RoboCup 2026 Humanoid Soccer League
Robo-Erectus
Team Description Paper

Carlos Acosta (Team Leader), Yusuf Pranggonoh, Han Xin Yu (Faculty Members)
Chew Ding Xuan, Zhang Feng Yi, Ng Zhi Yang, Meenakshi Ramasubramanian, Phang Chun Hoe, Jonathan Lim Wei Kang (Student Members)
School of Electrical & Electronic Engineering
Singapore Polytechnic, 500 Dover Road, 139651, Singapore
Email: carlos_acosta@sp.edu.sg, yusuf pranggonoh@sp.edu.sg, han_xinyu@sp.edu.sg
www.roboerectus.org

Abstract

This paper presents the team description of team Robo-Erectus, which will participate in the RoboCup Humanoid Soccer League (HSL) Large Division at RoboCup 2026. Team Robo-Erectus is based in the School of Electrical and Electronic Engineering (EEE) at Singapore Polytechnic. Marking the team's return to the RoboCup Humanoid Soccer League after more than a decade, the team adopts the Booster Robotics T1 humanoid platform as a unified system for both competition and research. This paper provides an overview of the overall system architecture, emphasizing the integration of sensing, perception, localization, navigation, and behavioral control required for humanoid soccer play.

1 Introduction

Research and development in bipedal locomotion at Singapore Polytechnic (SP) began in 1996. Since then, SP has remained actively engaged in advancing bipedal robotics research. In 2002, this effort expanded to humanoid robotics with the establishment of the Robo-Erectus project (www.roboerectus.org) under the Advanced Robotics and Intelligent Control Centre (ARICC) in the School of Electrical and Electronic Engineering at the Singapore Polytechnic. The humanoid project at SP aims to develop and demonstrate humanoid robots for both applied research and educational applications [1].

Team Robo-Erectus has been among the pioneer soccer-playing humanoid teams in the RoboCup Humanoid League, having participated in RoboCup 2002 in Fukuoka, Japan, when the humanoid league was first introduced. Over the years, the team has actively competed in RoboCup events and achieved multiple accolades. The team's most recent participation was in RoboCup 2016 in Leipzig, Germany, where it attained fourth place in the humanoid KidSize League [2]. In 2025, the team has decided to come back to the Humanoid Soccer League, Large Division, by adopting Booster Robotics T1 humanoid robots. The T1 is one of several standard platforms selected by the league. Currently the team has two T1 robots Sam and Paul, and during the competition the team intends to borrow one of the T1 robots provided by Booster Robotics in a pool for the teams to share. Figure 1 shows the Robo-Erectus Team's robots Sam and Paul in a practice match in the lab.

Figure 1. The two Booster Robotics T1 humanoid robots from Team Robo-Erectus, Sam and Paul.

Team Robo-Erectus formally commits to participation in the RoboCup 2026 Humanoid League Competition. We have secured comprehensive funding and support from the Singapore Polytechnic's management to travel and participation expenses. Our participation represents our dedication to advancing humanoid robotics research whilst maintaining the highest standards of competitive integrity and collaborative excellence that characterize the RoboCup international competition.

This paper is organized as follows: Section 2 describes the robot hardware, including mechanical and electrical design; Section 3 presents the software architecture. Section 4 describes our perception system which mainly addresses the vision in the robots. Finally, Section 5 concludes the paper.

2 Hardware Design

As mentioned in the introduction our team has adopted Booster Robotics T1 humanoid robot for our team. We currently have two T1 robots, we intend to borrow one more robot during the matches from the poll of robots that Booster Robotics will provide. Our T1 robots have not been modified or altered, they still use the currently the same computer that is shipped with the robot from the factory.

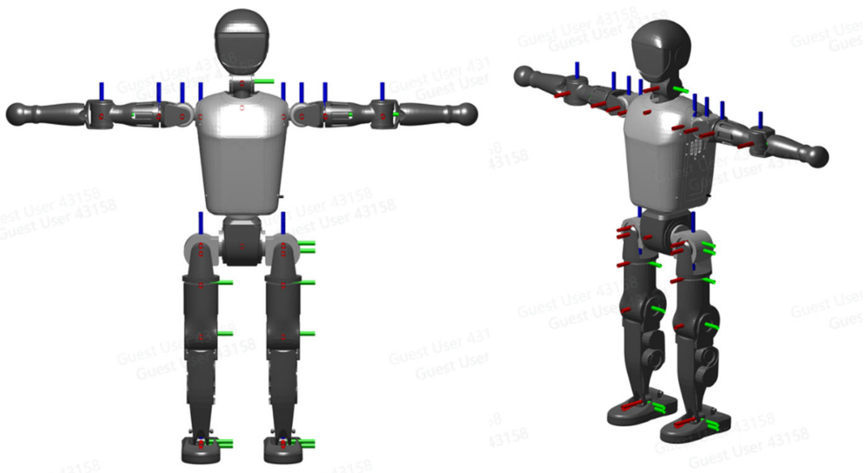

Figure 2. Booster Robotics T1 humanoid robot overview of the 23 degrees-of-freedom in the robot.

Figure 2 illustrates the Booster Robotics T1 humanoid robot, which is adopted as one of the standard platforms for the RoboCup Humanoid Soccer League, Large Division competition. The T1 robot has overall dimensions of 118cm × 47cm × 23cm and a total mass of approximately 30 kg, including the onboard battery. Its mechanical configuration consists of a head, torso, two arms, and two legs, providing a total of 23 degrees-of-freedom (DoFs) to support full-body motion and posture control.

The head features 2 DoFs (yaw and pitch) and integrates a depth camera, microphone array, and speaker, enabling active visual scanning, perception, and object tracking. Each arm is equipped with 4 DoFs (shoulder pitch, roll, yaw, and elbow), allowing for balancing actions and basic manipulation; the arm modules are designed with extensibility in mind to accommodate future enhancements. The waist incorporates 1 DoF (yaw), which improves turning capability and coordination between the upper and lower body. Each leg provides 6 DoFs (hip pitch, roll, and yaw; knee; and ankle pitch), supporting dynamic locomotion, directional changes, and recovery behaviors essential for humanoid soccer play.

Table 1. Specifications of the electronic components in the Booster Robotics T1 Humanoid Robot.

Category	Sensor / Device	Description
Vision	RGB-D / Depth Camera	3D perception camera for environment mapping, object detection, and navigation
Orientation / Motion	9-axis IMU	Inertial Measurement Unit with accelerometer, gyroscope, and magnetometer for balance and orientation
Audio Input	Microphone Array	Multi-microphone array for voice capture and sound localization
Audio Output	Speaker	Built-in speaker for audio feedback and interaction
Joint Feedback	Joint Encoders	High-resolution encoders on each joint for position and velocity feedback
Range Sensing (Optional)	3D LiDAR	Optional LiDAR for long-range sensing and SLAM
Computing	NVIDIA Jetson AGX Orin	Main AI computer for perception, planning, and autonomy
Computing	Motion Control CPU	Secondary processor for real-time motor and joint control
Connectivity	Wi-Fi 6	Wireless networking for remote control and data transfer
Connectivity	Bluetooth 5.2	Short-range wireless communication
Connectivity	Gigabit Ethernet	Wired high-speed network interface
Connectivity	USB Interfaces	Peripheral and sensor expansion ports
Power	Battery Pack	Rechargeable lithium battery system
Power	Safety & Power Management	Battery monitoring, thermal protection, and power distribution

The main control board and battery are housed within the torso to centralize mass distribution and protect critical electronics. Table 1 shows a complete list of the components inside the Booster Robotics T1 humanoid robot. The robot’s link dimensions include a leg length of 57cm and an arm length of 45cm, contributing to stable locomotion and providing a sufficient operational workspace for soccer-related tasks.

3 Software Architecture

The Booster Robotics T1 robot uses a three-layer architecture for their software control. Figure 3 shows this architecture. The Service Layer provides various basic services of the humanoid robot for upper-layer applications, including, robot status query, motion control and so on. The Interface Layer is a middleware that allows upper-layer applications to make calls to the Service Layer through ROS2 and the Booster Robotics SDK. The upper layer is the Application Layer, in which the developers can create their applications. The team is using this layer to write our software control.

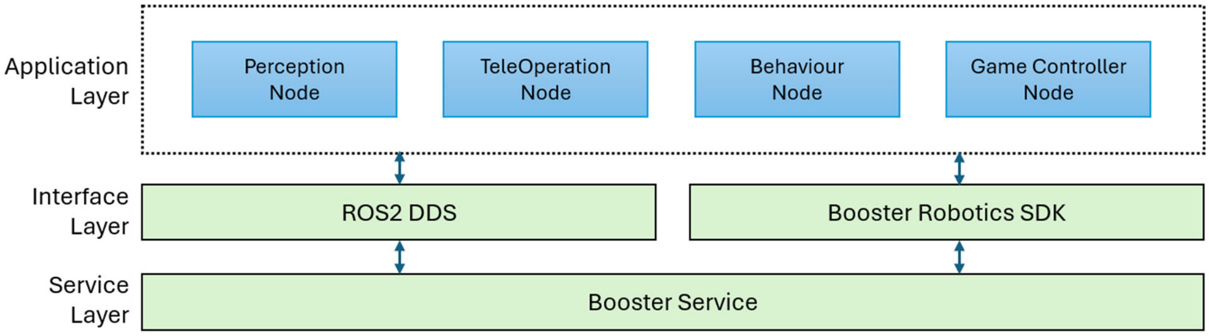

Figure 3. The Software Control Architecture, it is a layer architecture with ROS2 nodes in our Application Layer.

In our software architecture, the sensor inputs (e.g., depth camera and onboard state feedback) are processed into a world model, used for decision making, and then converted into joint-level motion commands. The system consists of a hardware interface layer that communicates with the control board and enforces safety limits, a perception layer that detects and tracks soccer-relevant objects and field features (with active head scanning via yaw/pitch), a state estimation layer that fuses inertial/kinematic feedback with perception updates to estimate robot pose, a behavior layer (FSM/behavior tree) that selects skills such as search, approach, align, kick, and recovery, and a motion layer that executes walking/turning gaits and predefined or parameterized actions. This separation improves robustness, simplifies debugging, and allows modules to be developed and tested independently.

Each robot's behavior is like the one implemented in our previous KidSize robots [3], but some adjustments in the roles and the behaviors are still tunning to get a better strategy for the games with these new robots and the their capabilities. The team is also exploring to develop our gaits and poses for the robot to enhance our soccer skills. Booster Robotics also provides several tools and environments to speed up the development and learning of such skill [4].

4 Perception System

In the perception system the team has mainly focus to process the vision inputs employing the same object detection model used by team Robo-Erectus@work which takes part in the Smart Manufacturing League (formerly RoboCup@Work League under RoboCup Industrial League) [5]. Figure 4 shows some of the output of our training model used for object detection.

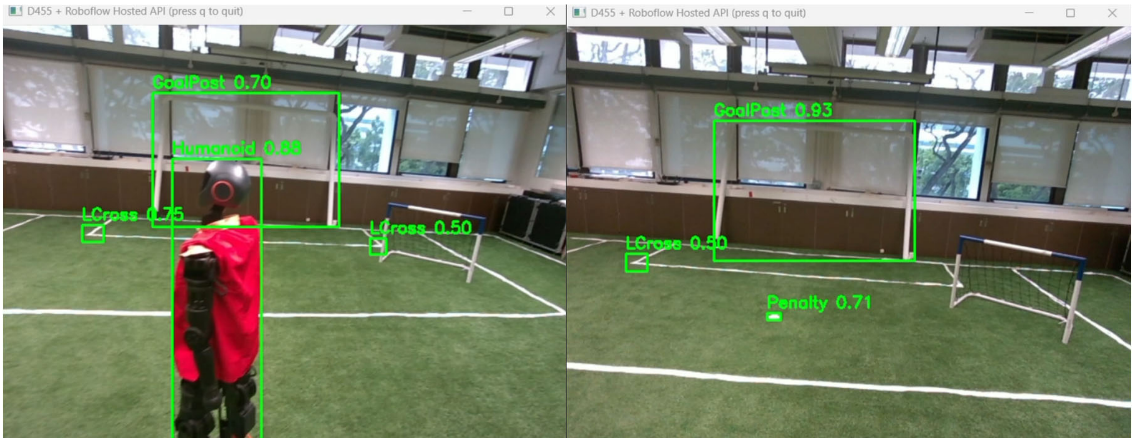

Figure 4. The output from our trained model in our laboratory setup.

In our perception system we have also adopted self-localization, where onboard state feedback is combined with vision-based observations of soccer objects and field landmarks to estimate the robot's pose and maintain a world model for decision-making. We are actively developing this pipeline and will introduce improvements in robustness and accuracy for competition use. Using the measured and predicted distance from field lines, L crosses and T crosses, the Monte Carlo localization is implemented to provide the motion feedback through consistent updates to correct the odometry drift. Utilizing the IMU and odometry, the Monte Carlo localization is used for global field localization.

5 Conclusion

In this paper, we presented an overview of the Team Robo-Erectus that is planned to participate in RoboCup 2026 in Seoul, South Korea. The team's robots are competition-ready, and we look forward to introducing and demonstrating our latest hardware at this year's event. For more information about Robo-Erectus, please visit www.roboerectus.org.

Acknowledgements

The authors would like to thank the staff and students at the School of Electrical and Electronic Engineering and the higher management of Singapore Polytechnic for their support in the development of our humanoid project.

References

1. Changjiu Zhou, and Pik Kong Yue. Robo-Erectus: A low cost autonomous humanoid soccer robot. Advanced Robotics, 18(7):717-720, 2004.
2. Buck Sin Ng, Carlos A Acosta Calderon, and Changjiu Zhou. Robo-Erectus jr-2016 Kidsize Team Description paper. Robocup Germany, 2016.
3. Carlos Antonio Acosta Calderon, Changjiu Zhou, Pik Kong Yue, Mike Wong, and Mohan Rajesh Elara. A distributed embedded control architecture for humanoid soccer robots. In Proc. of Advances in Climbing and Walking Robots, pages 487-496, Singapore, July 2007.
4. Wang, Y., Chen, P., Han, X., Wu, F., & Zhao, M. (2025). Booster Gym: An End-to-End Reinforcement Learning Framework for Humanoid Robot Locomotion. arXiv preprint arXiv:2506.15132
5. Yusuf Pranggonoh, Carlos Acosta, Emanuel Joseph Rodrigues, Ng Yan En, Chia Zhi Feng, Mahesh S Kunalan, Tan Tian Kovan, and Chang Yong Qua. RoboCup 2024 - RoboCup Industrial @Work Robo-Erectus@Work Technical Description Paper. RoboCup Netherlands, 2024.