# Ball Dribbling Control For Soccer Robot

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**Abstract**. This paper details the ball dribbling control system in the robocup middle-size league competition. The research aims to find the best method for natural robot ball dribbling. Initially, design calculations derive a dribbling mechanism adhering to robocup rules. The mechanism must flexibly accommodate translational or rotational robot movements for natural dribbling. The PID control method regulates the dribble motor response, sustaining ball dribbling at varying speeds or when the robot is at rest. The results section presents ball dribbling responses across trials of different robot movements and speeds.

**Keywords**: natural dribble, middle-size league.

## 1 Introduction

RoboCup[1](Robot World Cup) is an international competition that aims to develop and promote Robotics and AI, one of which is Robocup Middle Size League. [2]–[4]. In the Robocup Middle Size League, researchers continue to research the ability of robots to play like humans play soccer. The competition consists of five autonomous robots that play soccer with standard regulations from FIFA and in 2050 aims to fight humans.[5], [6] In the Robocup Middle Size League match, each robot has the ability to play soccer like a human starting from guarding the goal, kicking the ball, dribbling and deflecting the ball [7]. From one of these abilities, there is a problem with the unnatural dribbling system that causes violations in the robot that holds the ball at all times and does not comply with the rules of the game[1]. and research to control the ball on the robot with the use of a dribbler which aims to make it easier for the robot to dribble and make movements, with a good dribbler design, the ball will look natural when dribbling[8], [9].

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There are several dribbling control mechanisms and systems that other teams have used to solve the problem, mainly classified into two types, one using the motor on the front of the robot to control the ball and the other using the sensor on the motor arm of the dribbler[4],Tech United team [13] using a non-linear model as feedback and feed forward control to maintain the distance between the ball and the robot by measuring the arm angle and maintaining according to the distance between the ball and the robot[11]. The CAMBADA team developed the same method developed by other teams but used omni wheels to improve controllability[12].

In this study, we developed a dribbling control mechanism and system for a wheeled soccer robot that complies with the rules of the Middle Size League where the robot can only catch 1/3 of the ball when the robot is dribbling[1], [11]. Therefore, calculations are needed when designing the ball dribling control mechanism to comply with the middle size league.
regulations. For the controller, we use PID speed control on the dribbler motor[13] to maintain the position of the ball by getting the output value from the sensor reading as a speed regulator for the drible motor and keeping the ball from being released from the robot[10]. Then an input is needed for the direction of rotation on the dribble wheel with reference to the movement of the robot so that the ball can rotate naturally according to the movement of the robot, The research goal is to finding the best method to make tha ball dribbling naturally for robot.

## 2 Method

### 2.1 Design Calculation

When designing the design, it is necessary to know that the relationship between the surface of the dibbler wheel and the ball is very influential for the movement of the ball. Therefore, to design a ball dribbling mechanism for the radius of the ball in use must be known where $r_b$ is the radius of the ball used. The first step is to calculate $r_\alpha$ the radius of one-third of the sphere looking forward from the center point of the sphere and also rα is the limit of one-third of the sphere looking forward. As seen in Figure 1. To calculate the limit, the equation is given:

$$r_\alpha = \sqrt{r_b{}^2 - (\tfrac{1}{3} r_b)^2}, \quad (1)$$

after obtaining the results of the radius of one-third of the front view ball, angle $\psi$ determined at the beginning of the manufacturing concept as a reference point for the position of the dribble wheel in the horizontal direction and this angle is used to determine the distance and at what height the wheel touches the limit of one-third the diameter of the ball. Therefore, to calculate the distance and height, the equation is given:

$$r_\beta = r_\alpha \cos(\psi), \quad (2)$$

where $r_\beta$ is the distance from the center of the ball to the corner point ψ, to calculate the height of the wheel when touching the ball with respect to the center of the ball, the equation is given:

$$h = r_\alpha \sin(\psi), \quad (3)$$

After obtaining the completion of the front view, proceed to calculate the radius and angle of the reference point as a wheel limitation when touching the ball with the equation:

$$r_{wb} = \sqrt{r_\beta{}^2 - (\tfrac{1}{3} r_b)^2}, \quad (4)$$

and

$$\theta = \arctan\left(\frac{\frac{1}{3}r_b}{r_\beta}\right). \quad (5)$$

where $r_{wb}$ and $\theta$ is the one-third boundary of the wheel when it touches the ball as seen from the top view in Figure 1 Projection View.

The Symbol description :

$r_a$ : The one-third of the ball.
$r_b$ : The radius of the ball.
$r_\beta$ : The distance from the center of the ball to the corner point ψ.
$h$ : The height of the wheel when touching the ball.
$rwb = \theta$ : The one-third boundary of the wheel when it touches the ball

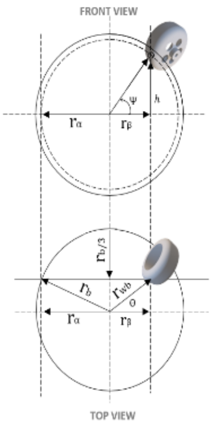



**Fig. 1.** Projection View

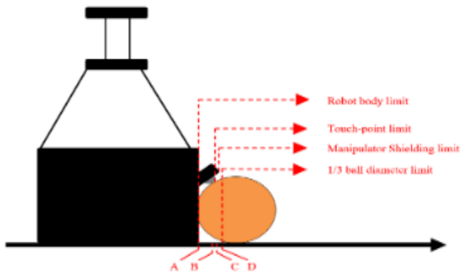



**Fig. 2.** Rule Of Dribbling Mechanism

### 2.2 Mechanical Design

This section describes the design of the ball dribbling control mechanism that uses a drive in the form of a DC motor and sensor from the potentio for the dribbling system. An overview of the ball dribbling mechanism design is shown in Figure 3, Where when the robot dribbles, a design with an ideal position is needed so that the ball rotates naturally according to the movement when the robot moves forward, backward, right, left and rotates. To keep the ball from being released when the robot moves, the angle sensor reading on the dribble motor arm is used as one of the references to adjust the speed of the dribble motor. Illustration of the angle reading on the ball dribbling mechanism is shown in Figure. 4.

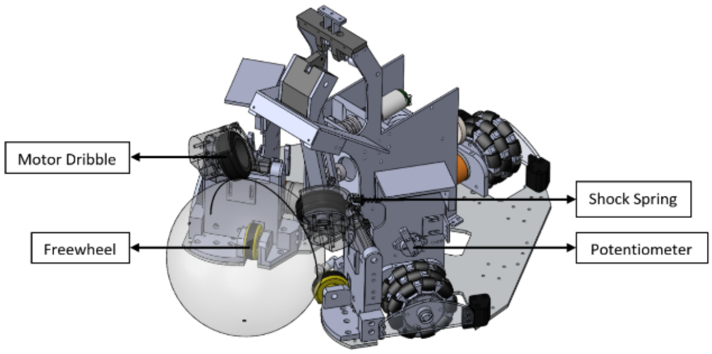



**Fig. 3.** Design Mechanism Ball Dribbling.

In the ball dribbling control mechanism, two motors with a pair of wheels are installed to rotate the ball according to the direction of motion and also with the help of two freewheels as a barrier so that the ball is not pulled into the robot and makes the ball move in place. With a design that looks like Figure 3, the design of the mechanism is ideal for making the ball rotate naturally. As an angle reading when the robot dribbles, a potentio is installed in the dribbler arm joint as a sensor to determine the state of the ball during dribbling with an angle range of 0 to 10 degrees. With that, a compressive spring is used as a pushing mechanism for the dribbler arm and as a damper when the ball enters the one-third of the robot. An illustration of the angle reading on the ball dribbling mechanism is shown in Figure 4.

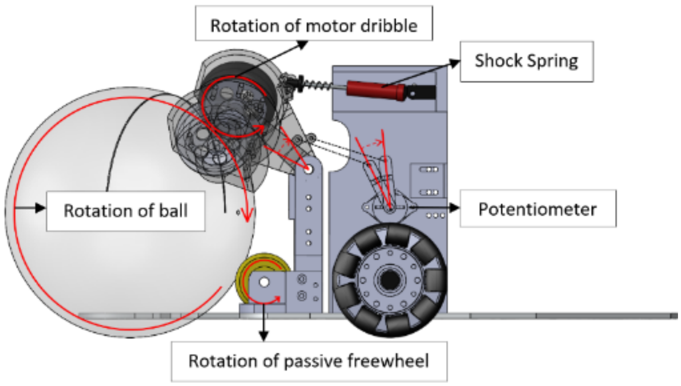



**Fig. 4.** Illustration Of Dribble Angle Reading Mechanism

### 2.3 PID Controller

PID (Proportional Integral Derivative) is a control system with a control loop mechanism that uses feedback from the results to adjust the desired target. PID control works by calculating the error value as the difference between the desired set point and the measured process variable. To get good control, each parameter of the PID must be adjusted so that the control system can work properly, therefore the control equation is given:

$$u(t)=K_p e(t)+K_i \int_0 e(\tau)d\tau + K_d \frac{de(t)}{dt} \quad (6)$$

where Kp, Ki, Kd are constant values determined as parameters to get good control. After the design of the previous method is complete, then this pid control method is used as a speed control for the dribbler motor which will be used as a dribbling system when the robot dribbles. The use of a potentiometer on the dribble motor arm is also used to determine the position of the ball on the robot, in the rules of the game when the robot is stationary the ball cannot continue to rotate in place, therefore the use of PID as a dribbling control system is applied by adjusting the motor speed based on the output of the potentiometer as an angle sensor to determine the position of the ball when the robot is moving and when the robot is stationary. PID control is applied to each dribbler motor so that each motor has its own response to different angle readings.

**u(t)** : is the drive coming form the Controller, into the process, at time t.

## 2.4 Inverse Kinematic

The method that is then used as a robot movement is inverse kinematics where this method is what we will use as input data for the direction of rotation on the dribble wheel. In the robot itself, the kinematic equation defines several parts of the robot's movement in the form of linear velocity and angular velocity. *vx, vy* and ω The inverse kinematic diagram of the robot is obtained from equation (7) so that the movement control of the robot is easy to do. The inverse kinematic diagram can be seen in Figure 5.

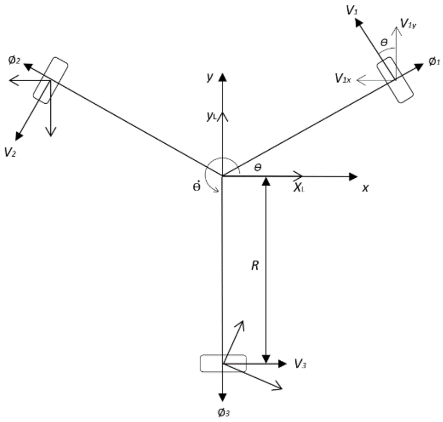



**Fig. 5.** Diagram Inverse Kinematik

The inverse kinematic diagram in Figure 5 above is intended to find the angular velocity of the wheels in order to obtain the desired robot movement. To get the speed of each wheel, an equation is needed:

$$
\begin{aligned}
\text{Ø}_1 &= (-\sin(\theta+\alpha_1)\cos(\theta)x_L + \cos(\theta+\alpha_1)\cos(\theta)\,y_L + R\dot{\theta})/r \\
\text{Ø}_2 &= (-\sin(\theta+\alpha_2)\cos(\theta)x_L + \cos(\theta+\alpha_2)\cos(\theta)\,y_L + R\dot{\theta})/r \\
\text{Ø}_3 &= (-\sin(\theta+\alpha_3)\cos(\theta)x_L + \cos(\theta+\alpha_3)\cos(\theta)\,y_L + R\dot{\theta})/r
\end{aligned} \tag{7}
$$

With the following description:

α : Angle of the wheel from the axis $x_L$ (degree)
R : Distance of the wheel to the robot's center of mass (cm)
r : Ball Radius (cm)
$\dot{\theta}$ : Robot angular velocity (radians /s econd)

$X_L$ : Velocity with respect to x axis (cm /second)
$Y_L$ : Velocity with respect to y axis (cm /second)
$\varnothing_n = M_n$ : Angular velocity of motor–n (radians/second)

### 2.5 System Control

This section will explain the ball dribbling control system on a soccer robot consisting of speed control on two dribble motors with potentio readings as angle sensors with an angle range of 0 to 10 degrees and input from the movement of the robot in the form of directional direction of each motor obtained from the inverse equation. Figure 6 shows the ball dribbling control system on the soccer robot.

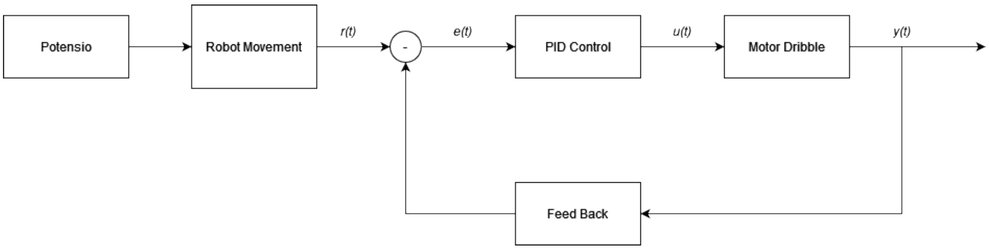



**Fig. 6.** System ball dribbling control

First, kinematics is used for robot movement so the robot can calculating the direction of dribble, Figure 7 showing how the kinematic controlling the direction of motor dribble.

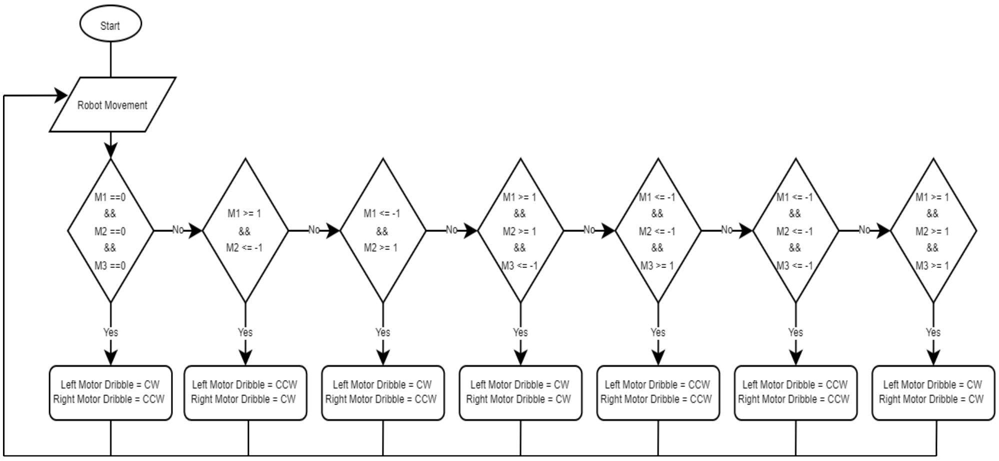



Fig. 7. Calculation for driblble based on kinematic

The ball dribbling control system on the robot uses PID control speed and potentio value reading as an angle sensor where the potentio is used to determine the position of the ball when dribbling, therefore the angle reading on the dribble arm is used to adjust the speed of the dribble motor if the ball will be released from the robot in a dribbling condition, the dribble motor will be faster. To get natural ball movement when the robot moves forward, backward and rotates, the direction of the motor when the robot moves is made into reference data to change the direction of rotation of the dribble wheel so that the ball rotates naturally according to the movement of the robot. Which if the condition of the robot moves forward the direction of the motor direction Ø1 will rotate CW and the motor Ø2 will rotate CCW which makes the right motor dribble rotate CW and the left motor dribble rotate CCW so that the ball will rotate naturally according to the movement of the robot. Which if the condition of the robot moves forward the direction of the motor direction Ø1 will rotate CW and the motor Ø2 will rotate CCW which makes the right motor dribble rotate CW and the left motor dribble rotate CCW so that the ball will rotate naturally according to the movement of the robot, so u(t) that used in the robot is from PID that converted to pwm, and then the pwm is inserted

## 3 Result

This section describes the results of testing ball dribbling control using PID as dribbling control speed.Testing is done by trying to dribble the robot with different robot speeds. On the test, experiments were carried out with experiments in each robot movement starting from catching the ball, moving forward, backward, right, left and rotating. the results of experiments conducted by recording the dribble motor speed and sensor response to show the results carried out with different robot movements. It can be seen from the figure that the soccer robot has two dribble motors to grab and handle the ball. It can be explained that the mechanism allows the opportunity to handle the ball in front and sideways movements of the robot during the dribbling motion. More specifically, if forward motion is performed both wheels are driven in such a way that they push the ball and during sideways or rotational motion one of the dribble motors rotates clockwise to pull back the ball while the other dribblemotor also rotates clockwise to push the ball.

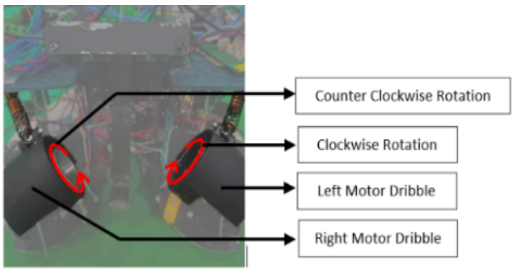



**Fig. 7.** Front view ball handling

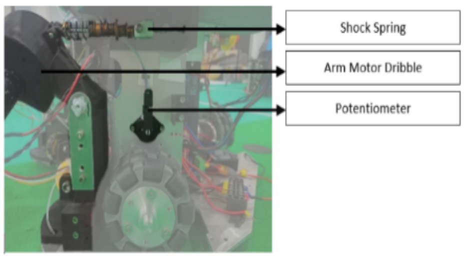



**Fig. 8.** Side view ball handling

### 3.1.1. Testing when the robot catches the ball

In this test, experiments were carried out with experiments in each robot movement starting from catching the ball, moving forward, backward, right, left and rotating. the results of experiments conducted by recording the dribble motor speed and sensor response to show the results carried out with different robot movements.

Testing when the robot catches the ball at rest can be seen in Figures 9-11. Where the sensor response from the potentiometer provides an angle value from zero to nine, each angle value will reduce the RPM value of the dribble motor as a reference as explained in the method section and also in accordance with the rules of RoboCup when the robot catches the ball, the ball must not continue to rotate because it will cause a violation, Therefore it can be seen that the results of the test show the value of each of the sensors and dribble motors where the right and left potentiometer sensor values give results from zero degrees to nine degrees, when the robot has not caught the ball the sensor shows a value of zero degrees and when the robot starts to catch the ball the sensor shows a significant increase in value so that the right dribble motor and left dribble motor show a reduced RPM value with each increase in the value given by the sensor from the potentiometer. So the PID used for decreasing the error from velocity dribble.

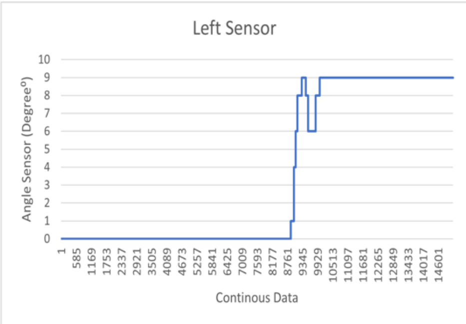



Fig. 9. Left Sensor Response

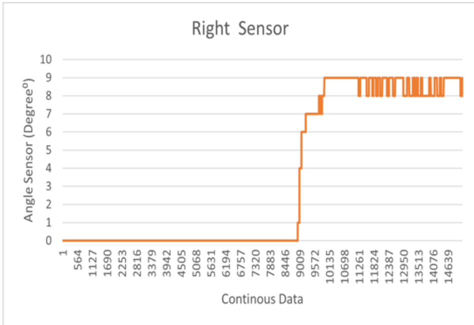



Fig. 10. Right Sensor Response

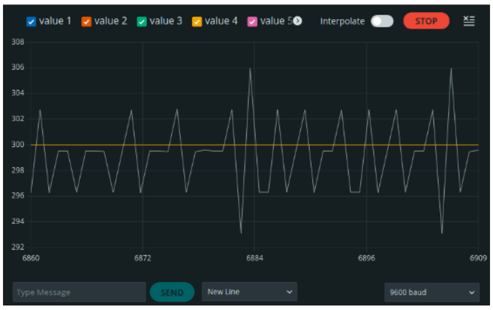



Fig. 11. PID result when catches the ball


Fig. 12. Right PID result when catches the ball

Continous Data = Data per cycle program
Orange Line = Setpoint
Green Line = Encoder Data

### 3.1.2 Testing When The Robot Dribbles Backwards

Testing when the robot dribbles with the robot moving backwards, this test is carried out when the robot is stationary and catches the ball then the robot moves in the y translational direction or backwards. The test results can be seen in Figures 13-16 where the right dribble motor response rotates CCW and the left dribble motor rotates CW and shows a value of 200 RPM when the robot dribbles and then stops. It can also be seen the response of the potentiometer sensor where when at rest the potentiometer sensor shows a value of zero degrees and when the robot moves the potentiometer sensor gives a value of up to a good degree, where as explained in the method section the value of the potentiometer sensor tells if the position of the ball will be separated from the robot then the dribble motor will accelerate and adjust the speed of the robot.

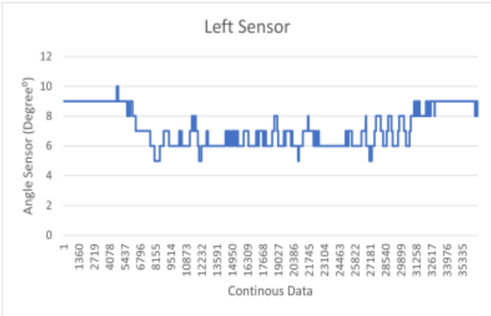



**Fig. 13.** Left Sensor Response

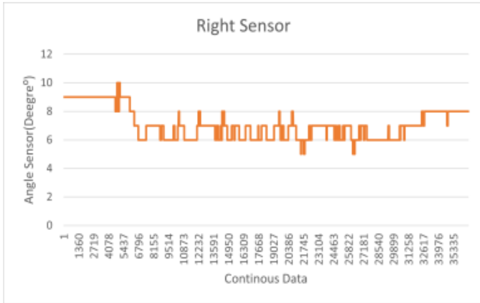



**Fig. 14.** Right Sensor Response

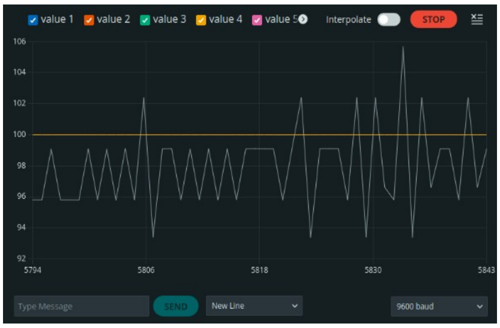



**Fig. 15.** PID result of left motor


**Fig. 16.** PID result of right motor

### 3.1.3 Testing When The Robot Dribbles Forward

Testing when the robot dribbles with the robot moving forward, this test is carried outwhen the robot is stationary in the state of catching the ball then the robot moves in the y or forward translation direction. It can be seen that the test results show a different response from the movement when the robot dribbles the ball backwards, the results show that when the robot dribbles forward the rotation response of the right dribble motor rotates CW and the left dribble motor rotates CCW, when the robot moves forward the dribble motor has to push the ball forward to make the ball rotate naturally.

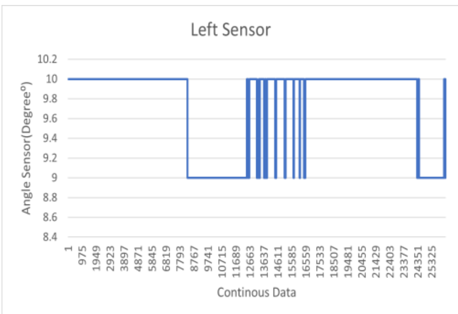



**Fig. 17.** Left Sensor Response

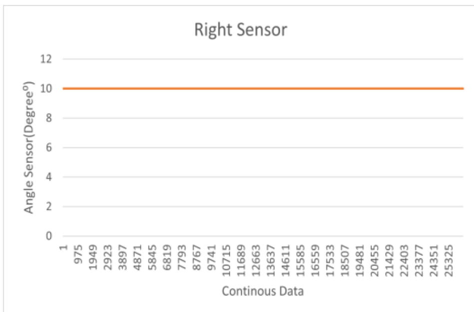



**Fig. 18.** Right Sensor Response

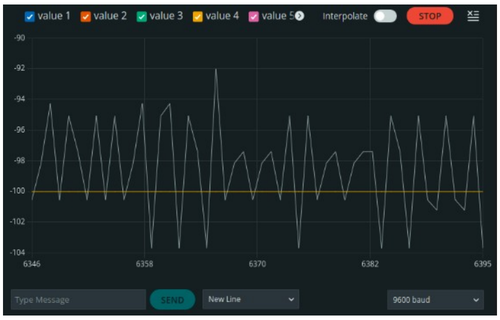



**Fig. 19.** PID result of the left motor


**Fig. 20.** PID result of the right motor

### 3.1.4 Testing when the robot dribbles to the left

Testing when the robot dribbles with the robot moving to the left, this test is carried out when the robot is stationary in a state of catching the ball then the robot moves in the x translational direction or to the left. It can be seen that the test results in this experiment show the response of the right dribble motor that rotates CW and the left dribble motor that rotates CW where when the robot moves to the left x translation direction the left dribble motor motorpulls the ball and the right dribble motor pushes the ball so that the ball can rotate naturallyand can be seen on the left sensor the dribble motor is always in a state of holding the ball while on the right sensor the dribble motor shows the sensor value between zero and one degree and then catches the ball back when the robot is silent.

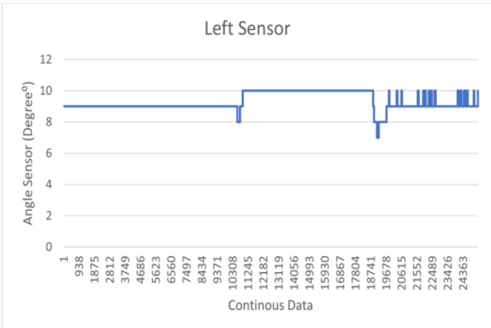



**Fig. 21.** Left Sensor Response

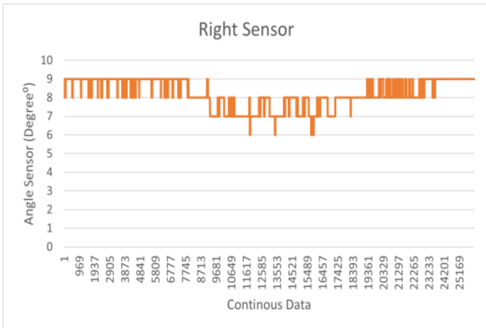



**Fig. 22.** Right Sensor Response


**Fig. 23.** PID result of left motor


**Fig. 24.** PID result of right motor

### 3.1.5 Testing when the robot dribbles to the right

Testing when the robot dribbles with the robot moving to the right, this test is carried out when the robot is stationary in a state of catching the ball then the robot moves in the x translational direction or to the right. It can be seen that the test results in this experimentshow the response of the right dribble motor that rotates CCW and the left dribble motor that rotates CCW where when the robot moves to the right x translation direction the right dribble motor motor pulls the ball and the left dribble motor pushes the ball so that the ball can rotate naturally this experiment is not too much different from the experiment when the robot moves to the left, it only has a difference in the rotation of the dribble motor because every different movement the dribble motor will rotate according to the movement of the robot so that the ballrotates naturally.

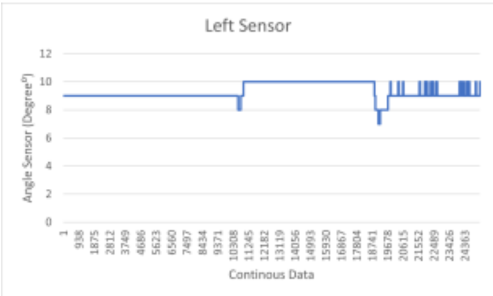



**Fig. 25.** Left Sensor Response

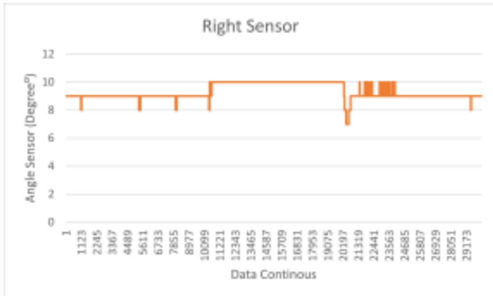



**Fig. 26.** Right Sensor Response


**Fig. 27.** PID result of left motor


**Fig. 28.** PID result of right motor

### 3.1.6 Testing when the robot rotates to the left

This test is carried out when the robot rotates while carrying the ball, the experiment starts when the robot is stationary then rotates one hundred and eighty degrees then stops, it can be seen in Figure 29-32 the response from the sensor and the dribble motor, the dribble motor response gives results when the robot rotates to the left where the right dribble motor rotates CW and the left dribble motor rotates CW when the robot rotates the left dribble motor pulls the ball and the right dribble motor pushes the ball which makes the ball rotate naturally.

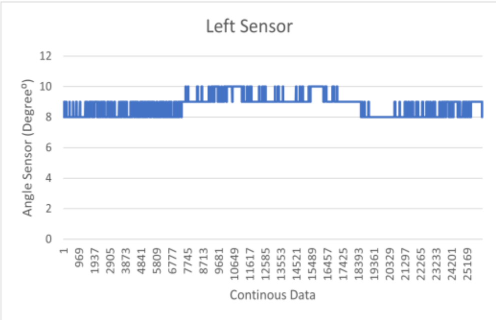



Fig. 29. Left Sensor Response

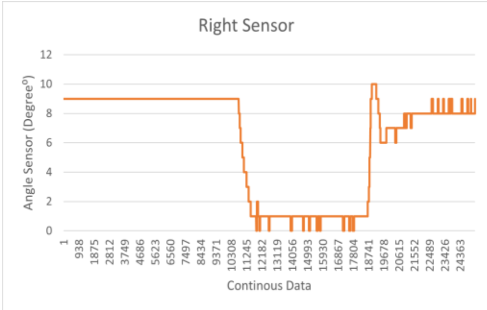



Fig. 30. Right Sensor Response


**Fig. 31.** PID result of left motor

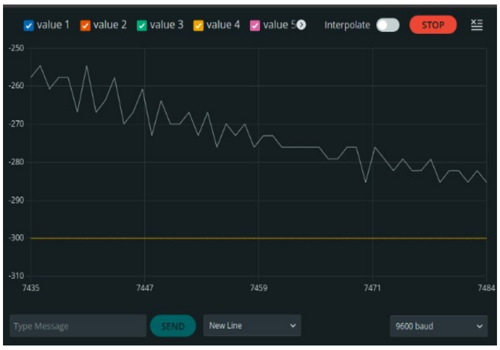
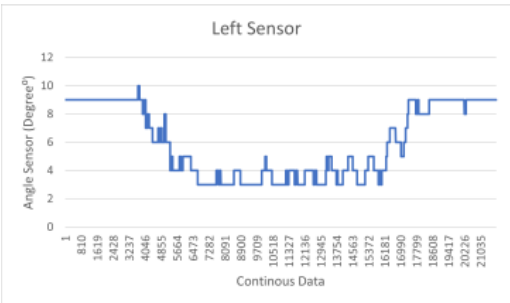



**Fig. 32.** PID result of right motor

### 3.1.7 Testing when the robot rotates to the right

This test is carried out when the robot rotates while carrying the ball, the experiment starts when the robot is stationary then rotates one hundred and eighty degrees then stops, it can be seen in Figure 33-36 the response from the sensor and the dribble motor, the dribble motor response gives results when the robot rotates right where the right dribble motor rotates CCW and the left dribble motor rotates CCW when the robot rotates the left dribble motor pushes the ball and the left dribble motor filters the ball which makes the ball rotate naturally.



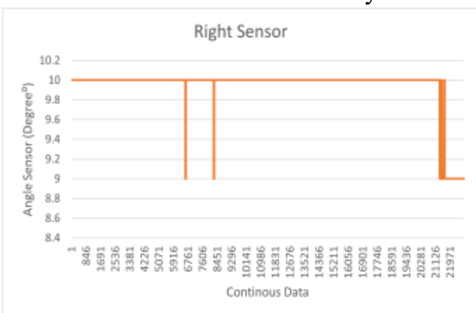




**Fig. 33.** Left Sensor Response

**Fig. 34.** Robot Rotates Right


**Fig. 35.** PID result of left motor

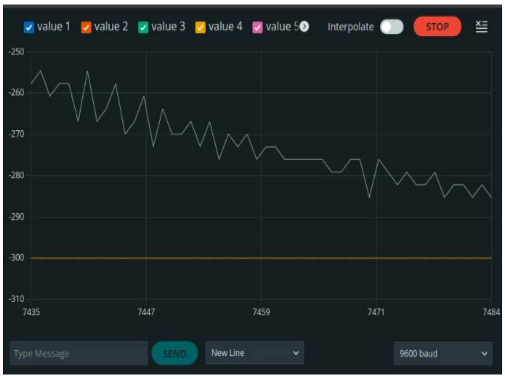



**Fig. 36.** PID result of right motor

## 4 Conclusion

Based on the results of this study, the dribble system design mechanism is veryinfluential to make the ball rotate naturally because when the system is not made to follow the diameter of the ball, it will make the ball easily detached, and the result also showingdribbling the ball by moving forward, backward, right, left and rotating with use of PID control as a dribble motor speed regulator is still less stable because when the robot dribbles the dribble motor will heat up faster if the ball is stuck in a depressed state. The choice of motor is also very influential where during the experiment when the robot dribbles backwards at a speed of 3 m / s the speed of the dribble motor cannot keep up with the speed of the robot when the robot moves because of the limitation of the maximum RPM released from the dribble motor. For further research to get maximum results, a more stable control system is needed to make the dribble motor not heat up quickly and also the selection of a lighter motor torque in order to get a higher motor RPM speed so that it can keep up with the robot's speed when the robot moves very fast.

## References

[1] M. Asada et al. : Middle Size Robot League Rules and Regulations for 2022 (2021).

[2] J. de Best and R. van de Molengraft. : An active ball handling mechanism for RoboCup in 2008 10th International Conference on Control, Automation, Robotics and Vision, ICARCV 2008, pp. 2060–2065. doi: 10.1109/ICARCV.2008.4795848, (2008).

[3] S. Chikushi, T. Weerakoon, T. Sonoda, and K. Ishii : Ball Dribbling Control for RoboCup Soccer Robot Vision-Based Behavior Strategy for Tomato Harvesting Robot (III):-Feature point matching for mosaic image generation expressing cultivation environment-View project Ball Dribbling Control for RoboCup Soccer Robot," Seagaia Convention Center. [Online]. Available: https://www.researchgate.net/publication/312595024 (2017).

[4] R. A. C. Bianchi, H. L. Akin, S. Ramamoorthy, and K. Sugiura, Eds. : RoboCup 2014: Robot World Cup XVIII, vol. 8992. Cham: Springer International Publishing. doi: 10.1007/978-3-319-18615-3. (2015).
[5] S. Chikushi, T. Weerakoon, K. Ishii, and T. Sonoda, :Motion Analysis and Control of the Ball Operation for Dribbling Action in RoboCup Soccer Robot, doi: 10.1109/SCIS&ISIS.2016.156. (2016).
[6] F. Ardilla, M. Irfan Mas, and I. Kurnianto Wibowo, : Implementation of Feedforward and Feedback Control for Active Handling and Dribbling System in MSL Robot Soccer,vol. 9, no. 6, (2019).
[7] M. Irfan Mas, F. Ardilla, I. Kurnianto Wibowo, R. A. Taufik Ulil, B. Mahardika, and M. M. Jauharul : Laboratorium Robotika Politeknik Elektronika Negeri Surabaya, Implementasi Sistem Handling dan Dribbling pada ERSOW (EEPIS Robot Soccer on Wheels). (2017)..
[8] rfan Rasyid, Muhammad Resa Arif Yudianto, Maimunah, Tuessi Ari Purnomo
Universitas Gadjah Mada, Proceedings of 2018 the 10th International Conference on Information Technology and Electrical Engineering : Smarter Technology for Better Society, Ramada Bintang Bali Resort, 24th-26th July 2018, Kuta, Bali. (2023).
[9] E. Verhees et al. : Tech United Eindhoven Team Description 2022. [Online]. Available: www.techunited.nl (2022).
[10] J. de Best, R. van de Molengraft, and M. Steinbuch : A novel ball handling mechanism for the RoboCup middle size league, Mechatronics, vol. 21, no. 2, pp. 469–478, doi: 10.1016/j.mechatronics.2010.04.001. (2021).
[11] B. Cunha et al. : CAMBADA Team Description Paper. (2015).
[12] A. Y. E. Dodu. : Sistem Kendali Umpan-Balik (Feedback Control) Menggunakan Teknik Pengendalian Pid (Proporsional-Integral-Derivatif (2009).