

Team Description Paper:

ERSOW 2026

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Abstract. ERSOW-PENS is a robotics team that has participated in the Indonesian Wheeled Soccer Robot Contest (adapted from MSL - Robocup) since 2017. In recent years, we have successfully won the national competition in Indonesia twice in 2023 and 2024. In addition to participating in competitions, as researchers, we have published numerous research findings in prestigious venues. ERSOW soccer robots operate autonomously through the integration of object detection systems, navigation, self-mapping, and real-time communication between robots. The embedded algorithms enable them to execute tactical strategies dynamically, whether defending or attacking. This year marks ERSOW's second participation in the Middle Size League RoboCup 2026, and we are ready to deliver our best performance.

Keyword: RoboCup Soccer · Autonomous Soccer Robot · Multi-Robot Communication · localization · ball-handling

1. Introduction

ERSOW is one of the robotics team from Politeknik Elektronika Negeri Surabaya (PENS) Indonesia. ERSOW team was formed in 2016 to participate in the exhibition competition for the Small Size League (SSL) category in Indonesia. Then in 2017 until 2024, ERSOW participated in the Indonesian Wheeled Soccer Robot Contest which was adopted from the Robocup Middle Size League (MSL) competition. The journey of the ERSOW team has been quite long and has made many achievements at the regional and national levels in Indonesia. ERSOW tries to show its best ability in the Indonesia Wheeled Soccer Robot Contest at the regional and national level to win the championship. ERSOW's ability is always improved to meet the target in the competition every year. Our best achievement is the winner of the regional and national competition in Indonesia. In recent years, we have successfully won the national competition in Indonesia twice in 2023 and 2024, achieving back-to-back champion at the national level. With experience in competitions in Indonesia, in 2022 we participated in the RoboCup competition to gain valuable knowledge and experience from other teams around the world. Now in 2026, we are participating in the RoboCup competition again, bringing our international experience and continuing to develop our team to compete at a higher level globally. Since 2017, ERSOW has progressively improved its hardware and software systems, including localization, multi-robot cooperation, mechanical robustness, and advanced intelligent detection to enhance overall match performance. ERSOW has five robots that have their own names and tasks. We have three striker robots named Joko, Wiro, and Bowo, and two midfielder robots named Pablo and Huda. Currently, the newest robot that we are

developing is Bowo, and currently we are focusing on improving Bowo's performance and system.

2. Mechanical

The ERSOW wheeled robot mechanism is designed in two different configurations, namely a three-wheel and four-wheel mechanism. The team uses two attacking robots with three wheels, two robots with four wheels, and one goalkeeper robot that also uses four wheels. As shown in Fig. 1(b), the four-wheel design has relatively larger dimensions and is used for the roles of midfielder, defender, and goalkeeper. This configuration was chosen because it provides better stability when moving omnidirectionally, allowing the robot to maintain balance when chasing the ball or avoiding obstacles. In contrast, the three-wheel design shown in Fig. 1(a) is applied to attacking robots. This configuration is lighter and more agile, supporting faster acceleration and more flexible maneuvers when dribbling the ball. Thus, attacking movements towards the opponent's defense area can be carried out more effectively.

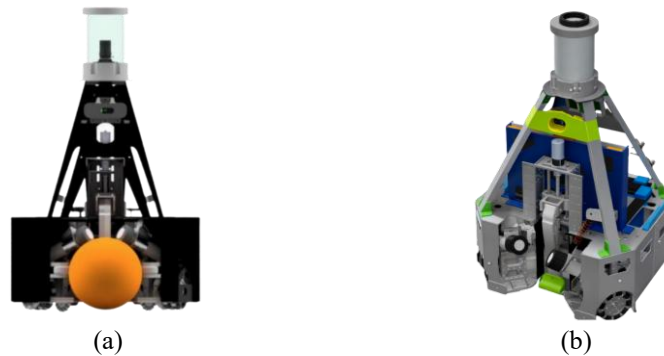


Fig. 1: (a) 3D design 3 Wheel Robots (b) 3D design 4 Wheel Robots

2.1. Ball Handling

Natural Ball Control is one of the main rules in the RoboCup Mid-Size League, and for 2026, we have specifically designed this mechanism to meet these standards. Mechanically, as shown in Figure 2, the position of the dribble wheel is adjusted to the ball so that its surface precisely follows the angle of contact with the ball. The addition of a free wheel allows the ball to move more flexibly when maneuvering, while maintaining stability in the interaction between the ball and the robot. With this configuration, the dribble wheel can attach directly to the surface of the ball and produce optimal grip. In addition to mechanical adjustments, the embedded system is also configured so that the dribble wheel's rotation speed is synchronized with the robot's movement speed. This synchronization is calculated using an inverse kinematics approach, so that the direction and speed of the dribble wheel's rotation automatically adjust to the direction of the robot's movement.

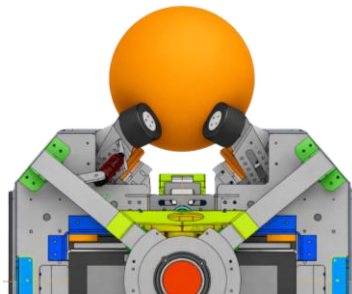


Fig. 2: Ball Handling ERSOW Robots

2.2. Kicking Mechanism

The kicking mechanism on the ERSOW robot uses a solenoid driven by voltage from a capacitor to generate a magnetic field that attracts the shaft. This thrust is used to kick the ball, with the aim of producing a hard and accurate kick. This latest mechanical model can produce straight kicks and rebounds. The speed and power of the kick depend on the voltage and current flowing in the solenoid coil. At a voltage of 235V, the kicked ball can reach a speed of 7 m/s. This design uses a pipe with a diameter of 28,3 mm and a length of 10,4 cm, with a copper coil wrapped around the center of the pipe. Inside the pipe is a 25 cm long piece of iron that can move freely, placed parallel to the pipe. When the copper coil is activated, the iron is pulled into the pipe until it is in the center of the pipe, which then pushes the kicking lever. The kick lever mechanism is connected to a lifting system, as visualized in Fig. 3, which allows the kick height to be adjusted according to the target position. The lifter system uses a vertical actuator to adjust the position of the kick lever, allowing the robot to dynamically adjust the kick height based on the target position determined by algorithm.

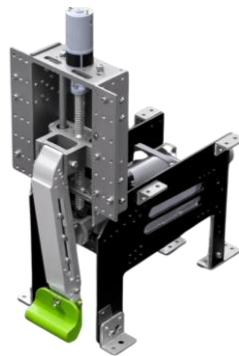


Fig. 3: Kicking Mechanism ERSOW Robots

3. Hardware

ERSOW robot is designed to operate autonomously, which means it must be able to detect the ball, know its coordinates, the coordinates between robots, and the goal, and shoot the ball into the opponent's goal.

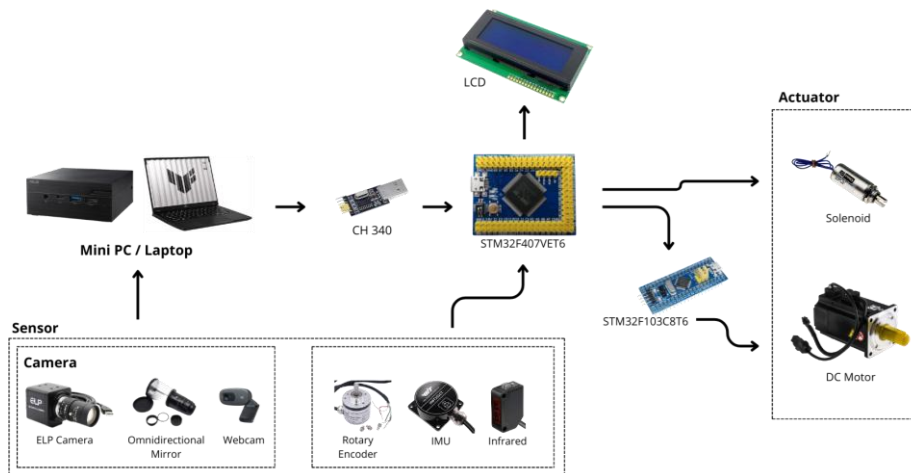


Fig. 4: Block Diagram of the ERSOW Robot's system

Based on the block diagram at Fig. 4, the main controller of the robot is a PC, while the secondary controller uses STM32F4 Discovery. The computer or PC is tasked with processing video data captured by the camera to determine whether

objects around the robot are balls, goals, or opponents. In addition, the main controller also functions as a strategy center for the robot, receiving data from the “referee box” and sending commands to the secondary controller. The secondary controller, on the other hand, is responsible for retrieving data from the gyroscope and accelerometer used to balance the robot. The secondary controller also sends data to the PC via serial communication for further processing. The STM32F4 Discovery acts as a link between the main controller and the actuator, where all strategy-related information is sent to the sub-controller that already contains movement data from the actuator.

4. Image Processing

4.1. Omnidirectional Vision Localization

In autonomous soccer robots, the ability to localize to determine the position (x, y, θ) on the field is one of the most important things. In the 2023 wheeled soccer robot competition, the ERSOW team implemented a localization method using odometry sensors, but this method produced significant errors due to slippage in the rotary encoder when the robot was moving, causing the target coordinates to shift [2]. As a solution to this problem, omnidirectional images can be used to independently estimate the robot's position, thereby determining its coordinates (x, y) on the field.

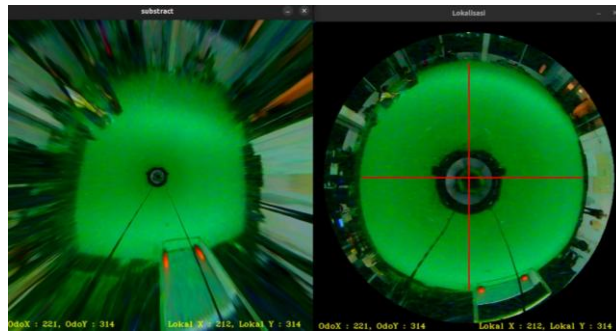


Fig. 5: Vision Localization Preview

This robot localization algorithm involves detecting the green field area and field boundary fences using color segmentation. The system will compare the image of the boundary fence with the image of the field to find the end point of the field. Next, the system forms a Cartesian line to determine the robot's coordinates (x, y) in pixels, as shown in Fig. 5. After obtaining the distance between the field edge lines and the robot position, the system will estimate the actual distance in centimeters using exponential and linear regression algorithms.

4.2. Goal Post Detection

In Goal Post Detection, Deep Learning Neural Network (DNN) methods are used to train robots to detect important visual characteristics of goalposts. The model used is Single Snapshot Detector (SSD) MobileNet V2 FPNLite 640x640, which is trained with a dataset of individual images of goalpost positions taken by an omnidirectional camera. In addition, the detection results provide the coordinate points of each goalpost's endpoints, which are further used for position estimation and shooting angle calculation, as shown in Fig. 6. This model produces a classification loss of 1%, a locality loss of 0.1%, and a total loss of 9%, with a detection confidence level of 96-100%. The accuracy of goal detection and recognition reaches 93%, with an average frame rate of 49 FPS [4], enabling the robot to detect goals with high speed and accuracy during the game.

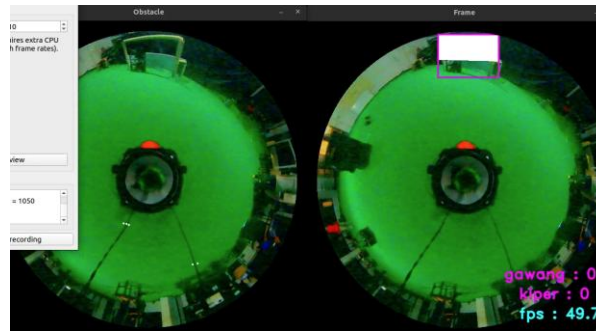


Fig. 6: Vision Goal Detection Preview

5. Communication Architecture

The communication architecture of ERSOW is divided into two primary layers: (1) the Wireless Distributed Communication Layer, responsible for inter-robot and robot-to-BaseStation data exchange via UDP socket programming, and (2) the Inter-Robot Communication Layer, implemented using ROS middleware for inter-node message passing within each robot.

5.1. Wireless Distributed Communication Layer

As illustrated in the diagram shown in Fig. 7, the communication system is implemented over a wireless network based on IEEE 802.11a/b standards operating at 5 GHz and 2.4 GHz. Communication between the BaseStation and the Referee Box uses IP Unicast for reliable point-to-point command delivery, while robot-to-BaseStation and inter-robot communication employ IP Multicast to optimize bandwidth usage. Real-time data exchange is conducted via UDP using socket programming. To reduce collisions and packet loss, a Reconfigurable and Adaptive TDMA scheme is applied, allocating dynamic transmission time slots to each active robot. Data packets include structured headers for filtering, duplicate detection, and sequence tracking. Exchanged information covers global position, ball status, role, motion parameters, and system conditions, with adaptive transmission rates to balance network stability and tactical coordination.

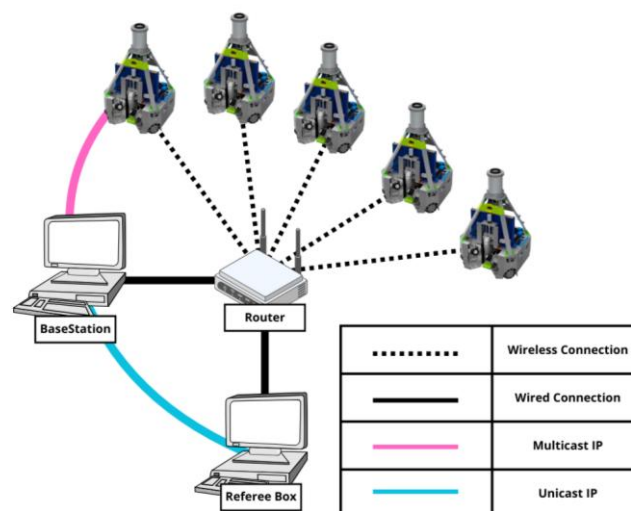


Fig. 7: Data Communication System Diagram

BaseStation is equipped with a Graphical User Interface (GUI), as shown in Fig. 8, which functions as the central control and monitoring system for all team robots. Besides handling official commands from the Referee Box, it provides manual control

for testing and debugging. Real-time data from active robots including global position, orientation, ball status, system condition, and operational state are visualized numerically and graphically on a real-scale field display based on official MSL dimensions. The system offers four operating modes: Manual, RoboCup, Regional, and National. The BaseStation also manages role assignment, job allocation, game state initialization (e.g., kick-off, free kick, defense, attack), and positioning configuration, enabling centralized coordination while preserving each robot's local autonomy during matches.



Fig. 8: ERSOW BaseStation Interface

5.2. Inter-Robot Communication Layer

Internal communication between each robot is implemented using ROS middleware, with some robots using ROS 1 and others using ROS 2 according to system requirements. This architecture is included in the Intra-Robot Communication Layer and utilizes the publish-subscribe mechanism as the main feature for data exchange between nodes. As shown in the diagram in Fig. 9, each module, including vision, localization, strategy, and motion control, operates as an independent node that exchanges messages asynchronously through topics, making the system modular and easy to develop. All information from these modules is consolidated by the synchronizer node, processed into /synchronized_data, and then transmitted through the wireless communication layer to maintain integrated team coordination. In ROS 1, the communication mechanism is controlled by the ROS Master, while in ROS 2, the DDS protocol is used.

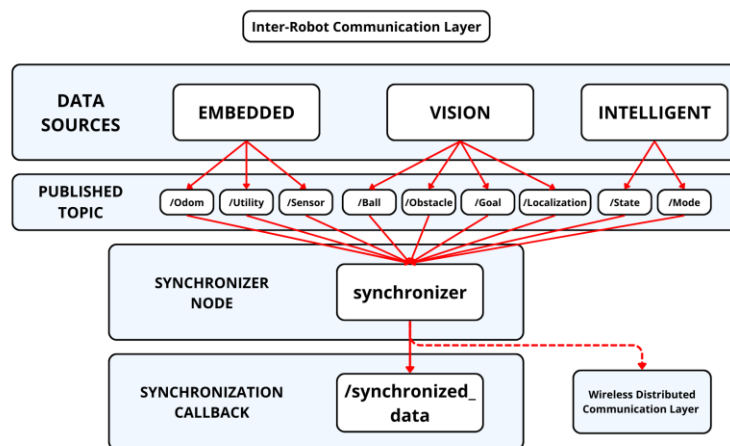


Fig. 9: Inter-Synchronization Design

6. Strategy

Strategy is key in soccer because it influences performance on the field. Interception is crucial, as it allows robots to predict and disrupt opponents' passes, gaining control of the ball before it reaches its target. Unlike tackling, interception relies on timing, positioning, and anticipation, minimizing physical confrontation while maximizing strategic advantage [1]. In addition, passing strategies help robots under pressure distribute the ball quickly and accurately, reducing the risk of losing possession and creating better attacking opportunities.

6.1. Ball Interception

The ball interception algorithm works by estimating the position of the incoming ball based on the point of contact between the robot and the ball. To obtain ball position data, images are processed from two cameras, namely an omnidirectional camera and a webcam that faces the front of the robot. The detected images are then processed using color thresholding techniques to identify the position of the ball. Then, based on the pixel location produced by the camera, exponential and linear regression methods will be combined to estimate the actual distance of the ball.

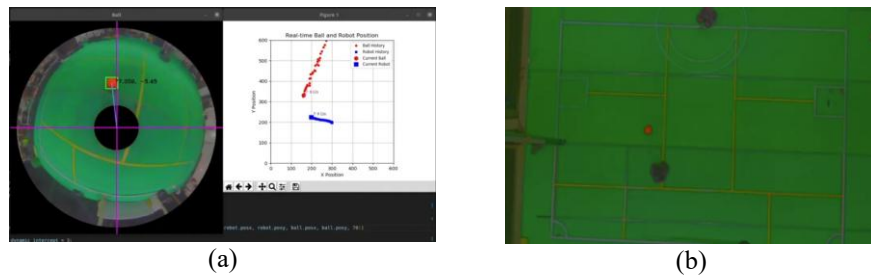


Fig. 10: (a) Robot POV During Intercept (b) Robot When Intercepting If Seen

Once the ball's position is detected, the next step is to predict the ball's intercept point. Using regression analysis, ball position data from several previous points in time is analyzed to estimate the ball's trajectory using the slope-intercept formula. The ball's speed is calculated to estimate the time required to reach the intercept point. Based on this predicted future position, the robot then moves toward that point by precisely controlling the omnidirectional wheel motor, as shown in the test documentation photo we took with our robot in Fig. 10.

6.2. Potential Passing Point

In the ERSOW soccer robot, the Potential Passing Point (PPP) serves to dynamically determine the optimal passing point during the game. The process begins with the generation of several candidate points for passing, which are calculated based on the position of the ball, the position of teammates, and the position of opponents, as shown in Fig. 11 (b). These points are then evaluated to ensure that the passing path is not obstructed by obstacles or barriers on the field. If there are obstacles, the algorithm will search for alternative paths that are safe for the ball to reach the receiver.

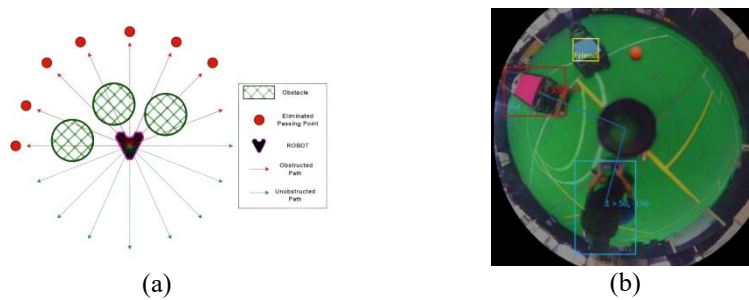


Fig. 11: (a) Visualization Algorithm PPP (b) Friend Robot Classification

To determine the most optimal feeding point, the system evaluates the scattered search line as visualized in Fig. 11(b), taking into account parameters such as the distance to the opponent's goal and the angle of the shot. Passing points that are too close to the goal will be adjusted to avoid camera vision limits or obstructed areas. Using the PPP algorithm, the robot can adapt its passing strategy in real time, optimizing scoring opportunities and improving team effectiveness by avoiding passes that are easily intercepted by opponents.

7. Conclusion

Since our last participation in the 2022 RoboCup MSL competition, ERSOW team has made significant developments, including mechanical design (chassis improvements, ball handling mechanisms, and robot kinematics optimization) to artificial intelligence enhancements through the development of more adaptive and responsive ball intercept and dynamic passing algorithms. The biggest changes have occurred in the vision sector, through the development of omni localization and goal detection, which have significantly improved the accuracy of the robot's perception and decision-making in the field. These updates not only improve the performance of the ERSOW soccer robot in terms of movement, stability, and game strategy, but also reflect our strong commitment and effort in RoboCup MSL 2026. More than just preparation for the competition, this development opens up opportunities for further research and innovation that has the potential to drive the advancement of soccer robot technology in the future.

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