Robot Sports Team Description Paper 2025

Ton Peijnenburg, Jürge van Eijck[0000−0002−2774−9009], Noah van der Meer[0000−0001−5729−2671], Charel van Hoof, and Roy Driessen

VDL ETG, De Schakel 22, 5651 GH Eindhoven, The Netherlands
ton.peijnenburg@vdletg.com
http://www.robotsports.nl

Abstract. Robot Sports is an open industrial team, meaning that its participants are all employed by, or have retired from, various high-tech companies in the Dutch Eindhoven region, or are active students. This year, the team continues to work on the upgraded robots, to increase robustness and playability. A new self-localization strategy is being developed based on the way humans localize themselves.

Keywords: robotics · machine vision · machine learning · artificial intelligence · motion control · RoboCup · MSL.

1 Introduction

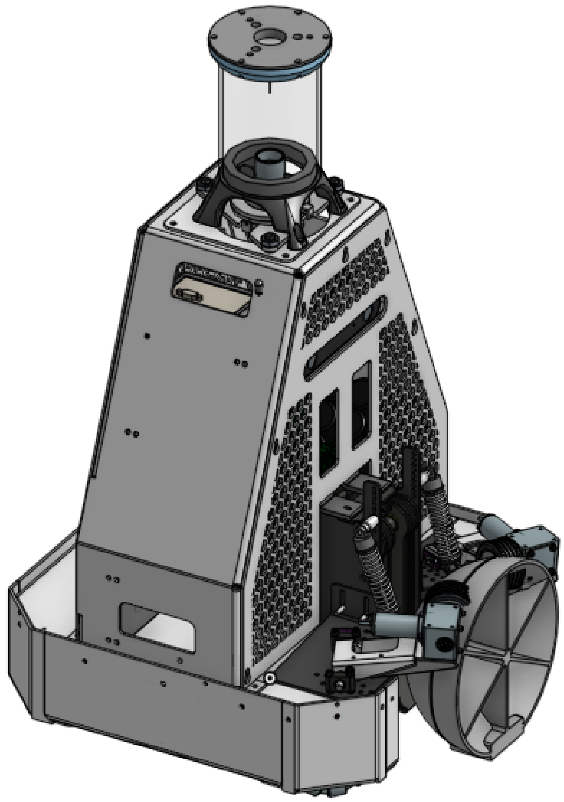
The Robot Sports team is an open industrial team supported by the main sponsor VDL, an internationally operating family-owned industrial business with more than 100 manufacturing companies, headquartered in Eindhoven, The Netherlands. The team shares a dedicated facility with the Falcons team in the city of Veldhoven, near Eindhoven. The team started as the Philips "Cyber Footbal Team" which started participating in 2002 and was renamed to VDL Robot Sports in 2012.

2 Robot hardware 2025

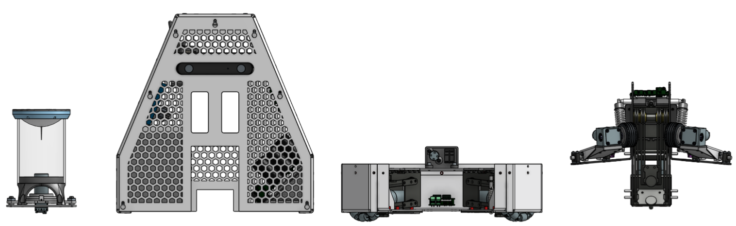
The hardware revisions implemented are small, with a primary focus on improving system reliability. This year's modifications include the integration of more robust omniwheels and the optimized mounting of the omnivision lens for improved durability.

In previous iterations, design efforts prioritized serviceability. The current configuration, which allows for quick removal of the front and back panels, demonstrated advantages during the most recent World Cup in Eindhoven.

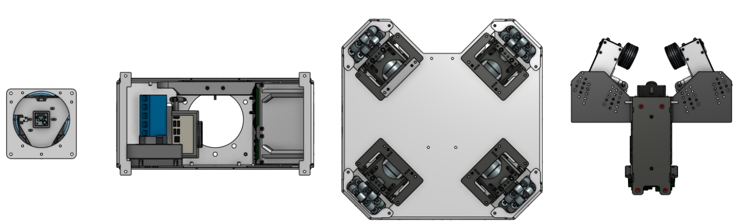
The robot's structural framework is composed of four modules: the Chassis, Tower, Top Vision, and Ball Manipulation. This modular architecture was designed with logistical benefits in mind, facilitating disassembly enabling flexible transportation options. The goal is to allow team members to carry individual



(a) Platform 2025



(a) Platform 2025 sub-parts



(a) Platform 2025 sub-parts (topview)

components in standard luggage, eliminating the dependency on custom shipping solutions to tournaments. The transport of batteries has received special attention because of generic regulations and airline-specific restrictions.

The robot control is updated with a new computing unit, the AAEON BOXER 8651AI. This computing unit has more 3 times more GPU cores and a faster CPU. This new computing unit now takes care of all compute tasks on the robot, from sensor processing to inference for the object detection. For all this, it only requires 15 W of power. It interfaces with a number of microcontrollers that take care of low-level tasks such as motor control and the safety PLC.

3 Software improvements

Our robotic action execution often suffers from abrupt transitions, leading to jerky movements and potential instability when controlling the ball. More smooth transitions between actions can minimize this, using centralized calculations to ensure global consistency and maintain continuity throughout transition phases. A centralized velocity control component will minimize discontinuities in velocity and acceleration profiles.

A robot that cannot accurately determine its own position enough and is unaware of its inaccuracy is significantly influencing team performance. The team strategy is robust for robots with limited inaccuracy, but large inaccuracy will lead to inefficient dynamic role-assignments.

An extra position accuracy validation will be added to the robot. This allows the robot to report a lower confidence of the own position when in the self-localization is inaccurate. The reported confidence of the own position of the robot should be low, when the own position becomes inaccurate. The dynamic role-assignment will take this confidence into account.

When a robot has low confidence in its own position, it should be replaced by another player. We are designing a fast calibration procedure with the need of limited inputs to make the robot able to play again.

3.1 MSL reference architecture

This year, Robot Sports published several MRA components [2]: the robot strategy and role assigner functional components and a new implementation of velocity control, which is using Ruckig [3] inside. Compared to the previous version, it is faster and adds support of jerk. These components will be integrated into our software.

Robot Sports still strongly believes in the concept of a reference architecture. However, adopting this architecture on our robots will be a significant step, which may lead to a missed season of participation. Until now, the team has decided to postpone this migration, but the team members have been working together to further develop the concept of the MRA and port the software modules to that new architecture. Limited experimentation has been done, but mainly in the simulator, not in real robots.

4 Brain inspired self-localization

Robot Sports is working on a brain-inspired self-localization method, improving the current line detection approach that suffers from localization errors. Drawing on the free-energy principle from neuroscience, the method treats perception as a dynamic process of making predictions and minimizing discrepancies between expected and actual sensory data. In doing so, it mirrors the human brain, where place cells and grid cells map out spatial environments.

In the field, robot 'place cells' respond to landmarks such as white lines, goals, and distinct line patterns, while odometry and IMU data drive the continuous update of robot's internal state 'grid cells.' Using Bayesian inference, the robot refines its internal model, learning from prediction errors, and adapting its position estimate. This framework aims to deliver a more robust, flexible, and precise localization system, reducing the risk that robots become 'lost.' Moreover, it enables robots to function effectively in a variety of environments, even when field lines are missing and only goalposts are available for orientation, much like humans can play on any makeshift field.

5 Compact Empirical Sensor Actuator Model (Cesam)

We feel the need to have an artificial model that reflects a number of physical interactions of the robot in its environment. This model could be trained using a neural network. However, we see an opportunity to significantly reduce resources such as CPU power, memory usage and training time. We call this Cesam: Compact Empirical Sensor Actuator Model.

We believe that reducing training time is important in the face of topological changes that naturally occur during development. In addition, biological systems train much more efficiently than neural networks, so we are convinced that improvements must be possible. We will start with ball handling and later include other actuators.

Once we have such an empirical model, we will be in a much better position to accurately evaluate our hand-crafted algorithm in a simulation environment. We could have separate models for the different robots to test the algorithm's robustness. In parallel, we could use the empirical model to train algorithms that compute optimal actuator responses.

Once we have this framework operational, we expect to have a much faster turnaround time in our development cycle.

6 Ball control

One current project is to use a webcam to observe the ball status on a test platform: the ball position relative to the robot, but also the current ball velocity/rotation. In a first prototype, a separate processor will be used to process the camera and derive the ball state from the video stream. A filter will be trained to analyze the state of the ball. In a first iteration, an optical flow sensor will be evaluated.

7 Recapturing innovation

The Robot Sports team has been struggling in recent years to get our platform ready to play soccer. Although we have achieved significant innovative steps, e.g., by implementing efficient neural network to do object detection and focusing on an energy-friendly platform for execution, our overall performance on the soccer field has been disappointing.

The most important factor underlying this suboptimal performance has been the limitation in resources (financial, personnel) that we have at our disposal. We, as most other teams, try to get all of the robot's components designed and realized ourselves, without explicit and full reuse of other team's components. The MSL reference architecture will give a significant improvement, since much effort is directed toward robot control software, and reuse of software components has been extremely rare. We, like other teams, suffer from legacy engineering and legacy debt in their software stacks.

However, there is another factor that affects most MSL teams, which is the path of innovation that has been followed. The main focus for robot development has been on optimizing the robotics and mechatronics for the MSL constraints - indoor, critical lighting conditions, smooth, flat surface in combination with the dimensions that we have. Robot designs have all converged to a reference design that works best. However, this reference design is not suitable for artificial turf, playing in daylight, playing with humans, etc. In Leipzig, there were challenges to test both artificial turf and daylight conditions, but these have never been upgraded to the MSL regulations.

8 Conclusion

Robot Sports is in an intermediate state. Our robots have been upgraded to new hardware, and our software is being cleaned up but has not yet been migrated to a new architecture. Robots can play, but their competitiveness is questionable. As a team, we cannot bring sufficient resources to upgrade all the robot's modules to regain competitiveness. Therefore, we will be working on innovations for specific functions, such as brain-inspired self-localization. In addition, we will embrace the direction of eliminating the ball handlers and develop machine learning strategies for the robot to capture and control the ball. This will open up the path of using more AI and focusing less on perfecting the hardware of the robots.

References

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