MANUAL MOBILE ROBOT FOR ROBOCON

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Bachelor of Mechatronic Engineering

2009

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This report is submitted in partial fulfillment of requirements for the degree of Bachelor in Mechatronic Engineering

Faculty of Electrical Engineering
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2009

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

Signature : ……

Name : ……

Date : ……

Specially dedicated to my beloved family especially my mother (M.Anjalay Devi) and my father (N.Shanmugam) for their support. To my project supervisor En.Ahmad Zaki Bin Haji Shukor for excellent guidance and supervision. This success will never be achieved without all of you.

ACKNOWLEDGEMENT

First of all, I would like to thank God for His blessings that lead to the success of this project. I would like to express gratitude to my family for never ending support and motivating me throughout the project development. My heartfelt appreciation to my Project Supervisor, En Ahmad Zaki Bin Haji Shukor for supporting my decisions, ideas and progress in this project. He has been a best guide and ideologist behind the development of the project with the confidence and inspiration given to execute this project. Thanks to Machine Workshop technician, Muhammad Azwan Bin Abdul Kadir for guiding me during development of Mecanum wheels and other mechanical structure for the project. Last of all, I would like to thank Robocon 2009 team members, Robocon lab technicians, and related lectures for the support and contribution towards the accomplishment of this project.

ABSTRACT

This project presents the research, designing, and development of multi-directional mobile robot using four custom-made Mecanum wheels for Robocon 2009 application. The Mecanum wheels that were designed and developed consist of six passive rollers made from rubber and the wheel body made of Polyethylene (P.E). The Mecanum wheels are autonomously controlled using four units of industrial specification VEXTA AXHM230K-GFH brushless geared DC motors and the motors were mounted directly to the robot platform constructed using an aluminum frame. The wheels are directly coupled to the motor shaft for direct actuation and precise control of each motor independently. IFC (Interface Free Controller) microcontroller board with build in PIC18F MCU used to operate the robot. The stackable boards contain a main board card, power card, two brushless motor cards, and a PS2 joystick card. A fundamental multi-directional mobility developed using MPLAB IDE programming software to analysis the basic mobility capabilities and performance of the mobile robot that will counterpart Robocon environment. A visual experiment was set-up to analyze the motion characteristic of the mobile robot motion in Y and X axis, rotary motion, and finally diagonal motion. Mecanum wheel mobile robot provides an opportune platform for further development in the mobile platform beyond research and educational purpose. The synchronization of Mecanum wheels mechanism, robot platform mechanical design, flexible motion control, and multiple feedbacks from input/output devices allows the exploration of great extend of control algorithm of the robot for practical and commercial applications.

ABSTRAK

Projek ini merangkumi kajian, merekabentuk, dan membangunkan robot insani pelbagai gerakan menggunakan tayar Mecanum buatan untuk aplikasi dalam pertandingan Robocon 2009. Tayar Mecanum yang direka bentuk dan dibangunkan ini mengandungi enam gelonsor getah dan rangka tayar yang diperbuat daripada Polyethylene (P.E). Setiap tayar Mecanum di kawal secara berasingan dengan motor *brushless* gear DC spesifikasi industri, VEXTA AXHM230K-GFH yang dipasang terus pada rangka robot yang dibina dengan aluminum. Kesemua tayar Mecanum ini dipasang terus pada *shaft* motor untuk pacuan terus dan kawalan yang lebih jitu bagi setiap satu motor. Mikrokawalan *IFC (Interface Free Controller)* bina dalam PIC18F MCU digunakan untuk mengawal gerakan robot yang dihasilkan. Papan kawalan bertingkat ini terdiri daripada kad utama, kad kuasa, dua kad motor *brushless* dan kad *joystick PS2.* Pergerakan asas robot pelbagai arah dibina dengan program MPLAB IDE dengan analisa kebolehan gerakan pelbagai arah untuk di gunapakai dalam pertandingan Robocon. Satu eksperimen visual dilaksanakan untuk menganalisis sifat gerakan robot insani ini pada gerakan paksi X dan Y, pusingan pada paksi tengah dan gerakan penjuru. Robot menggunakan Mecanum wheel mempunyai masa depan untuk berkembang maju selain untuk kajian dan pendidikan. Gabungan mekanisma tayar Mecanum,rekabentuk mekanikal rangka robot, kawalan gerakan bebas dan pelbagai suapbalik daripada perkakas masukkan dan keluaran memberi ruang yang luas untuk *algorithm* kawalan robot untuk aplikasi praktikal dan komersial.

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LIST OF ABBREVIATIONS

IFC	-	Interface Free Controller
ICR	-	Instantaneous Center of Rotation
DC	-	Direct Current
CCW	-	Counter Clock Wise
CW	-	Clockwise
CNC	-	Computer Numerical Control

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Multidirectional robot movement with real-time control interface has become an integral part of a modern robotic technology. Several designs of modern and technically enhanced wheels has been found and developed to improve the movements of robots and other robotic machines for industry appliances and commercial use. The designs of omni-directional vehicles have been proposed and the approaches divided into two classes as such the conventional wheel designs and special wheel designs.

The conventional wheels are mechanically simple, have high load capacity and high tolerance to work surface irregularities. Nevertheless, due to their non-holonomic nature (Fig 1.1), they are truly omni-directional. Designs have been proposed to achieve near omni-directional mobility using conventional wheels. The most common one is the steered wheels. They can move in any direction from any configuration but it is not a truly omni-directional because it need to stop and re-orient wheels to the desired direction whenever it need to travel in a trajectory with non-continuous curvatures. Special wheels designs are based on a concept that achieves traction in one direction and allow passive motion in another, thus allowing greater flexibility in congested environments. One of such wheel named as Mecanum wheel and most design of such wheel is based on its concept.

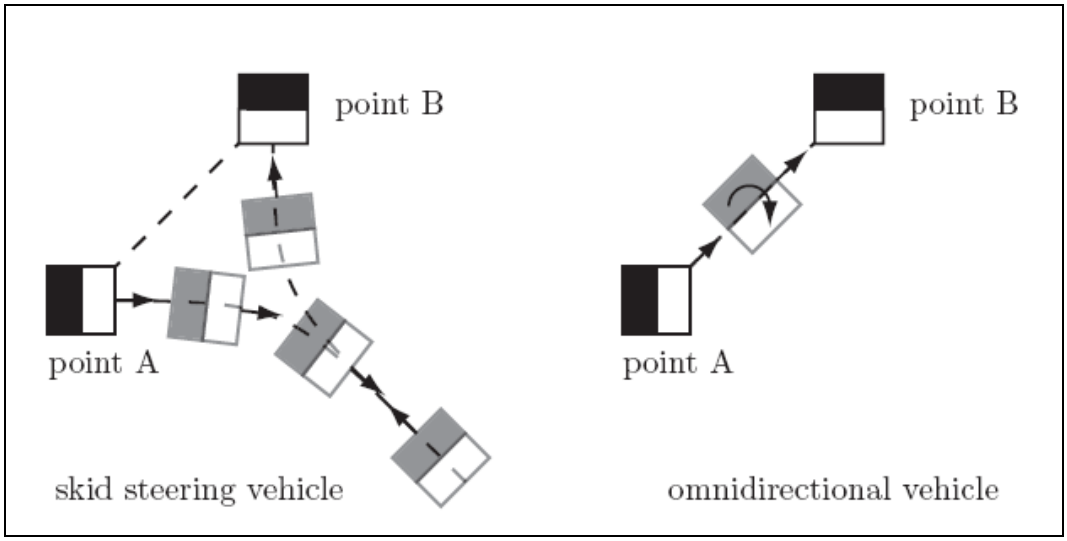

Figure 1.1: Non-holonomic mobility versus omni-directional mobility

This project employs a multidirectional actuating wheel name by Mecanum or Swedish wheel to develop a multidirectional manual mobile robot. The Mecanum wheel was invented in 1973 by a Swedish engineer (Mecanum Company), named Ilon (Ilon, 1975). This is why it is called Mecanum or Swedish wheel.

Mecanum wheel is based on the principle of a central wheel with a number of rollers placed at an angle around the periphery of the wheel. The angled peripheral roller translates a portion of the force in the rotational direction of the wheel to force normal to the wheel directional. Depending on each individual wheel direction and speed, the resulting combination of all these forces produces a total force vector in any desired direction hence allowing the platform to move freely in direction of resulting force vector, without changing the direction of the wheel. Figure 1.2 shows a traditional Mecanum wheel design by Ilon with the peripheral roller with 45° degree slope held in place from the outside. The concept is by using four mecanum wheels to provide omnidirectional movement for a vehicle without needing a conventional steering system.

Due to the dynamics of the mecanum wheel, it can create force vectors in both the x and y-direction while Fig. 1.2: Mecanum wheel based on Ilon's concept, only being driven

in the y-direction. Positioning four Mecanum wheels, one at each corner of the robot base (two mirrored pairs), allows mesh forces to be formed in the x, y and rotational direction (Fig. 1.3). A difficulty with this strategy is that there are four variables to control three degrees-of-freedom. In this case the system is said to be over determined and it is possible to create conflicts in the actuation. As a result of the constraints associated with the Mecanum wheel some form of controller is required to produce satisfactory motion.

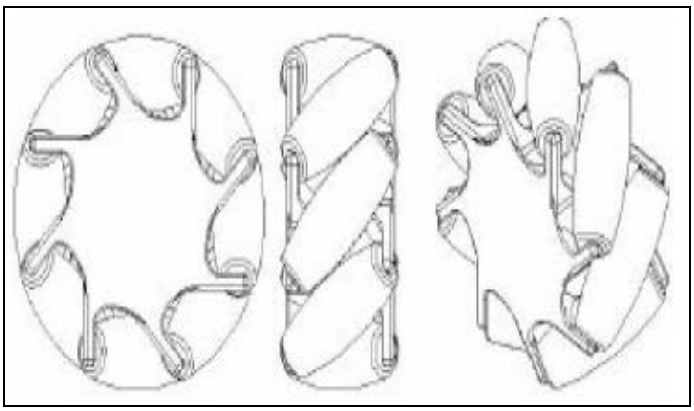

Figure 1.2: Traditional Mecanum wheel design by Ilon (1975)

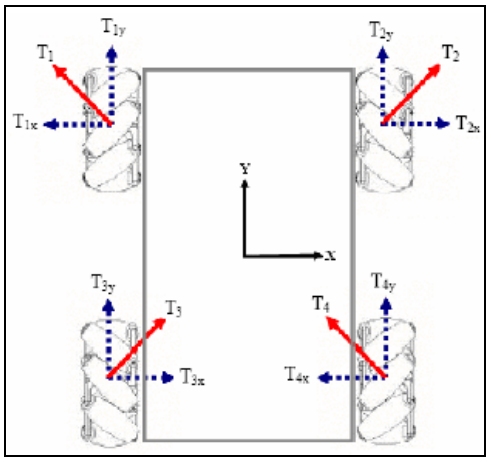

Figure 1.3: Force vectors generated by Mecanum wheel

1.2 Objective

Omni-directional mobile robot drive has wide range of studies and development, therefore the core idea of the project defined at initial stage of research and development. Although there are variety of wheels and configuration applied to achieve omni-directional mobility, this project emphasis multi-directional mobile robot using Mecanum wheel and the objective to be attained as following:

a) To design and fabricate a suitable Mecannum wheel for a mobile robot drive that could enhance omni-directional mobility.
b) To arrange the wheels in a suitable configuration for the mobile robot drive to achieve an efficient omni-directional movement
c) To achieve multi directional motion using the wheels arrangements on the robot base with appropriate mounting method.
d) To select required multidirectional motions for manual robot based on the Robocon environment. Commonly X-axis and Y-axis motion.
e) To implement joystick control for the multidirectional robot drive as input to the microprocessor to synergize with the program created to control the wheels independently.

1.3 Scope

The project scaled to accomplish specific requirement based on the project objective. This does employ certain project development proficiency to ensure the result achieved within the scope defined. Therefore, clear pictures of the project requirements need to be comprehended. The following are the scope of the project;

a) Research, Design & Develop the most appropriate & efficient mecanum wheel for a mobile robot in achieving multidirectional movement. This will consist of research

on types of Mecanum wheel design available and choose the most suitable type that can be fabricated yet applicable. The design for the wheels primarily focused to the ease to fabricate and efficient, low cost as well. Development process of the wheel entirely involves mechanical process and conducted with conventional machines.

b) Configure the mechanism of Mecanum wheel with driver to obtain the desired omni-directional motion. Each of the wheels required to be controlled independently because of the wheel mechanism as such to obtain omni-directional movements as desired combining the microcontroller and joystick to make up the system.

1.4 Problem Statement

Robots using conventional wheels such as steered / castor wheels, (Fig. 1.4) are inherently simple but the circumstances are it has high load capacity and high tolerance to floor irregularities such as bumps, cracks, dirt and debris.

Figure 1.4: Castor wheeled robot

Mobile robots based on this design have at least two active wheels, each of which has both driving and steering actuators. They can move in any direction from any configuration. However, this type of system is not truly omni-directional because it needs to stop and re-orient its wheels to the desired direction whenever it needs to travel in a trajectory with non continuous curvatures.

One major drawback of conventional wheel designs is the high friction and scrubbing during the steering as the wheel is actively twisted around a vertical axis. This reduces positioning accuracy and increases power consumption and tire wear. The fundamental cause of the scrubbing problem is that the wheel generates larger frictional forces when steered actively around a vertical axis than when it is rolling.

Besides of those stated circumstances, to control the conventional wheeled robots is complicated in a situation where it is required to achieve a target destination in most accurate position and high acceleration. This is the basic requirement that a mobile robot must have where it's one of the specification required for a Robot competition. In a state of time constrain, robot having a castor wheeled or steered wheeled difficult to achieve acceleration by remaining desired accuracy at the same instants.

1.5 Literature Review

1.5.1 Review 1

a) Title: Improved Mecanum Wheel Design for Omni-directional Robot
b) Author: Olaf Diegal,Glen Bright & Johan Potgieter
c) Institution: Massey University, Aukland
d) Description: The efficiency of Mecanum wheel can be improved mechanically by improving the energy losses during traveling & the peripheral rollers have the capabilities of having its angles dynamically adjusted to best suit the direction the platform is traveling. The efficiency explained as the technical performance that could be improved from modification in the core elements of the Mecanum wheel.
e) Review outcome: There are three main elements in this wheel that affects its performance that is:
    i. Angle of peripheral rollers on central wheel
    ii. Numbers of peripheral rollers

iii.Design of peripheral rollers

Based on the contents of this literature, it is learned that there are possibilities to improve the performance of the wheel by varying the main elements of the wheel. Therefore, the design of the Mecanum wheel should consider all three the elements of the wheel.

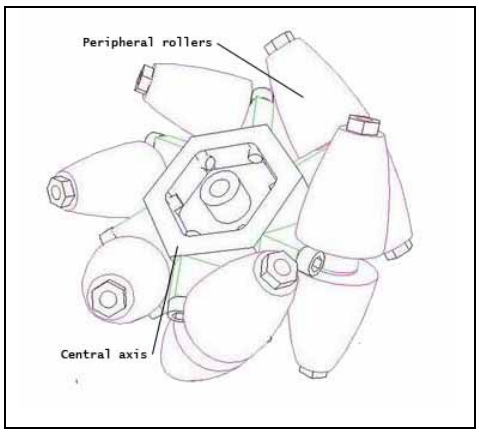

Figure 1.5: Mecanum wheel

1.5.2 Review 2

a) Title: Designing Omni-Directional Mobile Robot with Mecanum Wheel
b) Author: Jefri Efendi Mohd Salih, Mohamed Rizon, Sazali Yaacob
c) Institution: Terengganu Advanced Technical Institute, Malaysia
d) Description: Design and development of an omni-directional platform, using mechatronics system and Mecanum wheels creates intelligent behaviours and maneuvers. With the combination of a microcontroller interfaced with sensors the robot could achieve extreme maneuverability in congested environment. The combination of mechanical design on the wheel and chassis, motion control and multiple input/output sensors allow the exploration of large number of control algorithm and software to be implemented to the robot for desired applications.

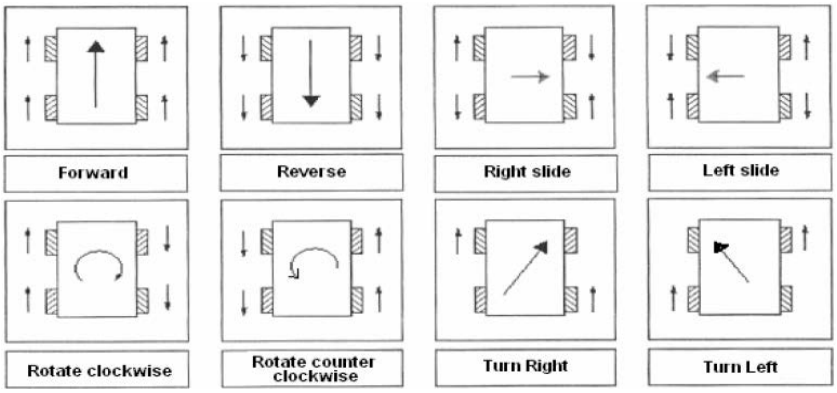

Figure 1.6: Required wheel actuation for general movements

Table 1.1: Motor control for basic motion

PWM_1	DIR_1	PWM_2	DIR_2	PWM_3	DIR_3	PWM_4	DIR_4	Basic Motion
High	High	High	High	High	High	High	High	forward
High	Low	High	Low	High	Low	High	Low	backward
High	Low	High	High	High	High	High	Low	right slide
High	High	High	Low	High	Low	High	High	left slide
High	High	High	Low	High	High	High	Low	Turning clockwise
High	Low	High	High	High	Low	High	High	Turning counter-clockwise

e) Review outcome: The literature explains that the Mecanum wheel could be used when an appropriate combination of mechatronic systems applied to the robot platform. This describes that when the synergized systems applied for the desired robots it depicts the intelligence behavior of the robot. Intelligent in this term can be explained as the robot capable to move to any direction from any configuration with a simple control. To achieve truly omni-directional movements using the Mecanum wheel, it requires an accurate motor drive whereby the system entirely depends on the rotation direction and speed of the driver motor. Furthermore, intelligent criteria for the robot be able to implemented in the programming as well.