OMNI DIRECTIONAL CONTROL ALGORITHM FOR MECANUM WHEEL

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ABSTRACT

The purpose of this project is to create an algorithm for controlling the speed of Mecanum wheels mounted with DC Brushless motor installed at a robot chassis, so it can be control to move at any desired angle ranging from 0° until 360° without changing the direction faced by the robot. A robot attached which use the Mecanum wheels to move is called Mecanum Drive. The Mecanum drive is a combination of 4 units of Mecanum Wheels. This type of wheel is designed to perform direction change without using steering control. The Mecanum drive will change direction according to the wheels rotation speed and rotation direction. To do this, a special control algorithm is needed to manage all the variables involve for controlling the speed of the Mecanum drive. The main objective for developing this algorithm is to manipulate the speed and the direction input from robot operator to produce a Pulse Width Modulation, PWM, multiplier for each of DC Brushless motor equipped at the Mecanum Drive. The speed of each motor and the rotation direction of the motors are different. To ensure the motor is rotating at the right speed and the right direction, each of the motor revolution per minute, RPM, will be display using XCTU software which read input received from XBEE module. The calculation for motor RPM is done by translating the pulse send by motor driver into interrupt pin input of micro controller. For a complete 1 rotation, there will be 30 pulse received from motor driver. By using a simple equation to translate the pulse into rotation counting data, the RPM of each motor is stored in variables for each of the motor and transmit through XBEE module.

ABSTRAK

Tujuan projek ini adalah untuk mewujudkan satu algoritma untuk mengawal kelajuan roda Mecanum dipasang dengan motor DC tanpa berus dipasang pada kerangka robot , supaya dapat dikawal untuk bergerak ke mana-mana sudut yang dikehendaki antara 0 ° hingga 360 ° tanpa mengubah arah yang yang dihadap oleh robot. Sebuah robot yang dipasang tayar Mecanum dipanggil Pemacu Mecanum. Pemacu Mecanum adalah gabungan 4 unit tayar Mecanum . Tayar ini direka untuk melaksanakan perubahan arah tanpa menggunakan kawalan stereng . Pemacu Mecanum akan berubah arah mengikut kelajuan putaran dan arah putaran tayar. Untuk melakukan ini, algoritma kawalan khas diperlukan untuk menguruskan semua pembolehubah yang terlibat untuk mengawal kelajuan Pemacu Mecanum. Objektif utama untuk membangunkan algoritma ini adalah untuk memanipulasi kelajuan dan masukan arah daripada pengawal robot untuk menghasilkan Denyut Pemodulatan Lebar , PWM, pengganda bagi setiap Motor yang dipasang dengan tayar Mecanum . Kelajuan setiap motor dan arah putaran motor adalah berbeza. Untuk memastikan motor yang berpusing dengan kelajuan yang betul dan arah yang betul, setiap putaran motor bagi seminit , RPM, akan menggunakan paparan pada peririsan XCTU yang akan membaca masukan data melalui peranti tanpa wayar XBEE. Pengiraan untuk RPM motor dilakukan dengan menterjemahkan denyut yang dihantar melalui pemandu motor ke dalam input pin sampukan pengawal mikro. Untuk 1 pusingan lengkap , akan ada 30 denyut yang diterima daripada pemandu motor. Dengan menggunakan persamaan yang mudah untuk menterjemahkan denyut ke dalam data putaran pengiraan , RPM setiap motor disimpan dalam pembolehubah bagi setiap motor dan dihantar melalui peranti tanpa wayar XBEE.

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GLOSSARY

DC	-	Direct Current
LCD	-	Liquid Crystal Display
RPM	-	Revolution Per Minute
PIC	-	Programmable Integrated Circuit
PWM	-	Pulse Width Modulation
BLDC	-	Brushless DC Motor

CHAPTER I

INTRODUCTION

1.1 MECANUM WHEEL

Figure 1: 152mm Mecanum Wheel

Mecanum wheel is a unique wheel that allowing a vehicle to move at any degree translation when moving at a certain speed and rotation direction. This wheel is designed by Swedish Inventor Bengt Ilon, an engineer from a Swedish company named Mecanum AB. [8]

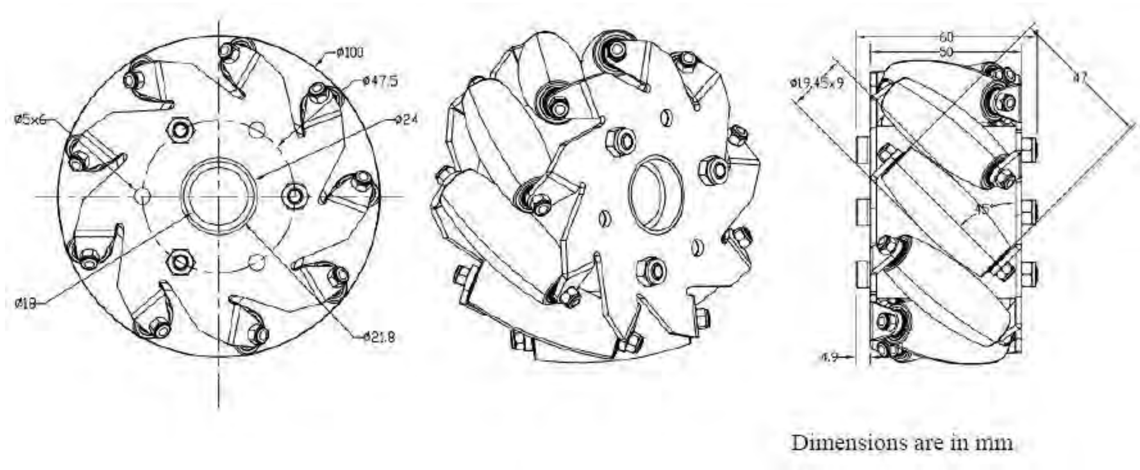

Figure 2: 100mm Mecanum Wheel Design

This wheel is a conventional wheel but mounted with a series of small rollers around its circumference. This small rollers is mounted along the wheel rim with a shifted of 45° angle to the wheel plane. By switching the wheel right and left side rollers, the vehicle with the wheel can move at any direction when each of the wheels is applied with a varying speed and direction of rotation.[4]

Figure 3: Mecanum Forklift

Ilon named the wheel after the company name but sometimes people calling it the Ilon wheel. Shortly after acquiring the pattern for the design, in 1980, the US military has bought the patent for the Mecanum wheel from Ilon and setup a research division to work on the wheel .This wheel is widely used in US aircraft carrier as it can provide a special movement for forklift in the carrier to maneuver in a tight space.

Figure 4: Tracked Wheel

There is another type of vehicle which using similar method for rotating around is the tracked vehicles. Usually, this tracked wheel is used by tanks and crane. Unfortunately, these vehicles will caused damage to the ground when they rotating around. This is caused by the track which has no roll able surface being drag as the vehicle rotate. The drag means high friction and high friction means, a lot of engine torque power are required to overcome the friction. By using Mecanum wheel, it is proven by the design which allowing a rotation to be done with a minimal friction thus required low torque engine which will reduce the cost of engine.

Figure 5: Electric trolley with Ilon wheels. [10]

Mecanum wheel can be control by simply turn on and off a certain wheel to make the vehicle move to certain direction. However, this method only limited to a certain degree of direction. Figure 6 below is showing the direction that can be obtained from the method. **[10]**

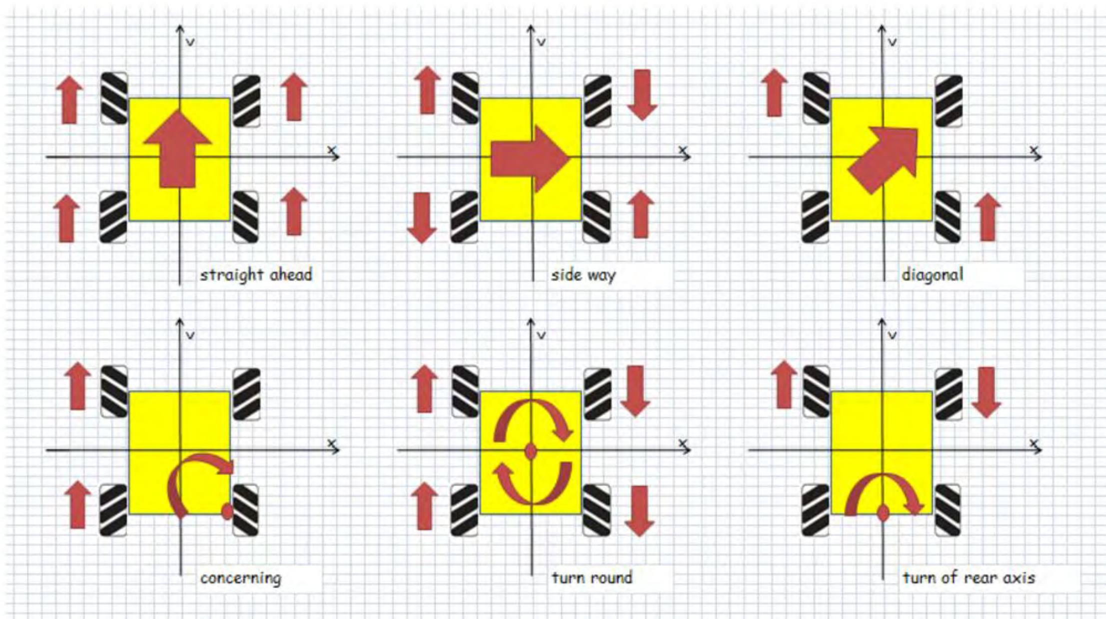

Figure 6: Basic Direction Control of Mecanum.[10]

In order to expand the direction limitation, each of the wheels needs to move at a different speed and different rotation. To do this, a special control algorithm is needed. The purpose of this project is to create an algorithm for controlling the speed of Mecanum wheels mounted with DC Brushless motor installed at a Robot, so it can be control to move at any desired angle ranging from 0° until 360° without changing the direction faced by the robot.

1.2 PROJECT OBJECTIVE

The objectives of this project are:

1. To study and analyze the speed of each DC Brushless motor needed in order to manipulate the Mecanum wheels for translating at specific degree of direction.

2. To construct algorithm for controlling each of the DC motor Speed and move the robot towards the desired angle of direction.

1.3 PROBLEM STATEMENT

The limitation of the robot movement using Mecanum by simply turning on and off the motor only enable the robot to move without changing it direction faced at 45°,90°,135°,180°,225°,270°315° and 360° only. To remove the angle limit, the speed and rotation direction of the Mecanum need to be manipulate. The difficulties faced in order to manipulate those variables are to calculate the speed required for certain angle translation, speed measuring and speed control in order to get the robot moving in the desired direction. This problem should be able to overcome by grouping each of the required tasks into a separate function and using a universal variable to hold the data.

1.4 WORK SCOPE

The work scope of this project is as listed below:

1. Develop an Algorithm for controlling Mecanum Wheels by using MPLABX and will be implement with PIC18F46K80, 4 sets of Mecanum Wheel & 4 Set of VEXTA DC Brushless Motor (30W).

2. Calculate voltage multiplier for each motor to translate the robot at a certain angle.

3. Capture speed output signal from VEXTA Motor driver that is giving out a 30ms pulse signal for every complete rotation through interrupt input at microcontroller.

4. Display the motor output speed to LCD.

1.5 REPORT STRUCTURE

Chapter 1

This is discussing about the overall project development planning starting from the objective, problem statement until the methodology for the project. This Chapter is basically an overview from top to down of the project.

Chapter 2

This chapter is to show the literature review that has been made for studying the method to be used in developing the algorithm. The content came from sources from other researcher who already doing research about the Mecanum wheel movement characteristic.

Chapter 3

This chapter shows the method will be used to develop the algorithm this includes hardware and software, flow charts and block diagram.

CHAPTER II

LITERATURE REVIEW

2.1 Mecanum Simplistic Control

From the research done by **Ian McInerney** from **FRC Team 2022- First Robot Conference** [2]**,** mentioned that variables need to be considered:

- **Desired Angle**: What angle the robot needs to translate at
- **Desired Magnitude**: What speed the robot must move at
- **Desired Rotation**: How quickly to change the direction the robot faces

All the variables are to be identified whether to let it be a constant or adjustable (within the limit).

From the variables that have been identified, he comes up with the equation to manipulate those variables in order to obtain the PWM multiplier for each of the wheel motor.

Using that information, the voltage multipliers for each wheel (numbers shown in Figure 1) can be calculated using the formulas found in Equation 1.

- $\boldsymbol{V_1 = V_d \; sin\left(\theta_d + \frac{\pi}{4}\right) + V_\theta}$
- $\boldsymbol{V_2 = V_d \; cos\left(\theta_d + \frac{\pi}{4}\right) - V_\theta}$
- $\boldsymbol{V_3 = V_d \; cos\left(\theta_d + \frac{\pi}{4}\right) + V_\theta}$
- $\boldsymbol{V_4 = V_d \; sin\left(\theta_d + \frac{\pi}{4}\right) - V_\theta}$

Equation 1

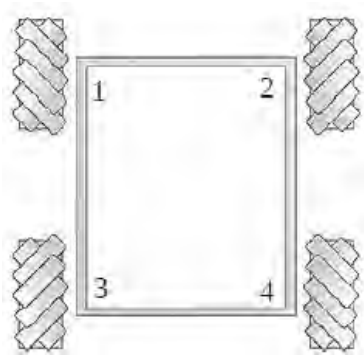

Figure 7: Number of Wheel

$\mathbf{V_x}$: Voltage Multiplier for X^{th} Wheel

$\mathbf{V_d}$: Desired robot speed [-1,1]

$\boldsymbol{\theta_d}$: Desired robot angle $[0,2\pi]$

$\mathbf{V}\boldsymbol{\theta}$: Desired speed for changing direction [-1,1]

This equation consists of 2 parts where:

1. **Force vector computation**
   - $V_d \sin\left(\theta_d + \frac{\pi}{4}\right)$ (2.1)
2. **Modification of rotation**
   - V_θ

The value for variable in those two parts can be modified using scalar quantity to adjust the rotation sensitivity. These equations will compute the voltage multiplier for the wheels, but they return a value which is between [-2, 2]. This range is larger than the desired range of [-1, 1]. The best way to fix that is to scale the outputs if any of them get above the desired range. This way the motors will travel at full speed in translation mode, but when rotation is commanded the outputs will scale to still be in the desired range of [-1, 1]. The process for scaling the motor outputs is shown in Chart 1.1.

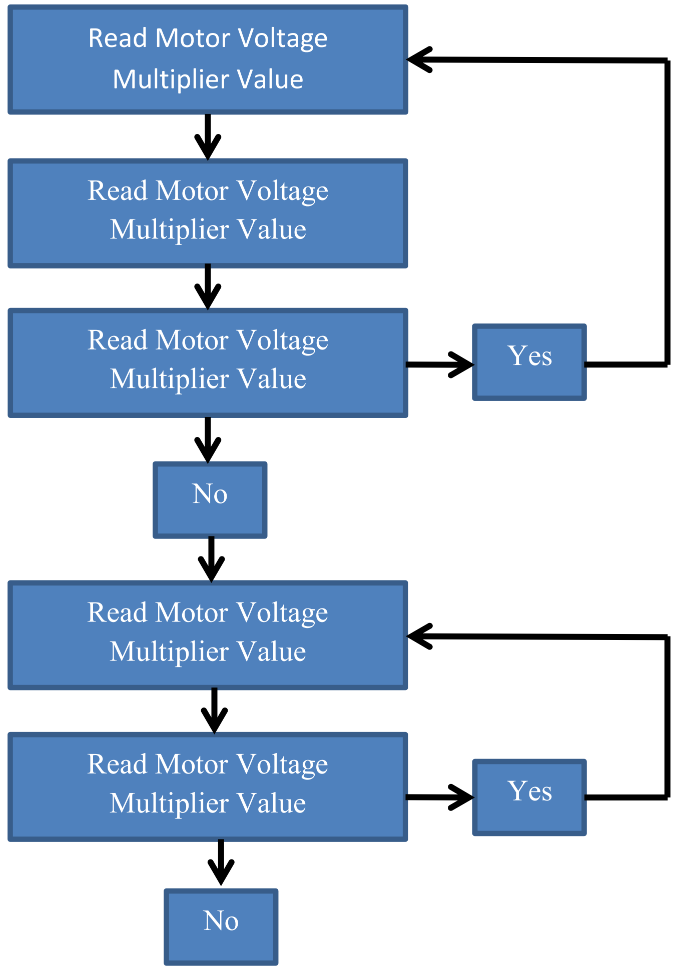

Chart 1.1: Normalization process for motor outputs

Ian McInerney state that when using this algorithm to scale the motor outputs when they go outside rang [-1, 1] the ratio between the motor speeds is preserved, maintaining the desired final vector. This process also has the advantage that when full power is demanded in translation mode, the wheels will output full power, whereas if any of the values were to be modified using a scalar in the formulas in Equation 1, then full power would not be provided when commanded. **[2]**

2.2 Brushless DC Motor

2.2.1 Introduction

Brushless DC electric motor, BLDC, or known by the other name, electronically commutated motors have many similarities to AC induction motors and brushed DC motors in terms of construction and working principles respectively. Like all other motors, BLDC motors also have a rotor and a stator. BLDC electric powered synchronous motors. The DC electric source is supply from an inverter which produces an AC signal. The AC signal in this context means a bi-directional current without waveform restriction. There are sensors and controllers to control the inverter output.

2.2.2 Stator

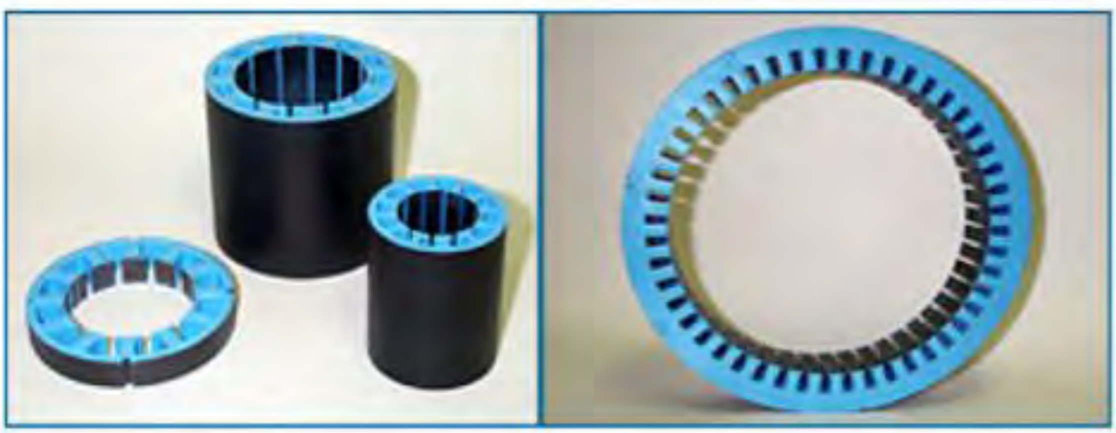

Figure 8: Laminated Steel Stampings - BLDC Stator

Similar to an Induction AC motor, the BLDC motor stator is made out of laminated steel stacked up to carry the windings. Windings in a stator can be arranged in two patterns; i.e. a star pattern (Y) or delta pattern (Δ). The major difference between the two patterns is that the Y pattern gives high torque at low RPM and the Δ pattern gives low torque at