni-wheel related mobile robot show that it always confronts with unprecise and inconsistent position and movement. The major factor for the problem is wheel's slippage and sliding. A closed-loop system is then introduced to produce feedback signal to control movement accuracy. Subsequently, the accuracy is then tested with resolution and sensitivity. Many researchers had done easily in constructing a closed-loop system, but the analysis and effort in improving the resolution and sensitivity of the overall system is still a fresh challenge. For example, moving a mobile robot to a specific coordinate such as (6m, 10m) is simple, but when moving the mobile robot to (6.00m, 10.00m), it is much tougher. Also, to revolve with angular displacement of $45°$ simpler than $45.0°$. Engineering knowledge on how physical parameters such as shaft length and wheel diameter, frequency of pulse-width modulation (PWM) and so on will affect the resolution. By reaching this stage, the precision will then play the key role in evaluating the value of the project. Hence, this is the real challenge that researchers nowadays need to deal with.

Classical remote control consists of many pushbuttons and big in size. It is as well as limited to specific operation as it is unprogrammable. This classic remote control become useless when the device it controls is no longer functioning, eventually become a junk. In addition, a normal pushbutton-based remote control may be too complicated to be controlled by old people and not suitable for handicapped person. Therefore, a voice controlled mobile application is introduced in this project to replace the classical remote control.

1.2   Motivation

All electronic and electrical appliances were once controlled by pushbuttons and switches only, but now, a speech-controlled device is the mainstream of today's technology. With the introduction of Google's Voice Actions, Apple's Siri and other offline human voice processing processor, many devices can now easily interface with speech-recognition technology [1]. In fact, speech recognition machine is now not merely transposing speech to words, but researchers and developers have been working on the capability to transpose and translate at the same time. Artificial intelligence is introduced to enhance the voice signal processing system. With the fact that this is the technology for this era, hence, speech and voice recognition are the inescapable method that needs to be approached and applied in this research and development. Figure 1.1 shows a few types of speech recogniser graphical user interface (GUI).
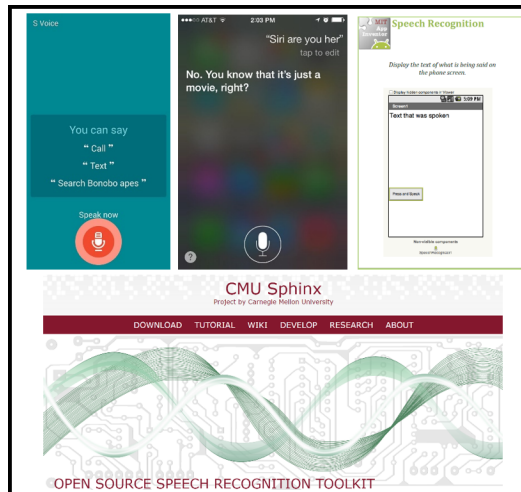
Figure 1.1: Types of speech recognisers

A mobile robot is known for its ability to perform task wirelessly via supervisory control or automation. However, a congested environment will hinder the mobile robot to exhibit its functionality, hence loses its primary course and objective. An advanced legged mobile robot is able to move in any direction in any orientation while for wheeled mobile robot, it has to rotate its orientation beforehand. In other words, wheeled mobile robot is not a headless system. However, there's an exception for omni-wheeled mobile robot as it is headless [2]. Hence, instead of creating a common wheeled robot, a omni-wheeled robot will be developed. Figure 1.2 shows a few general types of Omni wheels physical body.

Figure 1.2: General types of Omni-wheels

The combination and interaction of speech recognition method and omni-wheeled system will prominently outstand the superiority of a mobile robot, and the analysis result will 'speak' on behalf of this statement. This projects hope to contribute improvement and research result for future indoor transportation vehicle. For example, a better wheel chair for disabled, an accurate robotic waiter for restaurant and so on.

1.3   Objective

The objectives set for this project are:

1. To design, develop and fabricate a omni-wheeled mobile robot.

2. To develop mobile application that controls the robot functionality and navigation using speech recognition method.

3. To study and analyse the performance of the system controller developed for the mobile robot in term of steady-state error and positioning accuracy.

1.4   Scope

This project covers the design and development of a four omni-wheeled mobile robot. This omni-wheeled mobile robot has two degree-of-freedom. It is required to navigate and move based on coordination method. The coordinate value is fed from a PS/2 protocol fastball mouse. Then, Ziegler-Nichols method is used to tune and determine the most suitable system controller for the mobile robot, in this case, a Proportional controller. To further improve the positioning accuracy by reducing the steady-state error, gain-scheduling method is implemented. This project also involves the development of an Android-based mobile application to control the omni-wheeled mobile robot by using speech recognition. The speech recognition is capable to understand English, Malay language and Mandarin. The mobile application is created by using MIT App Inventor 2. Performance testing of the mobile robot is conducted and the comparison between P controller and gain-scheduled P controller is analysed and recorded.

CHAPTER 2

LITERATURE REVIEW

2.1   Introduction

Communication is the fundamental of all interactions between human beings; the bridge that leads to exchange of information. The importance of communication is foreseen by many legendary leaders thousand years ago. This includes King Sejong, the creator of Korean language character and Qin Shi Huang, the founder of Qin dynasty who is well-known for his masterpiece - Great Wall of China. During Qing Shi Huang's reign, he instructed everyone to write only in Chinese character disregard of their speaking languages and dialects, for the purpose of unity. Eventually and until today, many countries languages can be seen using some Chinese character. In some extent, a Chinese nowadays can understand a little bit about a Japanese-written product's title and description. Anyway, this reflects how language has evoluted and became a necessary tool in our daily life. Human was once communicates with other human only, but now, human instruct machines through speech. The speech recognition technology has reaches an extent where not only we tell machine, but machine tells us too. Speech recognition Application Program Interface (API) such as Google's Voice Actions and Apple's Siri have been working effortfully in their own way in bringing this technology to higher level [1].

The applicability of voice recognition technology is wide; from indoor to outdoor,

from personal to public, and they shares the same objective - to improve our living standard. The same objective applies to this research; to improve the quality and technology of this research. Therefore, generally, this research utilises voice recognition technology and see how far its advantage and flexibility extend.

The following subsections are studies and reviews based on specific hardware, software and feature for this research area. The initial direction for this research is achieving high flexibility and high movement precision of a robotic car via voice instruction command using mobile application. In addition, this research aims to contribute in the fields of voice recognition method and mobile robot system performance. Hence, sufficient study is constructed in order to understand the current technology and an improvisation will benefit the society, world and future generations.

2.1.1 Review on Existing Projects

This subsection reviews some existing studies that share some similarity with this research. These selected researchs have the similarity of using either voice recognition method, mobile application, Omni wheels or wireless communication method or all of them.

Ch. Pandu Ranga Sai *et. al.* has successfully developed a smart remote using MIT App Inventor, Bluetooth and Infrared (IR) transceiver. Generally, a smart phone will send command to a microcontroller equipped via Bluetooth, then the microcontroller will react and tramit specific IR singal to the home appliance. In this research, the IR signal needs to be set with specific protocol in order to communicate with the home appliance [3].

Prashanth Kannan *et. al.* controls automation using voice recognition. They apply a combination of Python Scripting Language and Android operating system to create the control system of the research. It is said that such combination is more efficient and flexible. The automation in the research is controlled by using relay while the relay is controlled by

microcontroller. The communication method between Android and the microcontroller is via Bluetooth [4].

Norhafizah bt Aripin *et. al.* has designed and developed a system that controls home appliances using voice via Android platform. The voice recognition and mobile application in the research are created using Basic4Android software. There are two controlling method in the research - either through voice control or button control, both requires Bluetooth. At the end of this research, analysis result shows that the Bluetooth module used has the ability to transceive up to 20m [5]

Sanja Primorac *et. al.* uses Android platform to create an mobile application that sends SMS via speech recognition. In this paper, the authors briefly compare Google's Voice Action and Apple's Siri. In this paper, Android operating system is described in detailed. Various types of voice recognition algorithms are mentioned and compared. Then, the author ends with most preferred algorithm [1].

Shraddha Uddhav khadilkar *et. al.* have designed and developed a smart wheelchair that operates via voice, gesture and touch methods using Android phone. Bluetooth connects the Android phone and an AVR microcontroller. Gesture method functions using built-in gyroscope in the Android phone. At the end of the research, a research was done based on how smart phone tilting angle affects the accelerometer [6]

R. Piyare *et. al.* have designed a home automation system that operates using merely a cell phone. Microcontroller Arduino Bluetooth board was connected to relays to control home appliances. The communication between the cell phone and the microcontroller is via Bluetooth transmission. [7]

Anurag Mishra *et. al.* designed and developed an assistant robot via voice-controlled. The assistant robot has a total of four DC motors. Two of them are used to control robot's body movement while another two are used to control robot's arm and hands. The robot has one arm and two hands and eventually forming a gripper. The research uses Bluetooth communication and mobile phone's Android operating system to perform voice recognition, however it does not mention the type of mobile application creator software used. At the end

of the research, several studies such as robot's body, arm and hand movement were done. The authors intends to explore the effect of noise and distance between mouth and the smart phone in future study. [8]

Kenjiro Tadakuma *et. al.* has designed and developed an Omni-directional wheel known as 'Omni-Ball'. This 'Omni-Ball'. The physical construction of 'Omni-Ball' is much simpler than Mecanum wheel and other exisiting Omni-directional wheels; it is basically made of of two hemisphere wheel. At the end of the research, the analysis shows that 'Omni-Ball' has better ability to perform step-climbing and gap-tranversing compare with Omni-wheel [9].

J. A. Cooney *et. al.* designed and developed a Mecanum-wheeled mobile robot with motion control using visual dead-reckoning method. The visual dead-reckoning method in the research is the implementation of two optical mouse in taking x- and y-coordinates. PID controller is used for the system. Open-loop and closed-loop tests are conducted to analyse system performance. [10]

K. Kannan *et. al.* has designed and developed a voice-controlled mobile robot with legged-system. Instead of using mobile application to perform voice recognition, a stand-alone speech-recognition circuit (SRC) is used. This circuit has the ability to be re-programmed. Hence, user can calibrate and uses specific voice command to control the robot instead of standard speech. The reason of applying SRC is because every person has unique speaking pattern, hence with such custom-programmed speech, the control of the robot may be easier. [11].

2.1.2   Review on Indoor Positioning System

The development of indoor positioning system is always a challenge for many researchers. Different approaches have been done and compared to achieve indoor positioning, these

include the application of accelerometer, Bluetooth Received Signal Strength Indication (RSSI), Wireless Fidelity Simultaneus Localization and Mapping (WiFiSLAM) and so on. Basically, indoor positioning method is divided into two types - inside-out system or outside-in system [12]. Inside-out system, such as RSSI, WiFiSLAM and GPS need another device or source as reference point to calculate the distance between two nodes. This method is normally more complicated as it is fully dependent on resources. Moreover, this method has flexibility limitation as it only works at specifically allocated area or region [13]. For outside-in system, such as accelerometer and PS/2 protocol mouse, do not depends on other devices to perform, but only needs a reference point. This method is known as dead-reckoning method.

J. A. Cooney *et. al.* foresee the problem of indoor mobile robot in to achieve high positioning accuracy. Hence, they have designed and developed a four-wheeled Mecanum robot with dead-reckoning method by using PS/2 protocol optical mouse. In their project, PID controller is implemented and is able to achieve ± 1mm for forward and backward movement whereas ± 5mm for arbitrary angled movement [10].

2.1.3 Review on Sound, Voice and Speech

Voice recognition and speech recognition are often mixed up being classified in the same category. However, they are not likely to be alike [14]. Speech is voice, but not all voice is speech. In other words, speech recognition recognises based on language while voice recognition recognises as long as there's human voice; disregards of the type of language spoken [14]. At the end, voice and speech are subcategory of sound. Sound includes noise as well, and as long as it is something that is audible to human (20 Hz to 20 kHz). However, there's some researcher insists that speech does not need to be understandable by human only; as long it is understood by a system [11]. At the end, this discussion creates some argument due to different perspective.

Sound recognition is easier compare to voice and speech. Meanwhile, voice recognition is simpler compare with speech recognition. Figure 2.1 shows the flow in recognising and processing sound, voice and speech.
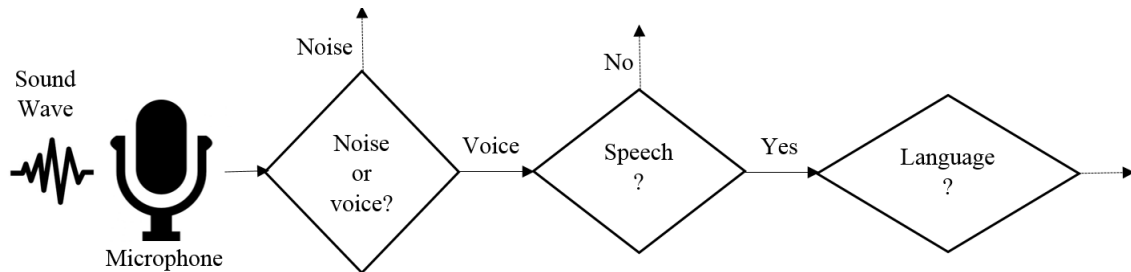

Figure 2.1: The flowchart in categorising sound, voice and speech.

The sound wave is analysed with its pitch level, tone, melody scale, bark scale and loudness level to determine whether it is a voice or noise [14]. Voice can be the voice of human or animal. Then, only human voice is classified into the category of speech. Then, the next step is to determine what type language the speech belongs. Throughout this process, different types of method are applied in order to reach the final state [1, 14, 4]. All methods are studied in order to understand the pros and cons of these different approaches.

The sound recorded by a microphone is a raw signal that may or may not contain any voices. Signal processing in this phase basically serves the purpose of removing noise. George Frewat et. al. have proposed three noise removal techniques, they are maginitude filtering, frequency filtering and calibration [14]. The buzz of noise is so soft until it is inaudible to us, but this does not mean that it does not exist. It can be clearly caputured by microphone. The magnitude of noise often lies at a low decibel (dB) range and has specific frequency. Hence, the techniques of magnitude filtering and frequency filtering in [14] make use of this fact by high-passing sound that is above a threshold and band-passes varying sound frequency respectively - as the frequency of noise is constant. Calibration is an approach that either to adapt noise or voice or both. In [11], the calibration method involves only voice adaptation while in [14], it involves both noise and voice adaptations. The noise adaptation and voice adaptation are generally a procedure of taking noise sample and voice sample respectively.

The filtering process itself is insufficient to determine whether the sound is noise or