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Case Study Project

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Design and Development for the Control of a Mecanum Wheel Car

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Abstract

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Declaration of Authorship

1. Introduction

2. Theoretical Background

2.1 Mecanum Wheel Technology | EJ

Mecanum wheels, a distinctive omnidirectional wheel design, enable vehicles to maneuver freely in any direction, including forward, backward, laterally, and rotationally. This unique capability is achieved through the arrangement of rollers on the wheel, which are mounted at an angle to the wheel's axis. The side view of such an wheel can be seen in fig. 2.1. Unlike conventional wheeled systems, which are limited to two degrees of freedom (longitudinal and steering), Mecanum wheels provide full omnidirectional movement with three Degrees of Freedom (DoF): longitudinal, lateral, and rotational (yaw) [1].

The rollers on a Mecanum wheel are positioned such that their axes are skewed relative to the

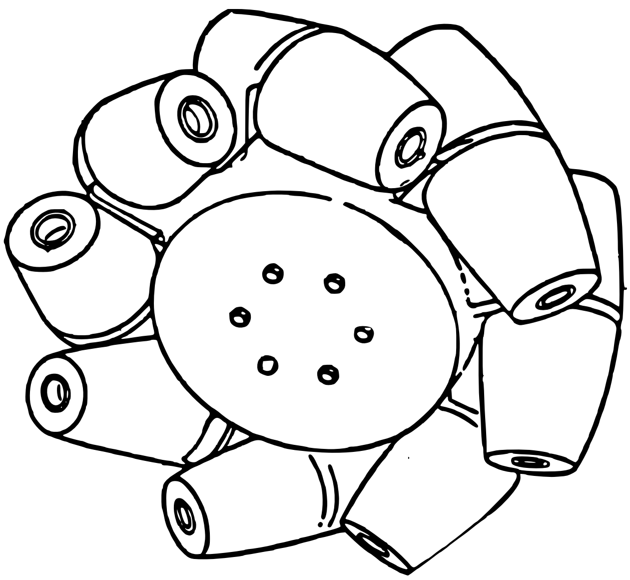

Figure 2.1: Side view of a Mecanum wheel [1]

central wheel axle. This geometry allows each wheel to produce a vector of force that, when combined with the forces generated by the other wheels, results in omnidirectional motion. This configuration avoids the singularities common in traditional wheel systems, which often require significant propulsion adjustments to perform small or intricate maneuvers. Vehicles equipped with Mecanum wheels are therefore able to perform complex maneuvers in confined spaces with greater efficiency, reducing both the time and area required for movement [1].

The kinematics of Mecanum wheels also play a crucial role in achieving precise control over a

vehicle’s movement. As each wheel operates independently, the control system must convert the desired motion into specific commands for each wheel, accounting for the interaction between longitudinal, lateral, and rotational forces. While this may seem computationally complex, efficient algorithms have been developed to simplify the process. These algorithms, often incorporating compensation for wheel slip, ensure that the vehicle can execute smooth, omnidirectional movement without requiring significant computational overhead [1]. In this case a simple control algorithm will be developed that does not use a compensation for wheel slip. As it is a fairly simple and lightweight remote controlled car for studying purposes, the required precision is not so high, that it would justify the increased development effort.
One notable disadvantage of the Mecanum wheel design is the inefficient transfer of kinetic energy from the motors to the ground. As the exterior rollers rotate, only a portion of the force generated by the wheels is effectively applied to the ground. This is due to the angled orientation of the rollers, which causes the total force exerted by each wheel to be split into components. Consequently, only a fraction of the force directly contributes to the vehicle’s motion, leading to reduced overall efficiency in propulsion compared to conventional wheels [2].
Therefore, Mecanum wheels are not commonly used in applications where efficient energy use is a priority but are favored in scenarios where the efficient use of time and space is essential. Many researchers focus on utilizing these wheels in the design of autonomous vehicles [3] and robots, particularly for environments where maneuverability is critical. Omni-directional platforms, like those equipped with Mecanum wheels, offer the ability to move instantly in any direction from any position. This provides significant advantages in congested environments filled with static and dynamic obstacles, such as factory workshops, warehouses, hospitals, and elderly care facilities, where conventional wheeled designs would struggle to navigate narrow aisles and tight spaces efficiently [4].

In this design, four Mecanum wheels are arranged at the four corners of a rectangular vehicle platform, with each wheel oriented to face forward along the X-axis, as can be seen in fig. 2.2. The arrangement allows the vehicle to achieve omnidirectional movement, with the X-axis representing forward and backward motion, the Y-axis representing lateral (side-to-side) motion, and the theta axis corresponding to rotational (yaw) movement.
The control system uses 8-bit signed integers to define motion in each direction, with values ranging from -127 to 127 to ensure symmetry in both positive and negative directions. While 128 would be the theoretical maximum for positive values, it is capped at 127 to maintain balance with the maximum negative value of -127, thus allowing precise and symmetrical control over the vehicle’s motion in all three axes.

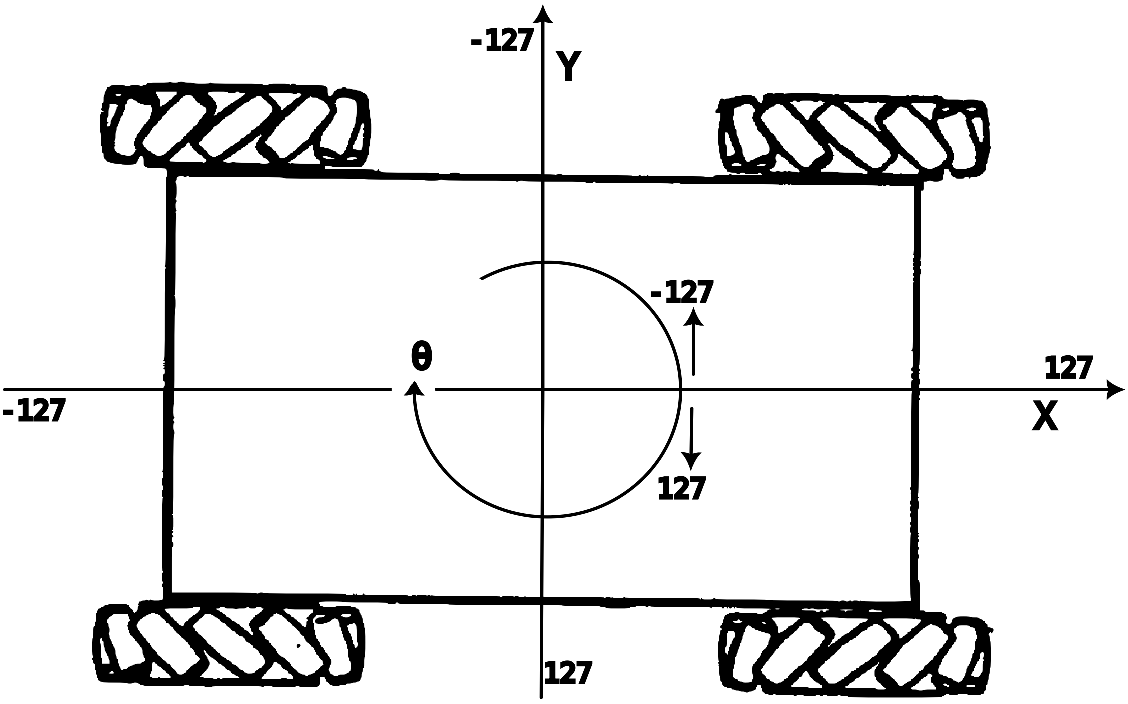

Figure 2.2: Wheel configuration and coordinates of Mecanum wheel car [1]

2.2 Motor Control using PWM

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2.3.2 Bluetooth

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3.1.1 Microcontroller (ESP32)

3.1.2 Power System

3.1.3 Motor Driver

3.1.4 Additional Components

3.2 Software Development

3.2.1 Command Protocol Design

3.2.2 Python Module

A python module is developed to provide access to control the car using its Software Development Kit (SDK) with short and easy commands in Python. The user only has to connect a client, where the Python module is installed, to the car's Wi-Fi Access Point (AP). Each Python command is translated to a string that is sent to the car's IP address and a predefined port. This string is then interpreted by the firmware running on the microcontroller that controls the car. The commands used for steering the car are interpreted as a vector, which is used to control the direction.

3.2.3 Firmware for ESP32

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List of Acronyms

AP	Access Point
DoF	Degrees of Freedom
SDK	Software Development Kit
EJ	Edmund Jochim

Appendix

Mecanum Car Commands

Use Wi-Fi to establish a connection between the Mecanum Car and a client device.

Send Command & Receive Response

Mecanum Car IP: **192.168.10.1** UDP Command Port: **4444** UDP Status Port: **4445**

Step 1: Set up a UDP client on the client device to send and receive messages from the Mecanum Car via the same port.

Step 2: Send any available command to the Mecanum Car to control it.

Control Commands

Command	Description	Possible Response
rc x y z	Apply speed to x y or z direction. x (backward - forward) = -127 to 127 y (left - right) = -127 to 127 z (rotation ccw - cw) = -127 to 127	-/error
keepalive	Keeps connection to Mecanum Car alive. Prevents timeout without changing last command.	ok/error
stop	Set all directions to 0.	ok/error

Status Message | Data Type: String

Data string received every second while controlling via WiFi

"batV:%.2f,batP:%d,mA:%d,mB:%d,mC:%d,mD:%d,:\n"

Description

"batV" = Measured voltage of battery in Volt

"batP" = Charge of battery in Percent

"mX" = Duty cycle of motor X in Percent

References

[1] S. L. Dickerson and B. D. Lapin, “Control of an omni-directional robotic vehicle with Mecanum wheels,” in *National Telesystems Conference proceedings*. New York: Inst. of Electrical and Electronics Engineers, 1991, pp. 323–328.

[2] F. Adascalitei and I. Doroftei, *Practical applications for mobile robots based on Mecanum wheels - a systematic survey*, 2011. [Online]. Available: https://www.researchgate.net/profile/ioan-doroftei/publication/233867057_practical_applications_for_mobile_robots_based_on_mecanum_wheels_-_a_systematic_survey

[3] N. Tlale and M. de Villiers, “Kinematics and Dynamics Modelling of a Mecanum Wheeled Mobile Platform,” in *2008 15th International Conference on Mechatronics and Machine Vision in Practice*, T. Moir, Ed. Piscataway, NJ: IEEE, 2008, pp. 657–662.

[4] O. Diegel, A. Badve, G. Bright, J. Potgieter, and S. Tlale, “Improved Mecanum Wheel Design for Omni-directional Robots,” 2002. [Online]. Available: https://forums.parallax.com/uploads/attachments/49124/55525.pdf