Optimization of Chasing and Catching Skills on Robot Soccer ERSOW

Abstract—**The wheeled soccer robot competition is held annually in Indonesia and internationally through the Indonesian Robot Contest and Robocup Middle Size League (MSL) competitions. The rate of occurrence of the ball moving freely on the field during the match is quite high. At this time the movement of the ERSOW robot to catch the ball is by chasing and following the path of the ball on the field without taking into account the speed of the ball. The movement of the ERSOW Robot with this method is very vulnerable and can still be optimized. The ball is very susceptible to failure to be caught due to being controlled by the opponent or the ball being out. In addition, chasing the ball requires a longer time due to the path of the robot that continues to change following the current position of the ball movement. So the development of robot skills in chasing and blocking the ball is needed to increase the chance of controlling the ball. Based on the results of the literature study, was found a ball blocking ability on the soccer ball intercept robot. This research is focused on how the robot can chase and catch the ball with the ability to intercept. The robot's ability to know the direction of the ball's movement and cut the ball's movement or intercept is needed. By utilizing data processing from vision to obtain ball speed data and speed algorithm calculations, a more optimal method of chasing and catching the ball is obtained. Based on the results of the 180-degree angle experiment, the success of ERSOW in catching the ball using this method was 94.7%.**

Keywords—Robot Soccer ERSOW, Ball Interception, Point Prediction, Ball Chasing, Robot Movement Optimization.

I. INTRODUCTION

The Indonesian Robot Contest (KRI) is one of the biggest annual national-level competitions on robotics, it is held by the Ministry of Education and Culture Indonesia. ERSOW (EEPIS Robot Soccer On Wheeled) represents the Surabaya State Electronics Polytechnic. Started participating in the Middle-Size League in 2017. The international competition that also takes part in middle-size robot soccer development is RoboCup [1].

Many types of research conducted on the topics of middle-size robot soccer by the ERSOW team [2], there was such as ball detection, kicking mechanism, localization [3], feature detection [4], etc. In this paper, we are focused on robot intercept skills to catch and chase a ball. Just like in humans, soccer in robots has a key aspect of the game, namely the ball. The team must utilize it efficiently to win. Currently, the movement of the ERSOW Robot to get the ball is to chase and follow the path of the ball from behind. Given the increasingly dynamic aspects of the game over the last few years, this method does not provide the most efficient path to regain control of the ball [7]. Mastery of the ball means the robot's ability to seize or get a free ball on the field while playing. The following research [7] shows that the development of intercept abilities in soccer robots is useful in defensive situations to stop the opponent from dribbling the ball. This ability also helped Team CAMBADA achieve important results such as winning the 2009 Robotica National Championship and 2010 Robotica, as well as reaching third place in the 2009 RoboCup World Championships and 2010 RoboCup [7].

So it is necessary to optimize the pursuit and ball capture skills of the ERSOW Robot. Through the development of intercept skills, the ERSOW Robot can increase the efficiency of skills in controlling the ball on the field. There are two main variables, namely:

- Ball Speed Data

For the robot to know the direction of movement of the ball and the point where the movement of the ball will be cut, it requires ball speed data obtained from vision processing in detecting the ball [2] [6]. The direction of the ball movement can be obtained from the velocity data because velocity is a vector quantity that has a value and direction in the X and Y axes. Meanwhile, the intersection point of the ball movement is obtained from the velocity value multiplied by the predetermined Time Prediction.

- Determining Time Prediction

Determining the right Time Prediction to determine the point of intersection of the movement of the ball is very necessary. The smaller the value of Time Prediction, the intersection point of the ball movement will be closer to the starting point of the ball moving. Meanwhile, if the value of Time Prediction is greater, the point where the ball moves will be farther away from the starting point of the ball moving.

II. METHOD

This research conducted several processes. The main objective of this research is to change the robot's roadmap from following the ball to predicting the robot's intersection point to the ball.

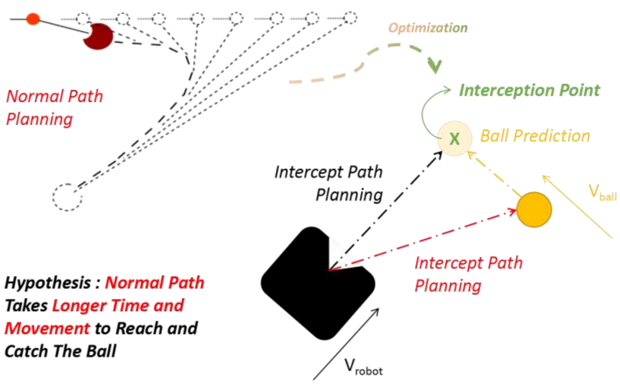


Fig. 1. Block System Design

A. Block System Diagram

The flow diagram of the ERSOW robot intercepting chasing and catching ball is shown in Fig.2. It starts with vision detection data that is processed by a robot computer and creates a decision to move.

Ball interception is done by finding the point of intersection between the direction of the ball's movement and the movement of the robot. So that the robot can make an obstruction at the ball prediction point. When the ball moves in a straight line, the robot will determine the prediction point to block the ball. The robot then moves towards the prediction point while still recalculating each iteration. So that at a certain time the robot can catch and stop the ball without following the ball from behind.

For the robot to know the direction of the ball's movement and the point where the ball's movement will be cut, it needs ball speed data obtained from vision processing. The development of ball speed calculation skills on the ERSOW Robot has been carried out in the following research [8]. The direction of the ball movement can be obtained from the ball speed data. While the point of intersection of the movement of the ball is obtained from the speed value multiplied by the predetermined Time Prediction. The smaller the value of Time Prediction, the intersection point of the ball movement will be closer to the starting point of the ball moving. Meanwhile, if the value of Time Prediction is greater, the point of intersection of the movement of the ball will be further away from the starting point of the ball moving [9]. The path planning stages in the implementation of the algorithm are described in the following diagram.

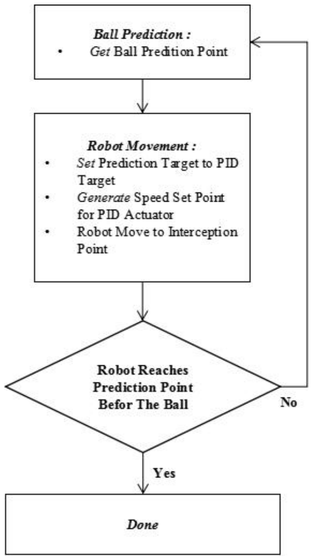


Fig. 2. Block System Diagram

The diagram in Fig 2. shows the stages of the robotic system in performing ball interception. The first stage is ball prediction which has been explained in the previous sub-chapter. The result of the ball prediction is the prediction point of the ball at a certain time. This point is then used as path planning for the robot. The prediction point will be updated every iteration until the robot can reach the prediction point before the ball. The movement of the robot is carried out by two PID Controls. After the prediction target is obtained as the first PID Control input, then the robot speed target is obtained to reach the target. This speed will be used as a second PID Control input to the actuator system so that the robot can move towards the target with the required speed.

B. Robot Soccer ERSOW

ERSOW is a wheeled KRSBI team from the Surabaya State Electronics Polytechnic consisting of three robots, namely two strikers and one goalkeeper. Each robot has its name. Striker robots named Okto and Hendro and goalkeeper robots named Jamil. Each role has a different program according to the task [3].

ERSOW uses four Omni wheels as the robot's driving mechanics. This is considered more balanced to help movement in all directions when chasing the ball and avoiding opponents.

Fig. 3. ERSOW Robot in KRSBI Beroda Regional IV 2019

The ERSOW robot is designed to run autonomously. Therefore the robot must be able to detect the ball, the coordinates of the ball, the coordinates between robots, the coordinates of the goal, and the movement of entering the ball into the opponent's goal. The working diagram of ERSOW is shown in the following figure.

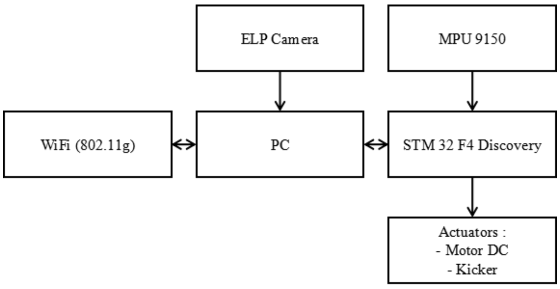


Fig. 4. ERSOW Robot System Flowchart

From the block diagram of the system in Figure 4, it can be seen that the main controller of the robot is the Personal Computer (PC) and the sub-controller is the STM32F4 Discovery Microcontroller. The PC processes the video data captured by the camera. The video is processed to find out objects around the robot, namely the ball and obstacles. In addition to processing video data from the camera, the main controller also acts as a strategy center for the robot, receiving data from the referee box, and sending commands to the sub-controller. Meanwhile, the sub-controller is in charge of retrieving data from the gyroscope and odometry sensors. In addition, the sub-controller is also in charge of sending the data to a PC serially for further processing. STM32F4 Discovery is a link between the main controller to the actuator. All information about the strategy will be sent to the sub-controller which already contains motion data from the actuator.

C. Robot Control

The movement of the ERSOW Robot is carried out by utilizing four Omni wheel actuators. The use of Omni wheels is rated to allow the robot to move in eight different directions without having to rotate. This movement is regulated and controlled via two nested PID controls. PID on the sub-controller to maintain the wheel speed of each robot and PID on the main controller to direct the movement and speed of the robot. Below is explained how all the components that exist in ERSOW when working and the flow of each component.

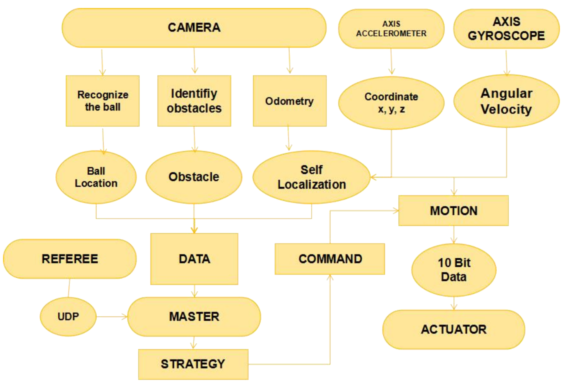


Fig. 5. ERSOW Robot Work Flow

According to Fig 5, the camera takes an image for processing. The data obtained on the camera is collected to be sent to the main controller. The main controller processes data from the Referee Box via wireless communication (WiFi), then the controller gives commands to the sub-controller in the motor driver to drive the DC motor where the robot will move.

Data from the IMU MPU-9150 sensor is used to determine the robot's heading and location mapping. To drive all DC motors with Omni wheels, the controller uses a special Omni drive system with the following mathematical equation:

$$V_w = V_b(cos\,.\,cos\,\theta\; cos.\,cos\,\emptyset + sin\,.\,sin\,\theta\; sin\,.\,sin\,\emptyset\;) + R\dot{\Psi} \qquad (1)$$

Motor speed regulation using Proportional–Integral–Derivative (PID) Control. PID control helps the robot in stabilizing the wheel speed. The robot will then take a kick when it gets the ball and has found a straight position with the goal.

D. Robot Vision

ERSOW uses an ELP camera equipped with a catadioptric mirror so that the robot can see 360o of its surroundings. The method used by ERSOW to detect the ball is thresholding. This method can detect the ball quite accurately and faster than the use of other methods. The ball data obtained is then processed to find the actual distance between the object and the robot. In calculating the actual distance, the method used is to perform a regression between the pixel distance and the original distance in cm. In addition to object detection, the vision system on the ERSOW Robot is used to obtain data on the speed of the detected object. This is used to help develop robotic skills in the future.

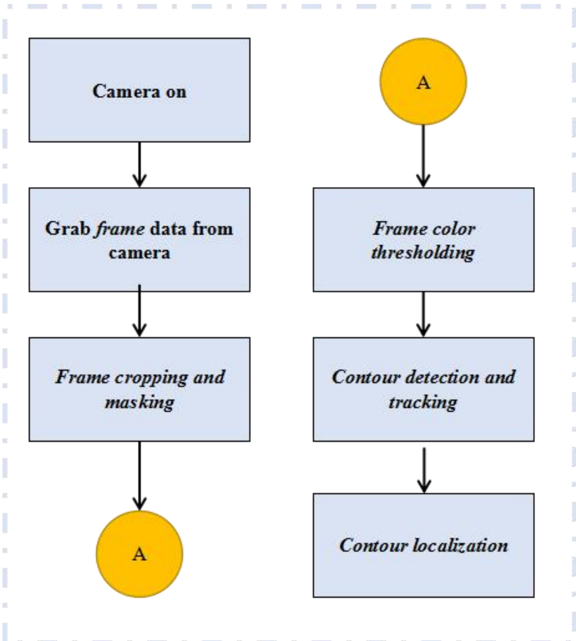


Fig. 6. ERSOW Vision System

The diagram Figure 6 shows the detection and localization process in the robot vision system. First, the data frame is taken from the ELP-USBFHD085 Camera for processing. To optimize the computation, cropping is done on the part of the frame that is not needed. From the previous frame with a resolution of 1280 x 720 pixels, cropping was done to a square of 640 x 640 pixels. The next step is frame masking on the image to ignore unused frame areas. Figure 7 shows the masking area on the frame.

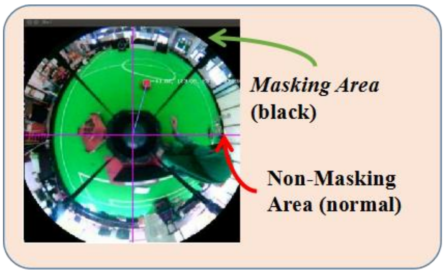
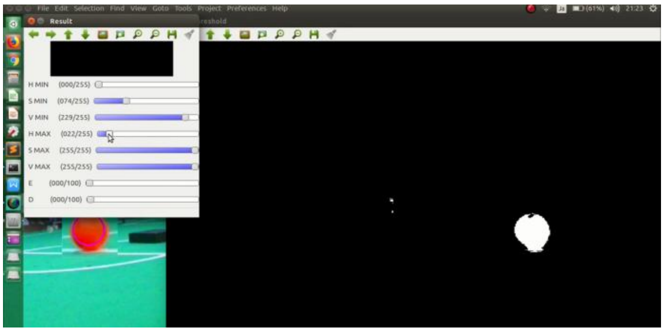
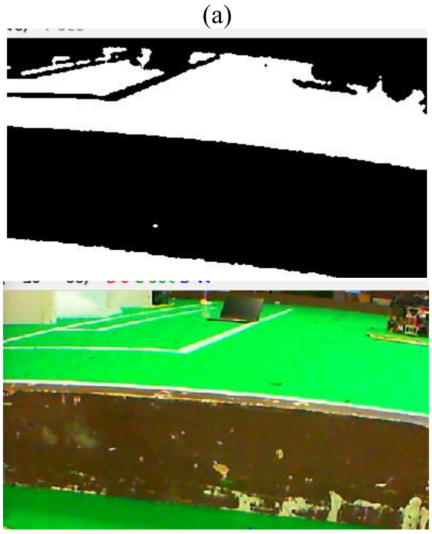


Fig. 7. Masking Area on Vision ERSOW

The next stage is frame color thresholding to detect ball objects on the field. Frame color thresholding on the ERSOW Robot is done by determining the value of the green color limit of the field and the orange color of the ball. If there is an orange contour above the green contour, then the orange contour is detected as a ball. Figure 8 is an illustration of the thresholded binary frame on the ERSOW robot.



(a)



(b)

Fig. 8. (a) Ball Threshold System on Robot ERSOW Vision, (b) Field Threshold System on Robot ERSOW Vision

The next stage is tracking the contour of the ball. Contours detected as balls will continue to be tracked to find out the current ball position. Localization of the ball contour to the robot is done by changing the pixel distance (tracking results) into cm with regression.

E. Intercept Point Calculation

Prediction of the ball is one of the important skills in a soccer robot match. The robot's ability to predict the direction of the ball can support the development of other abilities, one of which is in chasing and catching the ball. In this research, ball prediction is developed by calculating the speed and direction of the ball. The speed and direction of the ball can be converted into ball prediction points in a certain unit of time. The prediction point is then used to perform ball interception.

In the ERSOW Robot to determine ball prediction, the stages are (1) ball detection, (2) measurement of the distance of the ball to the robot, (3) localization of the ball to the field, (4) calculation of the distance of the ball displacement per iteration, (5) determining the speed of the ball to the X-axis and Y-Axis, and (6) get ball predictions. The following diagram describes these stages.

1. Deteksi Bola :
- *Thresholding* warna
- *Tracking* Contour

2. Jarak Bola (Δ_{ball}) :
- *Get* Jarak *Pixel* Bola ke Tengah *Frame*
- Δ_{ball} = Regresi *Pixel to* cm

3. Lokalisasi Bola (X_{ball}, Y_{ball}) :
- $\Delta_\theta = \theta_{ball} - \theta_{robot}$
- $X_{ball} = X_{robot} + (\Delta_{ball} \text{ x } \sin(\Delta_\theta))$
- $Y_{ball}, = Y_{robot} + (\Delta_{ball} \text{ x } \cos(\Delta_\theta))$

4. Perpindahan Bola (ΔX_{bal}, ΔY_{bal}) :
- $\Delta X_{ball} = X_{ball}(n) - X_{ball}(n-1)$
- $\Delta Y_{ball} = Y_{ball}(n) - Y_{ball}(n-1)$

5. Kecepatan Bola (VX_{ball}, VY_{ball}) :
- *Time Iteration* $\Delta t_i = t(n) - t(n-1)$
- $VX_{ball} = \Delta X_{ball} \div \Delta t_i$
- $VY_{ball} = \Delta X_{ball} \div \Delta t_i$

6. Prediksi Bola (PX_{ball}, PY_{ball}) :
- $PX_{ball} = X_{ball}(n) + VX_{ball} \text{ x } t_{pred}$
- $PY_{ball} = Y_{ball}(n) + VY_{ball} \text{ x } t_{pred}$

Fig. 9. Ball Prediction Calculation Process Diagram

Based on the diagram in Figure 9, the ball detection process is carried out using the Thresholding Method on the color of the ball. Then contour tracking is carried out on the contour of the ball detected in the binary frame. The tracking results provide the value of the contour position to the frame in pixels. The distance is then regressed to change units from pixels to cm (Δball). the ball is the distance from the ball to the robot in cm. Furthermore, the calculation of the localization of the ball to determine the position of the ball on the field. First, determine the angle of the ball (θball) and the angle of the robot (θrobot). The ball angle is obtained from the position of the ball pixels to the center point of the frame. While the angle of the robot is obtained from the IMU sensor.

Because the robot heading can rotate, this causes the ball angle to change, it is necessary to calculate the angular displacement (Δθ) as shown in the diagram. The calculation of localization to the X and Y axes of the field is determined by adding up the position of the robot (Xrobot, Yrobot) and the distance of the ball to each. each axis. To determine the speed of the ball, the displacement of the ball on the field (ΔXball, Yball) is divided by the time of one iteration (Δt). Finally, the results of the velocity calculation are multiplied by tpred (Time Prediction) and summed with the nth position of the ball. Time Prediction is a time value determined through tuning to determine the correct prediction.

III. Experimental Result

Before testing the algorithm, the data of the vision sensor is tested. The purpose of the test is to get the regression of the vision and communication stability to run the robot.

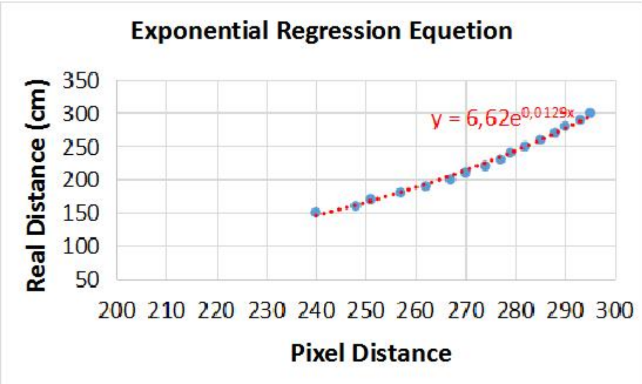


Fig. 10. Regression of The ERSOW Vision

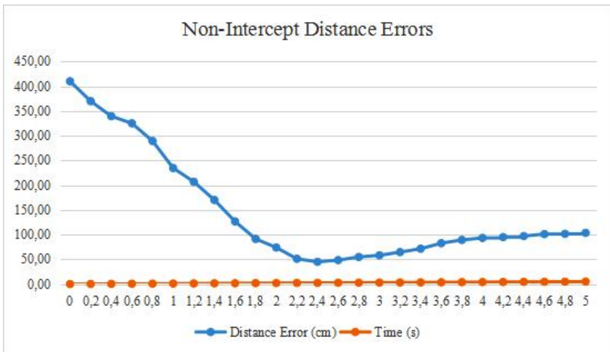
Fig. 10 is the result of testing on the vision robot to find the relationship between the distance of the ball to the robot in pixels and the original distance on the field. The formula for the results of the exponential regression analysis is used to determine the position of the ball while playing.

The results of the communication delta time test show that the stability of the data is at an average period of 12.83 ms. The process delta time in the control program is 10 ms with a tolerance of 5 ms, so the stability of the communication delta time is still within the tolerance.

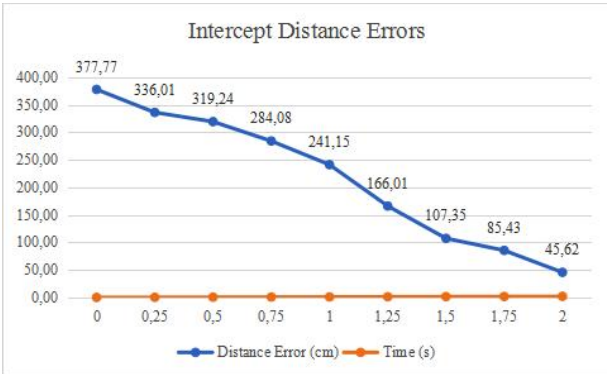
No	*Delta Time* (ms)	Average (ms)
1	12,63	12,83
2	14,01	
3	15,97	
4	10,65	
5	12,03	
6	11,97	
7	13,34	
8	12,01	
9	12,65	
10	11,33	
11	13,9	
12	10,84	
13	12,48	
14	13,33	
15	15,33	

Fig. 11. Communication Stability Test Result

Next is system testing. Before testing the accuracy of success, a test is conducted to compare the distance error between the robot and the ball during the process of chasing & catching the ball between with and without intercept.



(a)

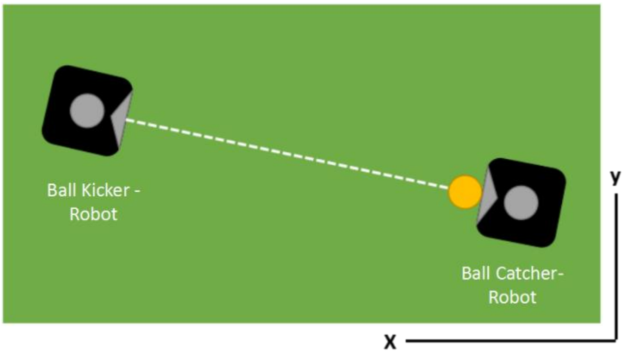


(b)

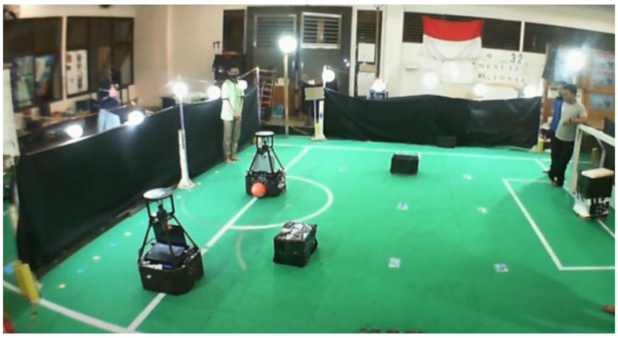
Fig. 12. (a) Distance Errors Between Ball & Robot with Non-Intercept , (b) Distance Errors Between Ball & Robot with Intercept

The data above shows that the time needed to chase and catch the ball using the intercept skill is faster, which is 2 seconds compared to without an intercept, which is 5 seconds. In addition, the pattern of decreasing the error distance between the ball and the robot on non-intercept indicates a ball bounce at 2.2 seconds. Whereas in intercept the ball can be caught perfectly without a bounce at 2.0 seconds. In non-intercept mode, the robot's motor control is controlled based on a live ball target without prediction. Cause the resulting control is less stable and must follow the slowdown of the ball. If the ball is decelerated high enough, the resulting control can overshoot due to imperfect braking.

The next experiment was carried out with the distance of the robot from the loose ball as far as 180 cm. The distance was chosen as a simulation of the loose ball condition. Another robot is used 180 degrees to kick the ball. This is to simulate the opponent's robot kick that releases the ball into an empty area. The robot is said to have succeeded in catching the ball when the ball was kicked by the kicking robot and caught by the receiving robot directly as shown in Figure 12.



(a)



(b)

Fig. 13. (a) Robot Test Position from Above View, (b) Robot Test Position in Side Real View

Meanwhile, the robot is considered unsuccessful when the ball cannot be chased or caught by the receiving robot directly. Based on the experimental results, the robot managed to catch up and get the ball 18 times out of a total of 19 trials. The robot can chase and catch the ball with accuracy through this test of 94.7%. In the 11th experiment, the robot failed to catch the ball. The ball bounced off the bumper of the robot.

Test No-	Result	Description
1	Success	Ball Caught
2	Success	Ball Caught
3	Success	Ball Caught
4	Success	Ball Caught
5	Success	Ball Caught
6	Success	Ball Caught
7	Success	Ball Caught
8	Success	Ball Caught
9	Success	Ball Caught
10	Success	Ball Caught
11	Fail	Ball Bounces Off The Robot Body
12	Success	Ball Caught
13	Success	Ball Caught
14	Success	Ball Caught
15	Success	Ball Caught
16	Success	Ball Caught
17	Success	Ball Caught
18	Success	Ball Caught
19	Success	Ball Caught

Fig. 14. Robot Test Result

Thus the robot means that it can chase and catch the ball, especially in conditions of 180 degrees. This ability can be used by the robot to increase the chances of the robot's success in mastering the loose ball.

IV. Conclusion

This paper contains the intercept algorithm on the ERSOW Robot for optimizing the ability to chase and catch the ball. Based on the results of testing this algorithm has succeeded in reaching 94.7% in a 180-degree ball condition. So that this algorithm can be applied to the ERSOW Robot. The failure of the robot was caused by the ball hitting the bumper of the robot so that it bounced. Research development is needed for optimizing ball possession time and testing various conditions of the robot's angle to the more varied ball. As the next development, the ball possession time will be optimized to be shorter. So it's more efficient.

References

[1] Ihsan, F.L., Priambudi, R.A., Bachtiar, M. M., Wibowo, I. K.. Heading Calibration on Robot Soccer ERSOW using Line Landmark on The Field, International Eelectronics Sysmposium, 2020.

[2] Robocup, Middle Size Robot League Rules & Regulation, Robocup, 2019.

[3] Haq, M.A., Priambudi, R.A., Wibowo, I. K., et al. The Development of EEPIS Robot Soccer on Wheeled (ERSOW) 2019, ISRSC, 2019.

[4] Wibowo, I. K., Priambudi, R.A., Bachtiar, M. M., et al. Penentuan Posisi Robot Menggunakan Odometery Omniwheel, ISRSC, 2018.

[5] Nurrohmah, E. A., Dewantara B. S. B., Bachtiar, M. M., Wibowo, I. K., Priambudi, R.A. Detecting Features of Middle Size Soccer Field using Omnidirectional Camera for Robot Soccer ERSOW, International Conference on Smart Technology and Applications, 2020.

[6] Wibowo, I. K., Haq, M.A., Bachtiar, M. M., Dewantara B. S. B., Ihsan, F.L. Ball Detection using Local Binary Pattern in Middle Size Robot Soccer (ERSOW). IC2IE. 2019.

[7] Cunha J., Lau N., Rodrigues J. (2012) “Ball Interception Behaviour in Robotic Soccer”. In: Röfer T., Mayer N.M., Savage J., Saranlı U. (eds) RoboCup 2011: Robot Soccer World Cup XV. RoboCup 2011. Lecture Notes in Computer Science, vol 7416. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-32060-6_10.

[8] Nurrohmah E. A., Priambudi R. A., Ariyadi B. N. D., and Dewantara B. S. B., "Real-Time Ball Speed Stabilization Acquisition using Low Pass Filter on Robot Soccer ERSOW" 2020 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM), Surabaya, 2020, doi: 10.1109/CENIM51130.2020.9297923.

[9] Bachtiar M. M., Ihsan F. L. H., Wibowo I. K., Wibowo R. E., "Intercept Algorithm for Predicting the Position of Passing the Ball on Robot Soccer ERSOW", 2021 Inform : Jurnal Ilmiah Bidang Teknologi Informasi dan Komunikasi, Vol 6, No 1 (2021).