IRIS Team's Autonomous Soccer Robot Development

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Abstract. IRIS ITS is a robotics team that competes in the soccer robot league. The team was founded in mid-2016 with the ambitious goal of competing in international robotics competitions with continuous research and technological developments. This paper presents the IRIS team's Middle Size League (MSL), covering team information, past research on hardware and software, as well as new developments in both areas for RoboCup 2025.

Keywords: IRIS · ITS · MSL RoboCup · Soccer Robot.

1 Introduction

The IRIS team competes in various robotics competitions, such as the annual KRSBI-B (a middle-size soccer robot competition organized by the Indonesian Ministry of Research Technology and Higher Education), where the IRIS team has consistently excelled since their first competition in 2017. IRIS Team achievements include 1st place in the KRSBI-B Regional II, 1st place in the KRSBI-B National competition, and Best Strategy in the KRSBI-B National competition. Internationally, the IRIS team has achieved significant recognition at events such as the RoboCup Asia-Pacific 2022, where IRIS earned 1st place in both the Open Challenge and Cooperation Challenge. The IRIS Team also secured 3rd place in the Middle-Size RoboCup League at RoboCup 2022 in Thailand, 5th place in the Technical Challenge at RoboCup 2024, and 6th place for the Scientific Challenge at RoboCup 2024, where the IRIS Team presented a paper highlighting their research advancements. As of 2017 to 2024, IRIS has done much research that improves the robots performance. There is some research that has been done by the IRIS team.

2 Past Research

2.1 Hardware Research

From 2020 to 2021, the IRIS team focused on developing the striker robot by changing its design from using 4 DC motors with an omniwheel as the drive to using 3 DC servo motors as the main drive. This change aims to improve the robot's efficiency and maneuverability in the field. This development involves several important electronic components, such as the PC Supply Board that manages power distribution, the STM Board for processing data from various sensors, and the Booster Board to increase the power voltage for the ball-kicking mechanism. From 2022 to 2023, the research focused on developing the height-adjusting mechanism of the ball dribbling system, as well as the ADC board for monitoring the battery voltage.

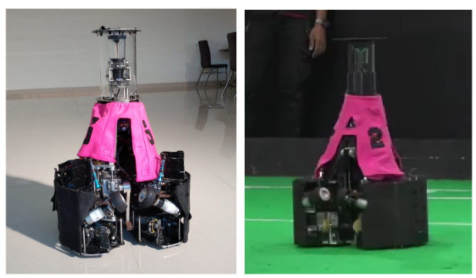

Fig. 1. Left image Old 4 Wheeled IRIS ROBOT. Right image Current 3 Wheeled IRIS ROBOT.

In 2017, the IRIS team also innovated by creating a goalkeeper robot adapted from a four-wheeled striker robot, using many of the same electronic components to maintain consistency and efficiency in design. The goalkeeper robot is equipped with a retaining pole at the top that serves to prevent the ball from entering the goalpost. Development of the goalkeeper robot continues, and in 2022, it was significantly upgraded with the addition of advanced technology. New features include a depth camera capable of detecting ball movement with high accuracy, as well as a LIDAR system that allows the robot to perform precise localization on the field. In addition to that, the ball deflection mechanisms on the left and right sides of the robot were updated, providing better ability to deflect balls from various directions, therefore improving the responsiveness and effectiveness of the robot in performing its goalkeeping role.

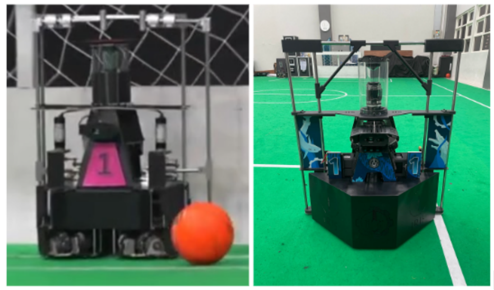

Fig. 2. Left image Old IRIS Goalkeeper Robot. Right image Current IRIS Goalkeeper Robot.

2.2 Software Research

At the same time, the Programming Division conducted various research projects, starting in 2021 with localization using vision with Monte Carlo Localization (MCL) and rotary encoders, as well as detecting the position of teammates using the front camera. In 2022, the IRIS team developed right and left extensions for the goalkeeper robot, new robot localization using ICP, which is lighter than MCL, adapted international dribbling rules, and new calibrations for omnidirectional cameras.

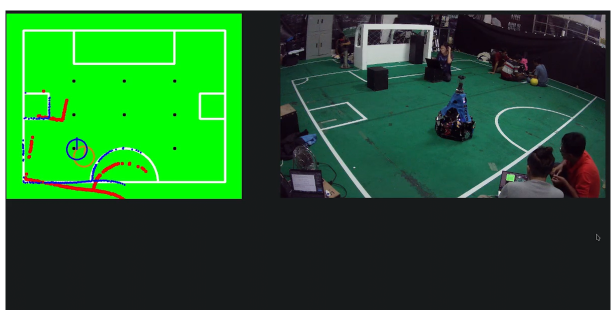

Fig. 3. Left image is robot's pose, red is raw robot localization, blue is a corrected robot's pose. Right image is robot view in real world.

The image above is the result for robot localization correction using Iterative Closest Point (ICP). The research has been conducted since 2022. Mainly, IRIS's robot is using incremental rotary encoders and an IMU gyroscope for calculating its pose. The pose that is calculated using incremental rotary encoders and IMU will drift over time. Many kinds that cause drifting, such as wheel slip, potholes on the field, and some kind of electromagnetic interference (EMI). Because of that, research that will correct a robot's pose using vision called ICP localization correction is done. The estimated pose from the ICP algorithm will be fused with the previous robot's pose calculated using incremental rotary encoders and IMU.

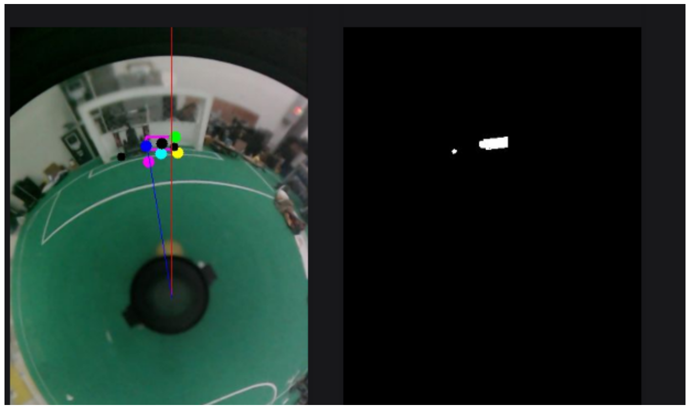

Fig. 4. Left image is the result from free goalpost detection, Right image is the result from color segmentation.

Another research that has been done by the IRIS team is detecting a free goalpost. The detection of a free goalpost using an omnidirectional camera. By using calculations from the real world in the camera's frame, robots can estimate the position of the goalpost inside their internal camera's frame. From that estimation, robots can do segmentation for white color and get a free goalpost from them. And then the main strategic algorithm is to change the orientation to the free goalpost and then shoot the ball.

3 New Software Development

New software improvement is divided into 3 sections: The main control software, world model process, and goalpost detection.

3.1 New Main Control Software

Main control software uses a Mini-PC with a customized Linux-based OS that runs ROS (Robot Operating System). The main software is divided into 5 packages: Communication, Hardware, Vision, World Model, and Strategy. All packages are packed in a ROS workspace and handled automatically using the Linux Systemd Init Service. The use of Linux Systemd Init Service makes the program automatically run after the PC is powered on.

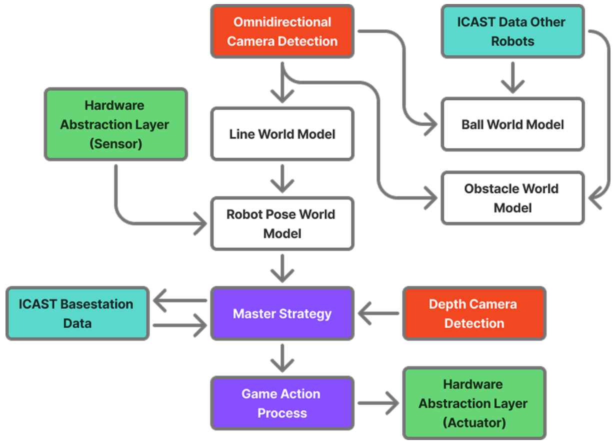

Fig. 5. Main Control Software Topology.

The overall structure of these communication systems is illustrated in Fig. 5. The communication package mainly consists of data exchange between the robot and the base station, utilizing UDP multicast with TDMA (Time Division Multiple Access) to avoid communication collisions. The Hardware Abstraction Layer (HAL) integrates two distinct communication protocols: EtherCAT, which facilitates direct communication between the mini-PC and sensors, and CAN-Bus, which serves as a communication bridge between the driver and the mini-PC. The vision package consists of two core processes. The first process involves ball detection using an omnidirectional camera, which identifies the ball, lines, obstacles, and goalposts. The second process uses a depth camera to detect additional environmental features. These sensor inputs are translated into world frame coordinates by the world model package, which outputs critical data such as obstacles with tags, positions, velocities, and statuses, as well as the robot's pose, including x-y coordinates, yaw orientation, and velocity. The strategy package, which functions as the brain, processes data from both sensors and actuators to compute optimal actions for the robot based on real-time environmental input.

3.2 New Goalpost Detection

It can be seen in the fig 6, the latest goal detection method on our robot uses the Intel RealSense depth camera. The RealSense camera captures data in the form of distance/depth frames and color frames. After that, a Region of Interest (ROI) will be generated in the color frame from the distance frame data. The ROI will be used to select the white color on the goal to determine the goal area. The threshold results will then be used to find the closest distance and determine the right and left posts. Finally, the empty area between the right and left posts will be located using color thresholding.

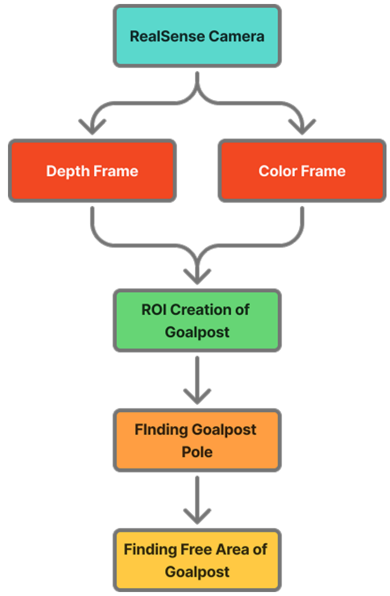

Fig. 6. Goalpost Detection Diagram

4 New Hardware Development

4.1 New Solenoid Driver Board

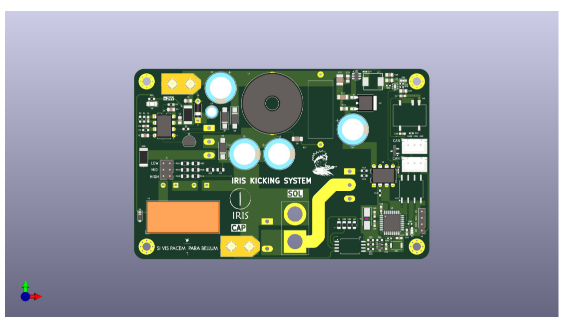

Fig. 7. New Solenoid Driver Board

The new Solenoid Driver Board for the IRIS Kicking System uses a flyback transformer, boosting from a 40-volt source to a 450-volt output. The transformer is employed in the boost converter to separate the 40-volt battery supply from the 450-volt high-voltage capacitor side. Compared to the previous model, this new solenoid driver board is more efficient and features a smaller design without the need for a microcontroller. Additionally, the new board includes a dummy load that discharges the capacitor when the booster system is deactivated.

4.2 New Brushed DC Motor Driver

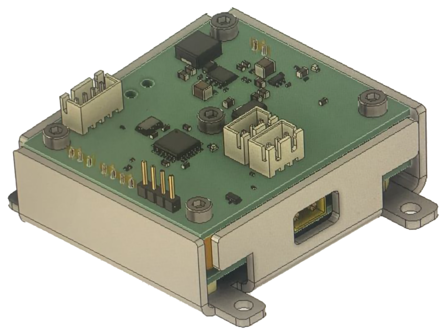

Fig. 8. New Brushed DC Motor Driver

Currently, IRIS uses brushed DC motors for some systems that require actuators. These systems need a driver system to operate the motors, and this year, we designed a brushed DC motor driver with MOSFETs as the main components in the switching process to ensure high-performance applications. Our new driver operates with a 40-volt input and a maximum output current of 20 amperes. The driver features an MCU-based system that ensures precise and customizable motor management. For enhanced safety and reduced noise interference, we use an isolated system that separates the MCU ground from the motor ground. This driver also integrates a built-in current sensor, enabling real-time output current monitoring for improved motor control protection. Additionally, it supports the CANOpen communication protocol for more robust data transmission

4.3 Upper Extender System for Goalkeeper

The new system shown in Figure 9 is designed to enhance the goalkeeper's ability to react swiftly to high shots by providing more precise and rapid movement. The belt mechanism, powered by the DC motor, allows smoother and more adaptable motion across the goal area. By adjusting the tension and speed of the belt, the system can position the goalkeeper's arms or hands at various heights, ensuring better coverage of the upper goal area. The DC motor provides high torque and responsiveness, allowing for quick adjustments based on the ball's trajectory. The belt-driven system also ensures continuous and smooth movement, minimizing jerky motions that could reduce the goalkeeper's effectiveness.

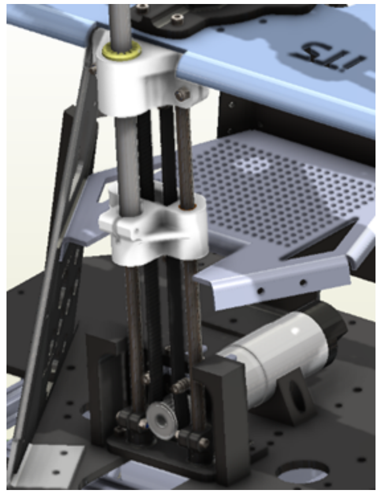

Fig. 9. Upper Extender System

5 Conclusion

Based on our experience in participating in Kontes Robot Indonesia 2024 and in RoboCup 2024 in the Netherlands, IRIS will have a strong commitment to participate in RoboCup 2025. We significantly enhanced the performance of their autonomous soccer robots. Key developments include an optimized drive system, enhanced goalkeeper mechanisms, and goalpost detection with omnidirectional and depth cameras. The integration of a Linux-based ROS framework has further optimized system performance. These innovations have strengthened the team's competitive success while contributing to autonomous robotics research. Future work will focus on refining AI strategies and multi-robot coordination.