Implementation of Three Wheeled Omnidirectional Kinematics on Soccer Robot

Aditya Nugraha Putra, Novendra Setyawan and Nur Alif Mardiyah

August 31, 2024

IMPLEMENTATION OF THREE WHEELED OMNIDIRECTIONAL KINEMATICS ON SOCCER ROBOT

Aditya Nugraha Putra[1,a)], Novendra Setyawan S.T., M.T[2,b)], Ir. Nur Alif Mardiyah, M.T.[3,c)]

[1,2,3] *Department of Electrical Engineering, Faculty of engineering, Universitas Muhammadiyah Malang, Jalan Raya Tlogomas No. 246, Tlogomas, Lowokwaru, Tegalgondo, Karangploso, Malang, Jawa Timur 65144, Indonesia.*

[a)]Corresponding author: novendra@umm.ac.id
[b)]aditya113@webmail.umm.ac.id
[c)]nuralif@umm.ac.id

Abstract. Omnidirectional three-wheeled soccer robots have become a focal point in robotics development for sports competitions. Understanding the kinematics of these robots is crucial for achieving efficient movement on the field, leveraging omnidirectional wheels to enable more flexible and precise maneuvers. The three-wheeled omnidirectional configuration, where each wheel can rotate independently, allows the robot to move in any direction without changing its body orientation. This study explores the kinematic model of the three-wheeled omnidirectional robot, including the mathematical formulation of the relationship between wheel speeds and the robot's linear and angular velocities. Additionally, the research delves into practical implementations of the kinematic model in robot control, including control techniques needed to enhance stability and responsiveness during matches. The findings offer valuable insights into the design and development of soccer robots with three-wheeled omnidirectional kinematics and highlight the potential for improving performance and strategy in competitions.

Keywords: Robot, Indonesian Robot Contest, Omnidirectional, Kinematic, Control

INTRODUCTION

The development of soccer robots has become a significant research area in recent years, especially in the context of competitions such as the Indonesian Robot Contest. Among the various configurations that have been explored, one of the most effective is the use of omnidirectional wheels[5]. This configuration allows the robot to achieve high flexibility and maneuverability in multiple directions, which is crucial for competitive performance.

This research aims to design and build a wheeled soccer robot with a three-wheeled omnidirectional configuration specifically optimized to enhance performance in competitions. The robot is equipped with three omni wheels, each mounted at a 120-degree angle to each other[6]. This configuration provides the ability to perform lateral, longitudinal, and rotational movements with high speed and accuracy[1].

In the design of this robot, key components include a microcontroller that serves as the system's control center. The microcontroller integrates various sensors and actuators needed to control the robot's movements with precision [2]. Custom-designed control algorithms are used to coordinate the robot’s movements, ensuring that each action is executed with a high level of accuracy[3].

This research aims not only to improve the robot's performance in competitions but also to contribute to the advancement of more sophisticated and applicable robotics technology within the context of soccer robot games.

METHODS

System Flow Diagram

The robot that was developed can move dynamically in various directions, including sideways, forward, backward, and diagonally, as well as in combinations of these movements. Additionally, the robot is capable of kicking the ball with power and precision, as well as receiving and dribbling the ball. Figure 1 illustrates the flow diagram of the wheeled soccer robot system. The motors with a three-wheeled omnidirectional configuration are controlled by kinematics and each motor has its own RPM. The encoder reads back the RPM, providing feedback for the PID controller. The diagram also includes the kinematics for position determination, which uses angle parameters and odometry.

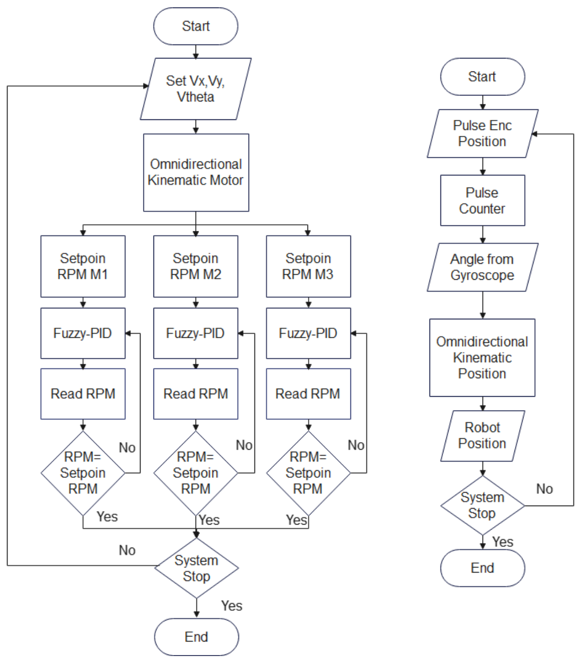

Figure 1. System Flow Diagram

RESULTS AND DISCUSSION

In the kinematics testing, the success criteria that must be met include the software's ability to determine the motor speed set point based on kinematic calculations.The kinematics testing procedure involves providing input for the direction of movement and the speed toward the desired direction, then monitoring the speed of each motor, observing the movement of the robot, and recording how far the robot moves from its initial position. The results can be seen in **TABLE 1**.

TABLE 1. Motor Direction and Speed

Coordinate Setpoint (X,Y)	Motor 1 Direction	Motor 1 Speed (RPM)	Motor 2 Direction	Motor 2 Speed (RPM)	Motor 3 Direction	Motor 3 Speed (RPM)
0,100	CW	81.84	-	0	CCW	81.84
100,0	CW	52,08	CCW	96,72	CW	52,08
0,-100	CCW	81,84	-	0	CW	81,84

-100,0	CCW	52,08	CW	96,72	CCW	52,08
100,100	CW	141,36	CCW	96,72	CCW	37,2
100,-100	CCW	37,2	CCW	96,72	CW	141,36
-100,100	CW	37,2	CW	96,72	CCW	141,36
-100,-100	CCW	141,36	CW	96,72	CW	37,2

This test evaluates the alignment between the robot's movement and the actual distance.The testing is conducted by moving the robot according to actual measurements; the actual distance of the robot is compared to the distance read by the robot, resulting in a measurement error. The table indicates that the largest error is 8%, resulting in an accuracy rate of 92% for the robot's movement. The results can be seen in **Table 2**.

TABLE 2. Robot Movement Measurement Based on Coordinates

Coordinate Setpoint (X,Y)	Position With Manual Measurement	Error
0,100	0,103	1,5%
100,0	109,0	4,5%
0,-100	0,-106	3%
-100,0	-104,0	2%
100,100	109,107	8%
100,-100	103,-105	4%
-100,100	-106,106	6%
-100,-100	-107,-106	6,5%

In this test, the robot is also operated to move to more than one coordinate and adjust its speed according to the set points specified. The results can be seen in **Tables 3 and 4**.

TABLE 3. Robot Movement with more than 1 Coordinate

Coordinate Setpoint 1 (X,Y,W)	Coordinate Setpoint 2 (X,Y,W)	Coordinate Setpoint 3 (X,Y,W)	Result
0,100,0	100,100,0	0,0,0	Success
0,100,90	100,0,-90	100,100,30	Success
100,100,0	-100,100,30	-100,-100,120	Success
200,0,0	200,150,0	0,200,0	Success
125,100,-90	-125, 200,-90	0,0,0	Success

Table 3 presents the results of testing the robot's ability to move to multiple setpoints in sequence. Each test consists of three coordinate setpoints, denoted as (X, Y, W), where X and Y represent the robot's position on a plane, and W represents its orientation. The first column lists the initial setpoint where the robot starts. Afterward, the robot is instructed to move to the second setpoint, as shown in the second column. Finally, the robot moves to the third setpoint, as indicated in the third column. The "Result" column confirms whether the robot successfully reached each setpoint in sequence. The table demonstrates that in all test scenarios, the robot successfully moved through the specified setpoints, indicating reliable performance in navigating to multiple coordinates.

TABLE 4. Change in Robot Speed while Moves

Coordinate Setpoint 1 (X,Y,W)	Speed Setpoint	Coordinate Setpoint 2 (X,Y,W)	Speed Setpoint	Result
0,200,0	50	200,200,0	150	Success
200,0,0	100	200,200,0	50	Success
0,50, 90	200	100,100,90	100	Success
250,30,-90	225	0,0,0	100	Success
50,350,0	50	200,-350,90	225	Success

Table 4 illustrates the robot's performance when changing speed between two different coordinate setpoints. Each test begins with the robot moving from an initial setpoint, indicated in the first column as (X, Y, W), where X and Y represent position and W represents orientation. The corresponding speed setpoint for this movement is shown in the second column. After reaching the first setpoint, the robot proceeds to a second setpoint, with the new coordinates and speed setpoints listed in the third and fourth columns, respectively. The "Result" column indicates whether the robot successfully adjusted its speed and completed the movement between the setpoints. The table demonstrates that in all scenarios, the robot successfully managed the speed changes while navigating between the given coordinates, indicating effective control over both movement and speed adjustments.

CONCLUSIONS

The research has resulted in the development of a Soccer Robot using a Three-Wheeled Omnidirectional Kinematic. Based on the findings, it can be concluded that the kinematic of the robot has been successfully achieved. The key conclusions is that the robot's movement aligns with the specified coordinates and there is a minimal error in position determination after movement. The robot can achieve high speeds with a positioning accuracy of 92%.

ACKNOWLEDGMENTS

The author would like to express gratitude to Icon-TINE Call for Papers for organizing the Seminar 2024 event. The author also extends thanks to Universitas Muhammadiyah Malang for supporting the ZHAFARUL team and providing funding assistance for the development of the wheeled soccer robot.

REFERENCES

1. I. K. Wibowo, M. M. Bachtiar, et al., "Penentuan Posisi Robot Menggunakan Odometry Omniwheel," in The Indonesian Symposium on Robot Soccer Competition 2018, 10 Jul. 2018.
2. M. M. Syeichu, E. Endryansyah, et al., "Hybrid Fuzzy-PID Controller untuk Pengaturan Kecepatan Motor DC pada Prototipe Elevator," Jurnal Teknik Elektro, vol. 10, no. 02, pp. 405-412, 2021. e-ISSN: 2337-4878, p-ISSN: 2086-9479.
3. A. Rosyidah, Hidayatullah, and R. M. Fitria, "Penentuan Posisi Robot Menggunakan Odometri dan Sensor Rotary Encoder dengan Algoritma Dead Reckoning," in Seminar Nasional Teknologi dan Aplikasi, 28 Jul. 2021. e-ISSN: 2502-7409, p-ISSN: 2337-5327.

4. M. I. Marzuki, I. N. Farida, and J. Sahertian, "Implementasi Controller PID (Proportional, Integral, Derivative) pada Robot Sepak Bola Beroda," in Seminar Nasional Inovasi Teknologi, UN PGRI Kediri, 24 Jul. 2021. e-ISSN: 2549-7952, p-ISSN: 2580-3336.
5. G. W. Kurniawan, N. Setyawan, and E. A. Hakim, "PID Trajectory Tracking Control 4 Omni-Wheel Robot," in *Seminar Nasional Fortei Regional 7, Forum Pendidikan Tinggi Teknik Elektro Indonesia Regional VII*, pp. 345-350, 2021. ISSN (Print): 2621-3540, ISSN (Online): 2621-5551.
6. R. T. Yunardi, D. Arifianto, F. Bachtiar, and J. I. Prananingrum, "Holonomic Implementation of Three Wheels Omnidirectional Mobile Robot using DC Motors," *J. Robot. Control (JRC)*, vol. 2, no. 2, pp. 65-73, Mar. 2021.
7. A.S. Deogan, D.M.J. Hameeteman, I. Kolodko, "Tech United Eindhoven Team Description 2024," Robocup Medium Size League, Feb. 2024.
8. Jo˜ao Cunha, Nuno Lau, Jo˜ao Rodrigues, Bernardo Cunha, Jos´e Luis Azevedo, "Predictive Control for Behavior Generation of Omni-Directional Robots," 14th Portuguese Conference on Artificial Intelligence, EPIA, Oct. 2009.