PID Control Schematic Design for Omni-directional Wheel Mobile Robot Cilacap State of Polytechnic

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Abstract — **Omni-directional mobile robot (OMR) is a robot that can move in all directions with an additional wheel around the core wheel. This research presents a PID controller method at the OMR plant with the specific purpose of getting to the specified point. OMR uses three wheels with an angle difference of 120 degrees. The application of this method using MATLAB assistance from knowing the kinematics to the performance results from the application of the control method. The stages of this research are robot design, component selection, electrical design of the robot, determination of forward kinematic and reverse kinematic and determination of PID controller for positioning. Testing is done by determining the position and determining the point to be determined. Simulation time testing is when the state is at 3,6,9,12 and 15 seconds. The results of the simulation robot can follow the specified coordinates.**

Keywords — PID controller, Omni Directional, OMR, Kinematic.

I. INTRODUCTION

An omnidirectional mobile robot (OMR) is a robot that can move in everything direction with wheel addition around the core wheel. The advantage of an Omni robot is that it can move in all directions without paying attention to the orientation of the robot itself. This robot can be said to be a holonomic robot [1]. OMR has several configurations that affect the kinematic equation of each configuration, there are three OMRs with 120 degrees different angles while OMR with four wheels which have 90 degrees different angles [2-3].

Applications of this OMR can be used in educational, health, industrial, military and many other applications [4-5]. OMR is also used in competitions to strengthen educational competence, namely with the robot branch in the soccer player robot division [6]. In this competition, the robot is seen from scoring as many goals as possible. The problems faced in this competition are communication and positioning of the robot. Communication between each robot to comply with regulations and score goals is an obstacle but positioning is the biggest problem because it is caused by several factors, namely input from sensors and determination from the robot itself. In determining the position of the robot, it is determined by several sensors it has, one of which uses a rotary encoder with a special purpose to get the rotational speed of each wheel [7].

Positioning requires control such as using a PID controller, odometry, NN, and Fuzzy so that it can follow a predetermined path [8]. Research [9] uses the potential field method to get to the target and avoid obstacles, this study is the same as using OMR, several stages of this research use kinematics to know the direction of the robot's movement orientation. This study uses Matlab with the results of being able to follow trajectory tracking.

The previous algorithm by utilizing if-else with some logic formed. The more logic that is given, the longer the process of reading the program will take, even though what we need is speed and accuracy in the system, hence the emergence of the potential field method. Avoidance of obstacles by using a potential field by utilizing attractive attractions such as a magnetic field when there is an obstacle, such as a positive charge that will leave from the source [10-12].

PID controller is a conventional controller but is widely used for precise and fast control. Research [13] used a PID controller to determine the position of the OMR robot, although some shortcomings must be considered in the influential PID Constanta tune. The PID controller is identical to reducing the existing error and can provide a fast response when using a DC motor system. This controller is very suitable for controlling DC motors that are used as actuators.

Study this present a method PID controller on OMR plant with objective special could going to the point that has determined. using a PID controller is a contribution to this paper. The PID controller will overcome errors in the system from closed loop from the observer signal to the motor speed and position on the OMR. OMR used is three fruit wheels with a different corner by 120 degrees. The application of this method using MATLAB assistance from knowing the kinematics to the performance results from the application of the control method. This paper is only limited to designing a system that will be applied to the KRI (Indonesian Robot Contest) competition in the KRSBI (Indonesian Football Robot Contest) competition branch.

II. METHOD

To reach the objective of the study needs many stages done. Stages for the implementation study can be seen in Figure 1. below.

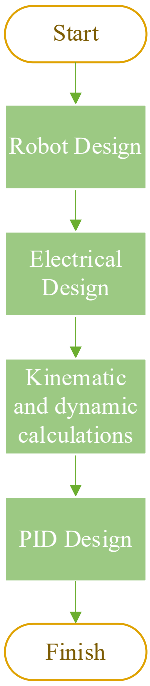


Figure 1. Research Flow

Fig. 1 describes the research stages of the robot design to determine the wheel radius and wheel base, then the electrical design of several components used, then the kinematic and dynamic calculations and the design of the PID controller. Stages begin with a planning system that is determined the number of components used in this robot.

Figure 2. Rotary Encoder

Fig. 2 is a rotary encoder component. This component is to determine the distance and speed of the motor generated by PWM. The equipment used is in the form of a Rotary encoder or also called a shaft encoder [14].

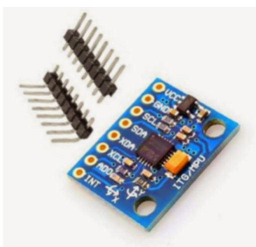


Figure 3. MPU-6050 sensor

Fig. 3 is a component of the MPU-6050 sensor. Component next namely the MPU-6050 is a sensor that contains a gyroscope and accelerometer with a micro-electromechanical system (MEMS) system that will inform in the form of the signal so you can read by the microcontroller. Configure this sensor using the I2C-Bus interface [15].

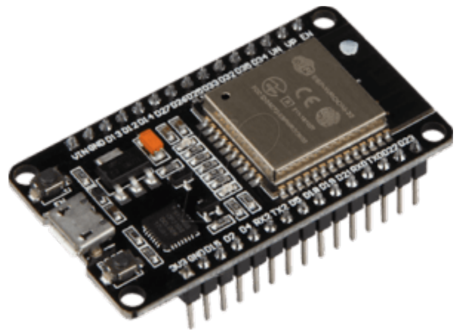


Figure 4. ESP32

Fig. 4 is a microcontroller that can be connected to wiif directly. Component next i.e. ESP 32 is a microcontroller that has module WiFi often used in Internet of Things applications. ESP32 can say as a successor from ESP8266 [16].

Figure 5. Motor Driver

Fig. 5 is an electronic device for actuator drive. The actuator of this robot is a DC motor, SC motor control uses the BTS7650 driver. Research [17] For control DC motor rotation used PWM and encoder calculations on the DC Motor PG-36.

Figure 6. Step Down Module

Fig. 6 is a voltage reducer to distribute the incoming voltage in the circuit. To get supply voltage moment distribution so use the LM2596 Step-Down module which is module reducer voltage. Excess module this moment existence disturbance from the incoming supply no influence specified output in other words module this stable from incoming interference [17].

Figure 7. Omni Wheel

Fig. 7 robot wheels that can move in all directions. wheels (Omni wheels) are the wheel that is tucked the wheel alone there is wheel functional little for can move in everything direction. Figure 7 is an Omni wheel display with 10 rollers with a width of 58 mm.

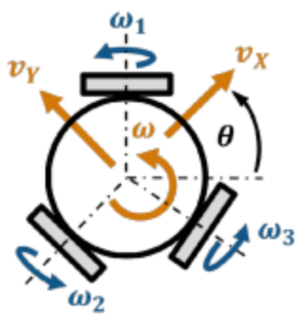


Figure 8. Kinematic OMR

Fig. 8 is kinematic in order to know the direction and rotation of the robot's position. To determine the previous robot moves use kinematics which is for know motion thing. OMR is used with three fruit wheels. Kinematics is the aim for know characteristics Movement style of three fruit robotic wheels [14].

Kinematics two shapes are forward and backward. Advanced kinematic is used to determine the speed of the robot (v_x, v_y, θ)that is obtained from the robot $(\omega_1, \omega_2, \omega_3)$. reverse kinematic for know Omni robot speed of robot speed. Equation (1) is forward kinematic and equation (2) is backward kinematic

$$\begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix} = \frac{R}{3}\begin{bmatrix} \sin\alpha_1 & \sin\alpha_2 & \sin\alpha_3 \\ -cos\alpha_1 & -cos\alpha_1 & -cos\alpha_1 \\ -\frac{1}{L} & -\frac{1}{L} & -\frac{1}{L} \end{bmatrix}\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{bmatrix} = M^{-1}\begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix} \quad (2)$$

For could change from framework reference body into the local coordinates to framework global coordinates needed equation (3) whereas otherwise from skeleton global reference to the body with use equation (4).

$$\begin{bmatrix} x_w \\ y_w \\ \theta \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} x_b \\ y_b \\ \theta \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} x_b \\ y_b \\ \theta \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} x_w \\ y_w \\ \theta \end{bmatrix} \quad (4)$$

PID controller that is combined from three control systems which is sickle math for remove / minimize error value in the control system. Equation (5) is a signal failure from PID control in the form of a PWM signal for arranged speed motor rotation.

$$u = Kp(e)t + Ki\int_0^t e(t)dt + Kd\,\frac{de(t)}{dt} \quad (5)$$

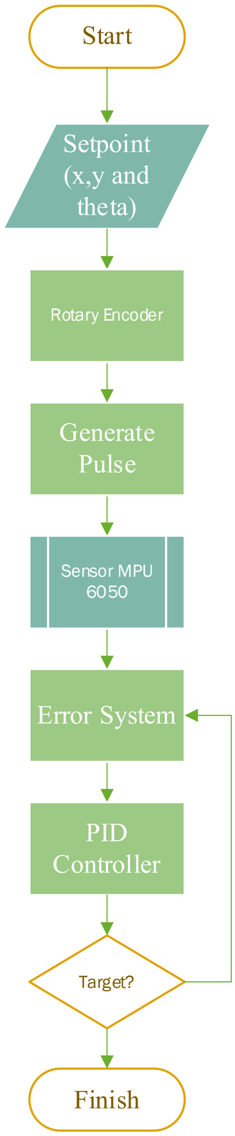


Figure 9. Flowchart Study

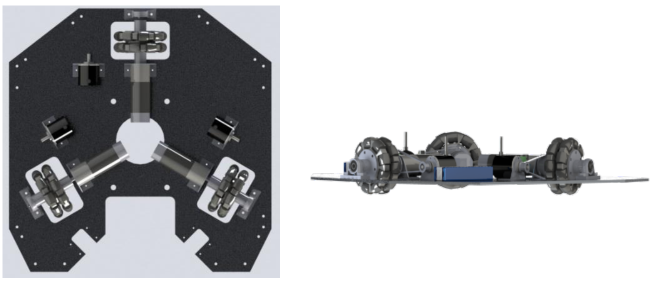
Where u is the control signal, Kp is the constant Proportional, Ki is the Integral constant while Kd is the derivative constant and e(t) is the error signal. Error signal obtained from subtraction from certificates and results in sensor reading. Method this used for overcome error forgot results position that is mark x,y and theta of the system obtained from encoder value.

After knowing several components and methods used so Step next that is to determine planning robot manufacture. Stages for making robots in research could see in Figure 9 flow chart research.

The flowchart from Fig. 9 begins with setpoints at positions x, y and theta. Next sensor readings and knowledge of the position to be crossed with make the given pulse so that it can be appropriate for the drive to trajectory. For suitability with a given trajectory, there is a ratio Among reading marks with a setpoint called system errors. Login system error into the PID controller so that it can correct the plant so that the error becomes zero and match with the desired target.

III. RESULTS AND DISCUSSION

In the design of the robot follow contest rules so that produce a picture as lower this. The design picture of this robot was meant to know the parameters so that the programming process was easier.



(a) (b)

Figure 10. KRSBI Robot (a) Top View, (b) looks side

Fig. 10 is a robot design (a) top view and (b) side view. The robot is designed using the components that have been presented in the previous chapter. From Figure 10 can determine the wheel base and base radius of the OMR robot. After knowing the picture so stages next determine the stages picture network. A picture of the circuit on this robot could be seen in the picture under this.

Fig. 11 OMR electronic circuit design. Where is the network started from the battery to the DC motor, battery use 2 pieces because we need a source 24v voltage for the DC motor source, and 5v for source the microcontroller, for our 24v source series second the battery, then for our 5v lower voltage use step down module. Next source 24v input voltage into the third port BTS7960 and from the port next to it enter into a DC motor. For source input 5v voltage into vin node MCU ESP 32, and enter into pin BTS8960 on pin VCC and pin L is and R is because this pin only need high logic.

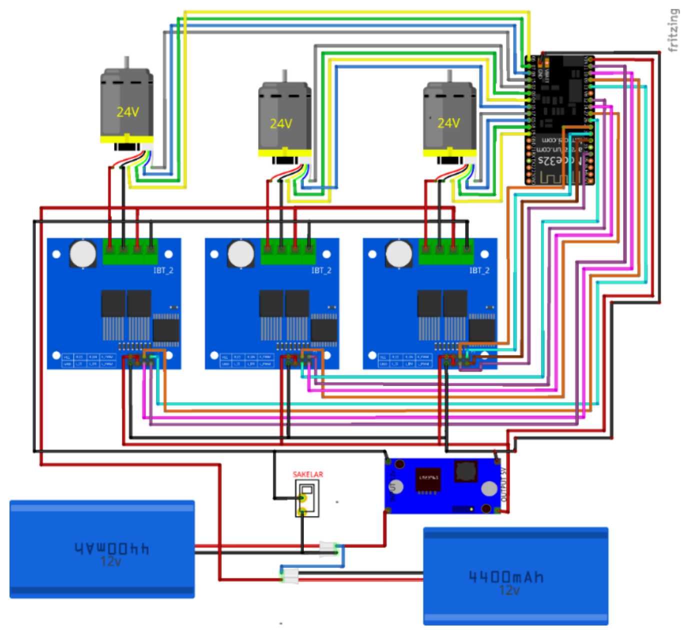


Figure 11. Circuit Electric Robot

The components used to assemble electronic equipment can be seen in Table 1. Table 1 is the number and several components of the OMR robot to be able to move according to the point we want.

TABLE I
COMPONENT ROBOTICS

N o	Component	Total
1	12V. battery	2
2	Step Down module	1
3	BTS7960	3
4	Node MCU ESP32	1
5	Switch	1
6	24V DC DC Motor	1
7	Encoder	1

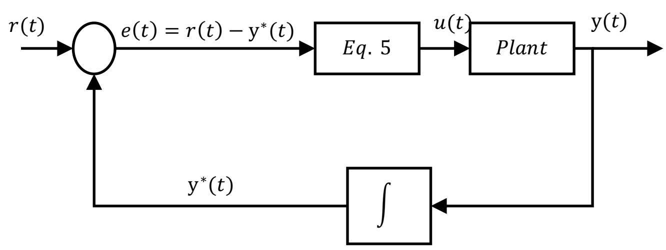


Figure 12. Block diagram planning system control

Fig. 12 is a block diagram of a closed loop system. This block diagram has a reference called the set point, controller, actuator, plant and observer output from the sensor. Algorithm control on image on with get around error $e(t)$value until you know the signal value control on $u(t)$. Error value can be seen in equation (6) while for could reduce error from exponential so could using the derivative error value follows equation (7)

$$e(t) = r(t) - y^*(t) \quad (6)$$

$$\frac{de(t)}{dt} = -\lambda e(t) \quad (7)$$

Or can written repeat Becomes

$$\frac{de(t)}{dt} = \frac{dr(t)}{dt} - \frac{dy^*(t)}{dt} \quad (8)$$

With follow equation (5) for got control $u(t)$signal can written repeat Becomes equation (9)

$$u(t) = Kp\left(\frac{dr(t)}{dt} - \frac{dy^*(t)}{dt}\right) + Ki\int_0^t\left(\frac{dr(t)}{dt} - \frac{dy^*(t)}{dt}\right) + Kd\left(\frac{dr(t)}{dt} - \frac{dy^*(t)}{dt}\right) \quad (9)$$

With use this control signal could got results on simulation robot position with trajectory tracking. After knowing the kinematics and control for try testing used the specifications on the wheel radius = 0.05 meters and the robot radius is 0.13 meters.

Fig. 13 is a simulation of the program by determining several points to be followed by the OMR robot. Tests carried out with giving point for can follow it. In unit time [0; 3; 6; 9; 12; 15] with point or waypoint with points x, y and theta [0,0,0; 0.5,0. 5,pi /4; 4,0.5,pi/2; 4.3, pi/2; 3.2,-pi/2; 1,2,-pi/2]. The result of the Kinematics and Control position of this robot could be seen in figure 13. Point first on [0,0,0] i.e. point beginning moment starting condition. Point second at [0.5,0. 5,pi /4] moment time at 3 seconds. Seen moment point 3rd and 4th for trajectory no until spot objective this can be because of current constant tuning that hasn't been right.

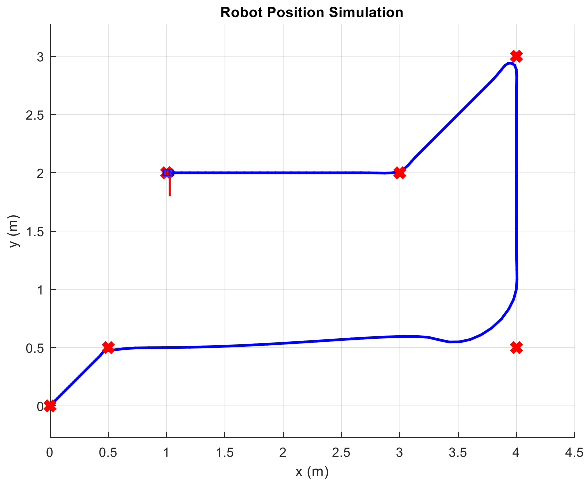


Figure 13. Trajectory Tracking Movement Results

Fig. 14 is the result of the rotational speed of the OMR robot wheel. Study this serve simulation on OMR with configuration three suitable Omni wheel with provision Indonesian robot contest with division Indonesian soccer robot contest. Study this done with stages from robot design, selection components, robot electrical design, determination of forwarding kinematic and reverse kinematic as well as determination PID controller for determination position. Tests conducted on research _ this with determine position and determination point be set. Test time simulation that is moment state at 3 seconds, 6 seconds, 9 seconds, 12 seconds and 15 seconds. There is for robot waypoint point can follow and for Omni wheel can see direction round When heading the point that has set.

Figure 14. Speed Omni Wheel

IV. Conclusion

This study has presented a simulation on OMR with a three-wheel omni configuration in accordance with the provisions of the Indonesian robot contest with the division of the Indonesian soccer robot contest. Research has been carried out with several stages from robot design, component selection, robot electrical design, determination of forward kinematic and reverse kinematic and determination of PID controller for positioning. The tests that have been carried out in this study are by determining the position and determining the point to be determined. Simulation time testing is when the situation is at 3 seconds, 6 seconds, 9 seconds, 12 seconds and 15 seconds. It can be seen that the waypoint points of the robot have been able to follow and for the omni wheel, the direction of rotation can be seen when it reaches a predetermined point.

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