Robot Club Toulon Team Description Paper 2026

M. Bièche, J.Deleuil, M. Walter
Supervisors : V. Gies, T. Soriano, and V. Barchasz

Université de Toulon,
Avenue de l'Université, 83130 La Garde, France rct@univ-tln.fr
Home page: http://rct.univ-tln.fr

Abstract. This paper presents the Robot Club Toulon (RCT) team and summarizes the main developments achieved over the last year, with a strong focus on perception, local world modeling, and dynamic motion planning for RoboCup Middle-Size League (MSL). We also report our contributions to the MSL community and describe how our robot designs and selected software assets are shared with other teams.

Keywords: RoboCup Soccer, Middle-Size League, Multi-Agent Robotics, Perception, Sensor Fusion, Multi-Object Tracking, Motion Planning, Decision-making

1 Team Presentation

Robot Club Toulon is representing University of Toulon, France, in the RoboCup Middle Size League (MSL).

Our team has been participating in the RoboCup competition since Sydney in 2019. We have also participated in 2021 (online), in 2022 (distant), in 2023 at Bordeaux and in 2024 at Eindhoven. Our results in the competition are :

- 5^{th} place in soccer competition 2024
- 3^{rd} place in the Scientific Challenge 2024
- 3^{rd} place in Technical Challenge 2024
- 3^{rd} place in soccer competition 2023
- 1^{st} place in the Scientific Challenge 2023
- 3^{rd} place in Technical Challenge 2023
- 1^{st} place in the Scientific Challenge 2022
- 2^{nd} place in the Technical Challenge 2022
- 2^{nd} place in the Technical Challenge 2021
- 3^{rd} place in the Scientific Challenge 2021
- 4 national titles in the French Robot Cups.

Complete list is on team's website. At the moment of writing this paper, RCT team consists of 3 PhD's, 1 Post-docs, 15 MSc, 3 BSc, 3 staff members including an embedded system engineer and 2 researchers in artificial intelligence, electronics and robotics.

2 Robot Club Toulon 2025 Innovations

2.1 Platform stabilization (hardware)

During the 2025, our hardware roadmap focused on consolidating reliability of the swerve-drive platform used in RoboCup 2024, improving serviceability, and hardening the power and safety chain for the kicking subsystem. Mechanical and electrical details are provided in the associated Mechanical and Electrical Presentation Papers.

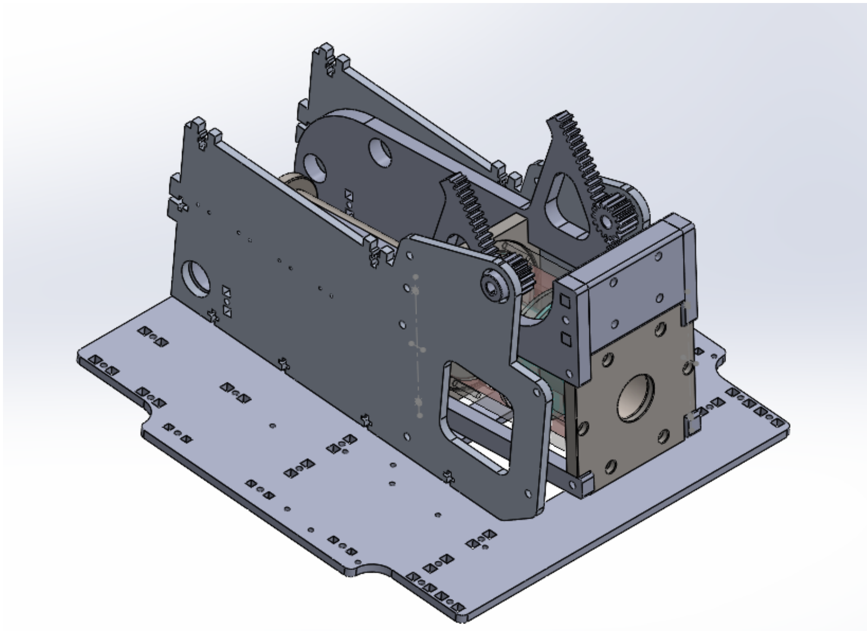

Fig. 1. Isometric view of the kicking system without the kicking foot

2.2 Motion planning improvements for swerve-drive robots

In 2025, we redesigned our motion planning stack to fully exploit the swerve-drive capabilities while ensuring dynamic feasibility and stable execution at high update rate. The objective is to produce fast and reliable motions (interception, marking, repositioning) without saturating actuators or inducing wheel slip, and while preserving controllability when dribbling.

We adopted a layered planning architecture:

- A *global planner* that produces a coarse route on a cost map derived from the Local World Model, accounting for static obstacles and field constraints.
- A *local planner* that generates a time-parameterized trajectory consistent with swerve kinematics and dynamic limits, continuously replanned in a receding-horizon method.

To enable time-efficient motions under swerve constraints, the local planner explicitly models aggressive lateral dynamics and rapid heading changes while avoiding control saturation:

- Trajectory generation with bounded velocity, acceleration, and jerk to ensure feasibility and smoothness.
- Coupled translation-rotation planning to keep wheel steering rates and propulsion demands within actuator limits.

2.3 Simulation, validation, and tooling

We continued to invest in our digital-twin simulator to validate perception-to-planning interactions at scale and to reliably reproduce corner cases observed on the field. In 2025, we introduced a dedicated unit-test framework for key modules, enabling the team to verify functional correctness, interface contracts, and numerical stability after each change. This test infrastructure supports automated regression testing on curated scenarios and log replays, providing quantitative performance tracking (e.g., latency, tracking consistency, localization drift, collision risk) and accelerating debugging of strategy and motion behaviors. 6

2.4 Electronics

Electronic architecture of our robots contains 2 main boards: one for the embedded system and one for the kicking system. This allows us a high level of electrical safety, particularly on one key point: the isolation of the kicking board, which now has its own power supply for safety reasons. In case of a shortcut between a capacitor or coil gun wire and the robot structure, electrical isolation ensures that kicking system ground is not connected to robot ground, avoiding electrical shock hazard for both humans and electronic boards. Moreover, this new electronic kicking system board is no longer exploding and has been successfully tested during RoboCup 2024. These new designs are fully described in the *Electrical Presentation Paper*.

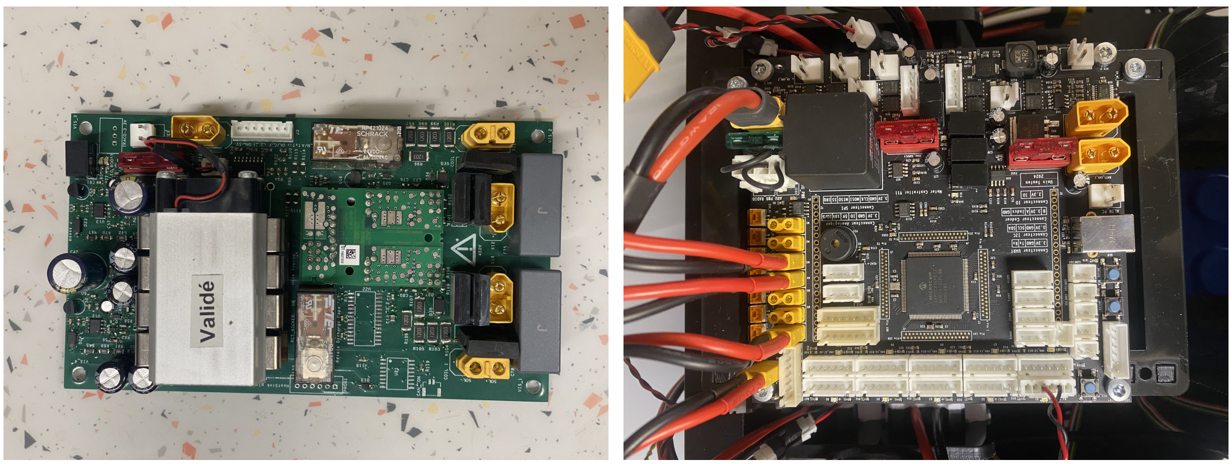

Fig. 2. Kicking system and main controller boards

2.5 Stabilizing 4-wheels swerve drive robots

Due to several constraints (no indoor field at our university, but possibility to play outdoor) and issues (lack of reliability and difficult servicing) on our robots, new robots were built based on swerve drive propulsion in 2024. This help us achieve a maximum speed of $7m.s^{-1}$ with an acceleration of $3m.s^{-2}$.

The new base has been designed in 2024 using 4 swerve drives a few days before the competion, integrated in a rectangular shaped design. Each propulsion motor of the swerve drive is a $500W$ brushless one. In order to improve the reliability of the robots, most of the parts are manufactured in aluminium, and the upper part of the robot is mainly in carbon fiber to lower the gravity center of the robot.

These robots were successfully tested at RoboCup 2024 and underwent further stabilization in 2025. The issues identified during RoboCup 2024 were traced to insufficient encoder precision, and the encoders have since been replaced.

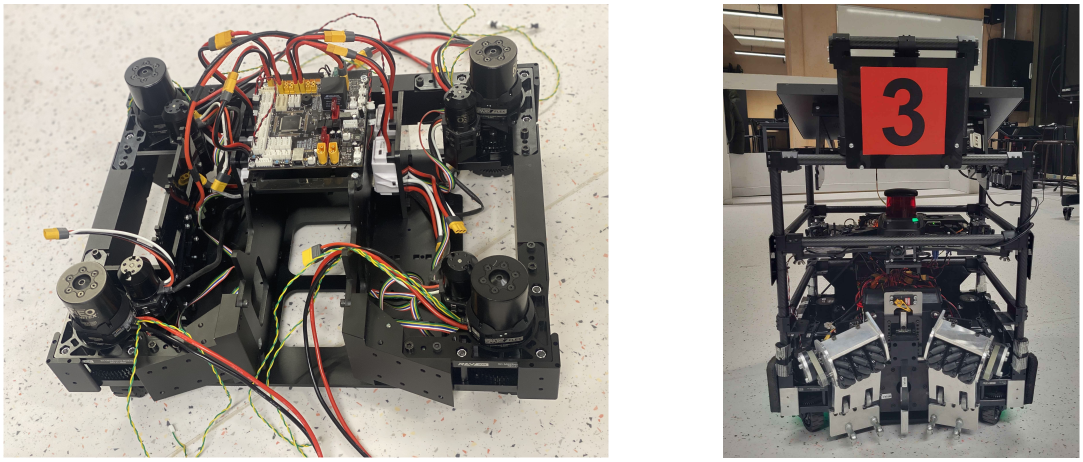

Fig. 3. Swerve drive propulsion (including new NEO VORTEX motors) and fully assembled RCT robot.

Mechanics of our new robots are fully described in the mechanical presentation.

2.6 Playing with humans : a milestone for MSL

Joining together the goal of the MSL for 2050 and aspirations of our team, playing with humans will be a key objective for us this year.

It requires a lot of improvements considering no digital information transmission can be done between robots and humans. This means each robot must identify, localize, and take into account humans in the strategy as if they were standard communicating robots. This leads to ensure that every robot can have a complete perception of its environment, without merging information given by other robots. In other terms, each robot has to be able to play without digital communication. This would be in fact a major evolution in Middle Size League and can use many improvements described here.

First of all, each robot must have an improved perception, enabling to identify robot and human teammates. This means that, as shown in Fig. 4, a local world map (LWM) has to be constructed by each robot as precisely as possible. It relies on a full set of sensors able to perceive playing situation on the full field, with a high semantic level. In RCT robots, 4 camera embedding deep learning algorithms running at 50Hz are used, completed with a Lidar operating at 50 revolutions per second. With these sensors, completed by an Inertial Measurement Unit (IMU) and odometry, a LWM is generated 50 times per second.

Having a nearly complete perception of the scene is the first step toward playing with humans. Second one is elaborating a team strategy without any digital communications. Considering humans and robot cannot communicate naturally, robots and humans have to make their decisions without any exchange between them, but in cooperation. This is the purpose of our *Decentralized Partially Observable Markov Team Decision (DPOMTD)* algorithm described in Fig. 5.

This DPOMTD algorithm is composed of two main steps. First one is to imagine all the actions that could have been done by a robot. The list is composed considering the playing situation (i.e. TryToCatchBall action is evaluated only when the team doesn't have the ball). For each type of action, several locations can be tested. They are determined using a genetic algorithm focusing on the most relevant ones in the field. The score of each action is its expected reward and its probability to be successful. *Expected Reward* depends on the importance of the action for going toward scoring a goal. The reward can be modulated by some characteristics of the action, for example getting closer to the goal. The probability of success is impacted by several criteria such as the risk of interception of the ball, the risk of collision with another robot or

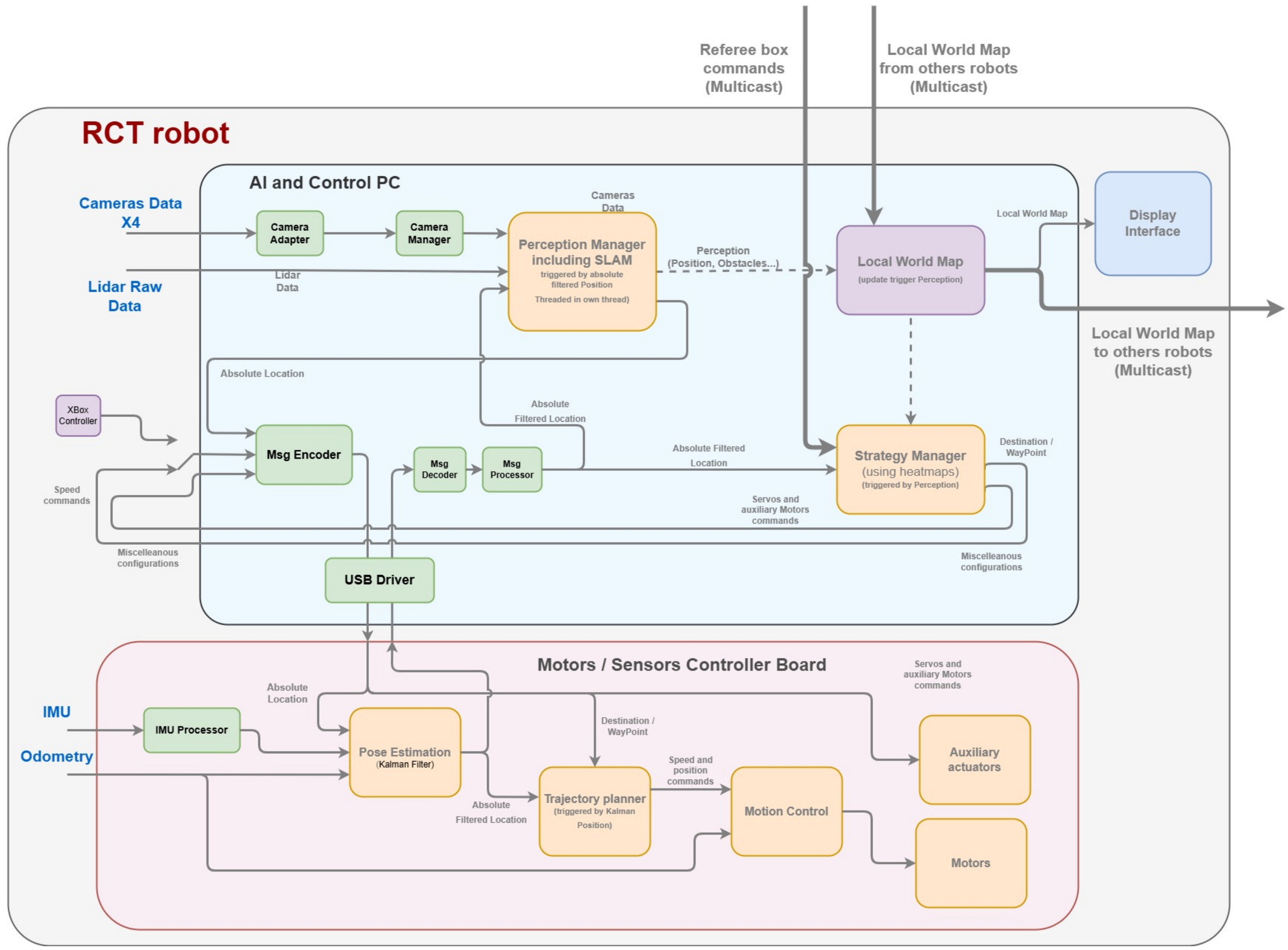

Fig. 4. RCT robots software architecture

the distance between a robot and the action destination. When all the actions are evaluated for each player (typically 150 action per player), the second phase of the algorithm begins.

In this second phase, the considered robot determines what should be the actions taken by each player (human or robot) based on its preceding evaluations and team strategy rules. These team rules are for example constraints on the minimum or maximum of player allowed to do an action : to illustrate, TryToCatchBall can be performed by one and only one player according to the rules. For this rule, each robot compare the score of this action for all the teammates, and decide to attribute the action to the one having the highest score. This attribution is not sent to any one, it is not necessary as if perceptions are the same among all robots, decision should be the same considering all robots have the same team rules. When a team constraint have been fulfilled, a second one is considered with the remaining players, robots or humans. When all team rules have been used, each robots decides its best remaining action freely.

This DPOMTP algorithm allows a decision process close to human one and not relying on digital communications. Its limitation is that it is based on the assumption that each teammate perceive playing situation in the same way. This is particularly important, so that every player converge to the same decision for every teammate. In real conditions, this is not always true, and construction of the LWM requires a strong effort

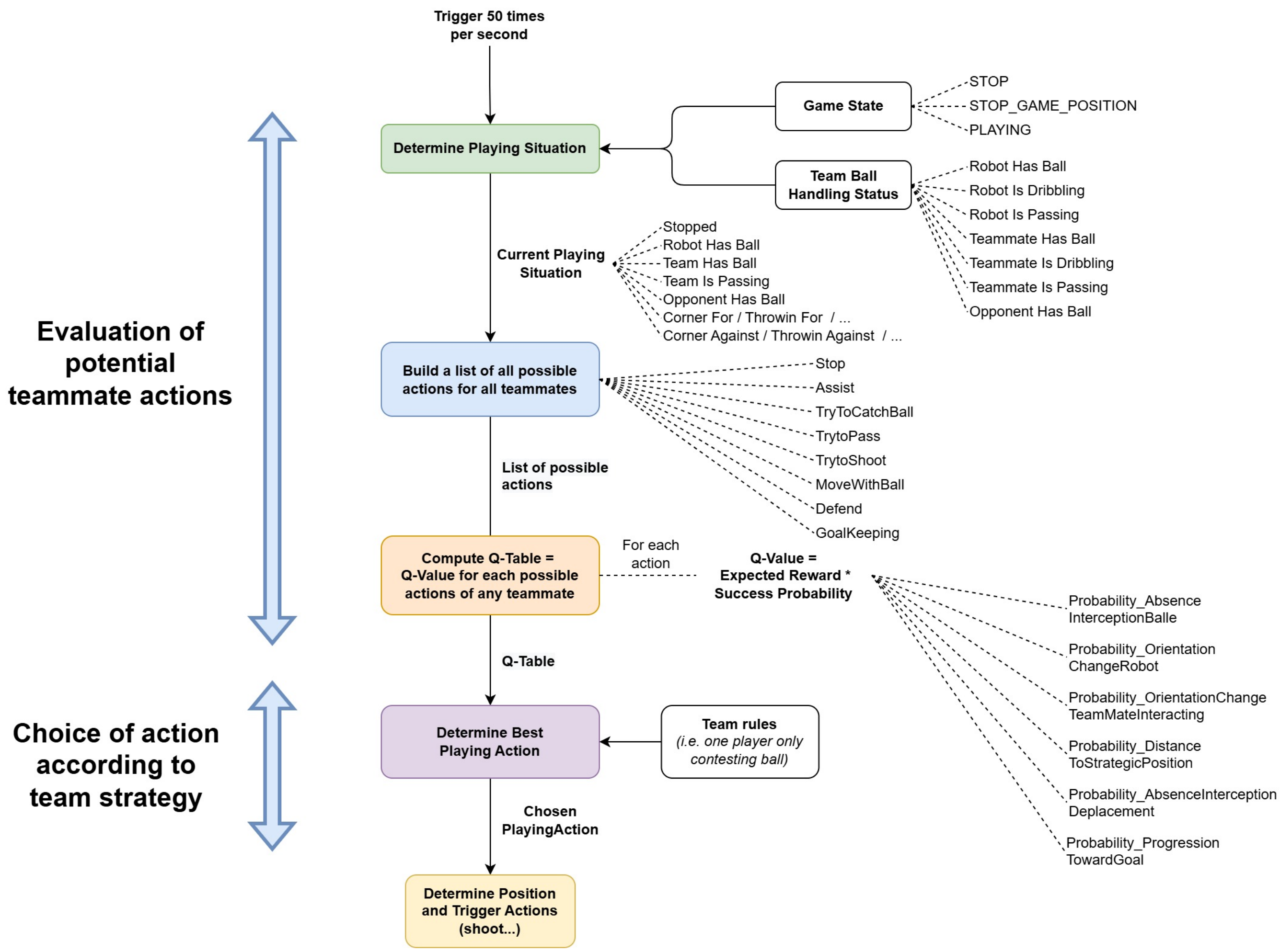

Fig. 5. Decentralized Partially Observable Markov Team Decision (DPOMTD) algorithm

in terms of sensors and world modeling, including methods for managing occlusions when they happen for example.

2.7 Dynamic auto-adapting strategies during games

Strategy in our Decentralized Partially Observable Markov Team Decision algorithm is based on the evaluation of each possible action by any of the teammates. However, this evaluation, and particularly its probability of success highly depends on the performances of the other team. For example, trying a deep pass toward the opponent goal should not be successful if the defender speed is higher than the forward one. If teammate speed is well-known, having information on opponents characteristics is very important to build advanced actions and to have a true evaluation of their chances of success.

In order to improve that, RCT team has implemented a model for monitoring in real time the performances of opponent players, allowing a better estimation of the probabilities of success for every possible action, leading to optimizing decisions during the game. Opponent parameters such as acceleration, average velocity, maximum velocity, or field occupation can be monitored and used in action evaluations.

DPOMTD algorithm, as well as opponent parameters monitoring have been tested using a team simulator based on the robot code itself, coupled with a physical simulator common to all the players (teammates and opponents). This simulator fully written in *C#* can be considered as a digital twin simulator (Fig. 6) as it uses the modules of the robots itself, but replicated for each teammate or opponent. The simulator enables the test of strategies and high level software in close to real conditions. This allows to improve the reliability of each module, and provides a reliable tool for debugging team behavior.

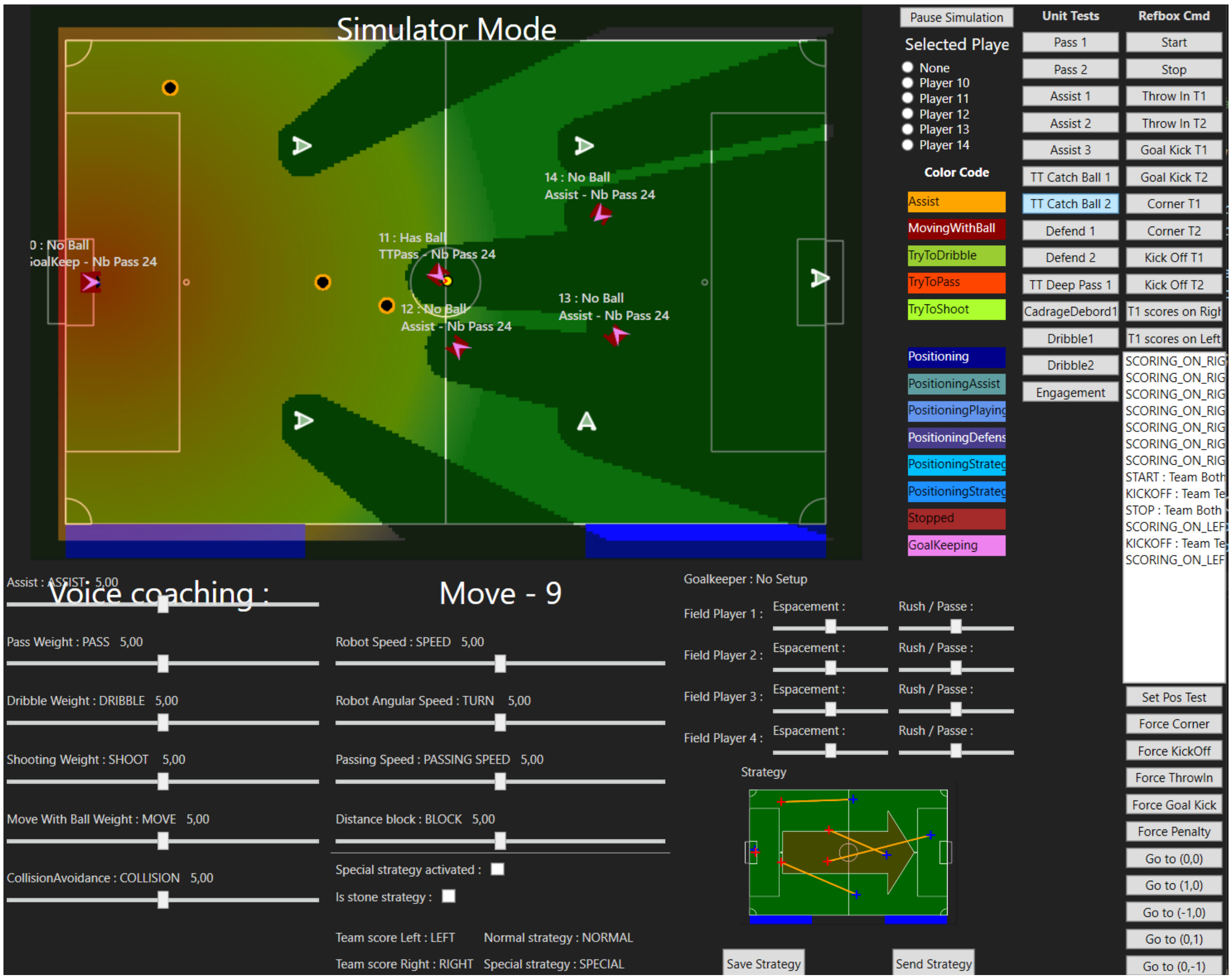

Fig. 6. RCT team simulator

3 Contributions to MSL

3.1 Participation to the League Executive Committee

Valentin Gies, Professor at Toulon University, is a member of the executive committee.

3.2 MSL Workshop 2025 organization

In 2025, our team had the pleasure of organizing the MSL workshop, which took place on January 24th and 25th at the University of Toulon in France. Six teams participated in this edition: TechUnited, Falcon, Sioux, and RobotSports, LAR@MSL and RCT. During the workshop, various objectives for the coming years leading up to 2050 were discussed. The exchanges focused on mid-to-long-term developments, goalkeeping, energy, safety, and preparations for RoboCup 2025.

4 Sharing of robot designs

4.1 Sharing of mechanical and electronic designs

Our mechanical and electrical designs are fully shared in the Electrical and Mechanical Presentation papers.

4.2 High Level Code documentation

A full description of the structure of our robots is provided at Fig. 4. Code cannot be fully shared due to confidentiality contracts, but parts can be shared on demand, and we invite teams to ask for any information.

4.3 Code sharing on GitHub

Our team has gathered images from several MSL teams, and from other leagues to build an image repository, with thousands of labeled images in different conditions, helping new teams to develop visual perception AI algorithms. This repository has been published on GitHub in public access, and fully described in a conference paper accepted last year at the RoboCup Symposium in Eindhoven. Repository can be accessed via the followig link :
https://github.com/iutgeiitoulon/MSL_Vision/

5 Conclusion

Participating in the RoboCup is a wonderful challenge for our team. This year, our primary focus was on hardware stabilization, along with significant improvements in perception, path planning, and strategic decision-making. Our key challenge is to dynamically adjust our strategy during a match and adapt in real time to the opposing team's actions.

Thanks to the help of the other teams, it has been a great adventure for us since 2019, and we are proud to now have a functional robot and to have developed some novel ideas for the MSL community.

The Robot Club Toulon MSL team's project for RoboCup 2026 hopes to stand out as as strong contenders in the competition by having a winning combination of mechanical innovation, advanced perception algorithms, and strategic decision-making.