

Robot Club Toulon Team Description Paper 2025

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Abstract. This paper presents Robot Club Toulon (RCT) team, developments of RCT robots done in the last year, contributions to the MSL leagues and how our robot designs are shared with other teams.

Keywords: RoboCup Soccer, Middle-Size League, Multi-Agent Robotics, Artificial Intelligence, Image Processing, Lidar, Decision-marking

1 Team Presentation

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

The team will be participating in the Middle-Size League for the third time in the soccer competition. Our team has been participating in the RoboCup competition since Sydney in 2019. We have also participated in 2021 (online), in 2022 (distant), in Bordeaux in 2023 and in Eindhoven last year. Our results in the competition are :

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

Complete list is here At the moment of writing this paper, RCT team consists of 2 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 2024 Innovations

2.1 Electronics

All the electronics boards have been redesigned in order to improve reliability, safety or to reduce size, especially for the kicking system board. Electronic architecture of our robots have evolved in order to integrate this new boards, and to improve global electric safety : particularly, one key point is the isolation of the kicking board, having now 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. 1. Kicking system and main controller boards

2.2 Introducing 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, the decision has been taken in 2024 to build new robots based on swerve drive propulsion. This decision has also been motivated by a need for improving performance, to be able to compete in the future with the best teams, especially in terms of maximum speed and acceleration. Our robots were limited to $3m.s^{-1}$, with an acceleration of $1.2m.s^{-2}$. With the new swerve drive propulsion, maximum speed can reach $7m.s^{-1}$ with an acceleration of $3m.s^{-2}$. These huge differences allow a lot of new strategy options for the future.

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

These robots have been successfully tested during RoboCup 2024, even if they were ready only 5 days before the competition. One drawback have been observed on motor control, due to the poor performances of the built-in encoders of the brushless motor (NEO V1.0) used (50 pts/revolution) Since this competition, motors have been replaced by a new version (NEO VORTEX) having more than 7000 pts/revolution. This allows a far better control.

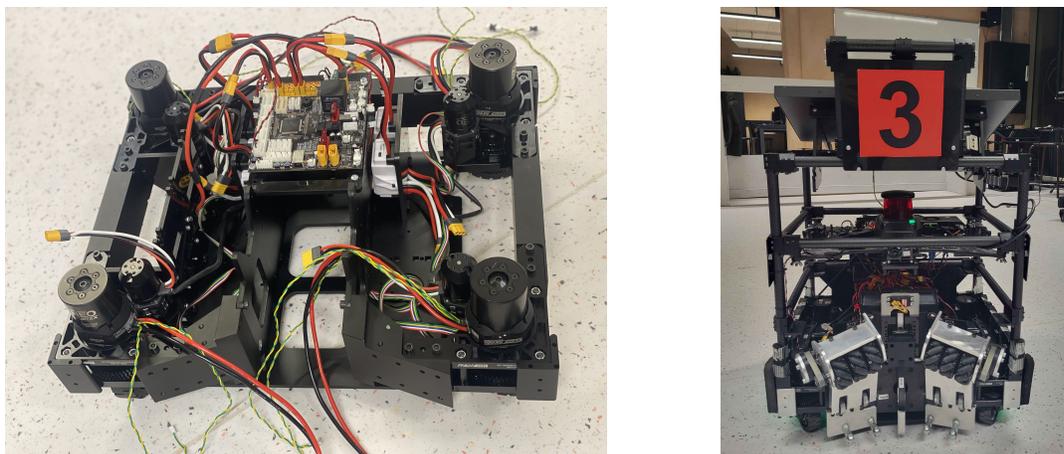


Fig. 2. Swerve drive propulsion (including new NEO VORTEX motors) and fully assembled RCT robot.

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

2.3 Ballhandling

Ball-handling has been fully redesigned in 2024 for performance and reliability reasons. Fully described in the *mechanical paper*, it has been improved using mecanum-wheels to automatically recenter balls after catching them, and during lateral moves. Plastic mecanum wheels have been chosen for durability, considering that they are less sensitive to mechanical shocks happening frequently, and twisting metallic parts definitely. Ball handling optical sensors have been removed due to poor performance, and have been replaced by torque sensors integrated in the motors. They allow a full dynamic control of the gripper velocity, allowing a good ball control under any circumstances. Even during lateral moves at speed up to $2m.s^{-1}$, ball control allows to shoot the ball as if the robot is idle.

The design of the new ball handlers has been done using 3D printing at first to optimize angles for better control and precision. Successfully tested at the 2024 RoboCup in Eindhoven, the system proved its efficiency.

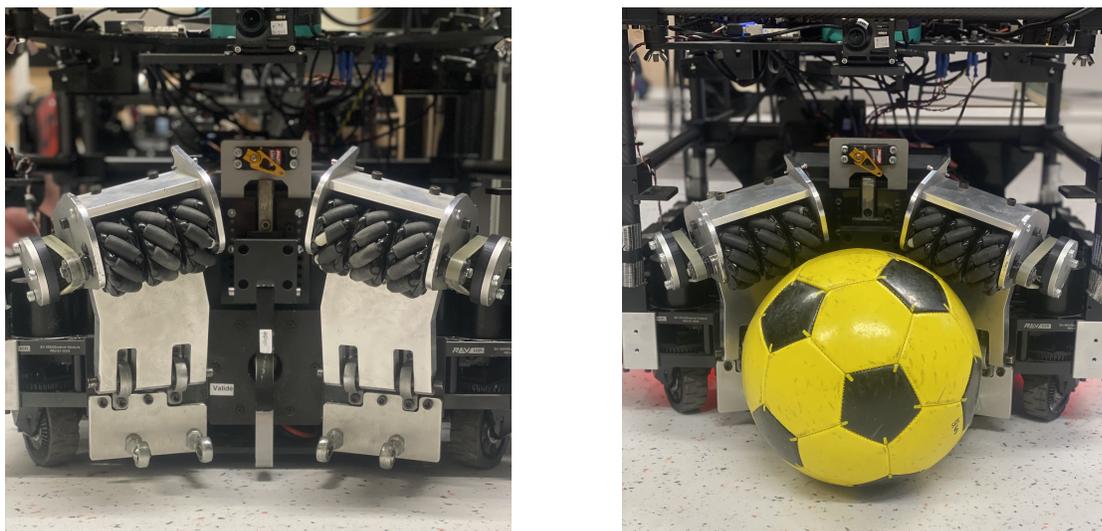


Fig. 3. Ball handling system of RCT robots

2.4 Goalkeeper

Our first armed goalkeeper was introduced during RoboCup in Bordeaux 2 years ago. Using 2 arms, it was not reliable enough and had a lot of drawbacks. In 2024, it has been replaced by a single arm, having an extension. This arm is fully described in the *Mechanical Description Paper*.

Not fully ready yet, it aims at being able to intercept balls in a maximum time of 0.5s. This requires a fast detection process (0.1s) and powerful actuators deploying in 0.2-0.3s.



Fig. 4. Goalkeeper arm of RCT robots

2.5 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. 5, 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. 6.

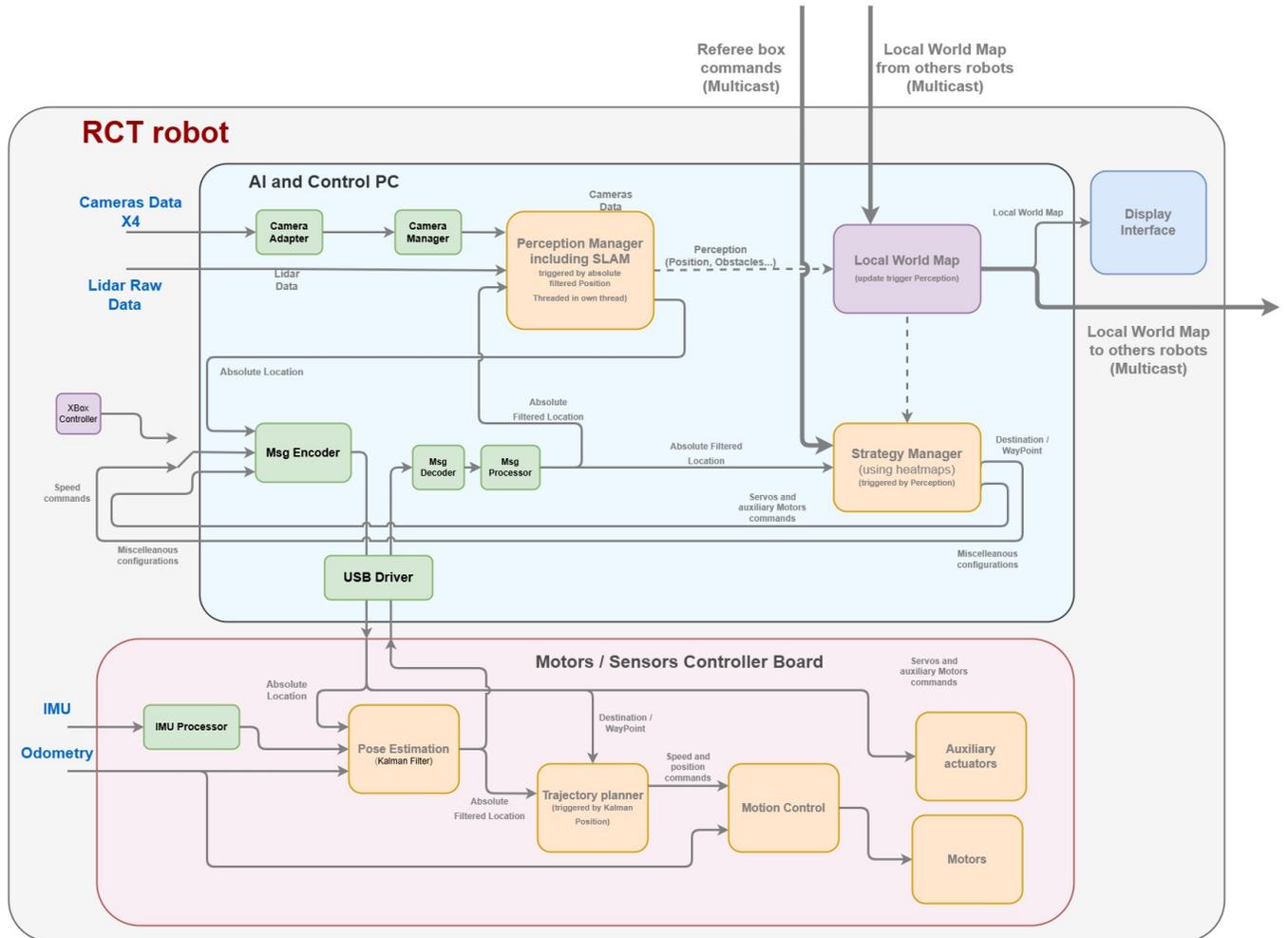


Fig. 5. RCT robots software architecture

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 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

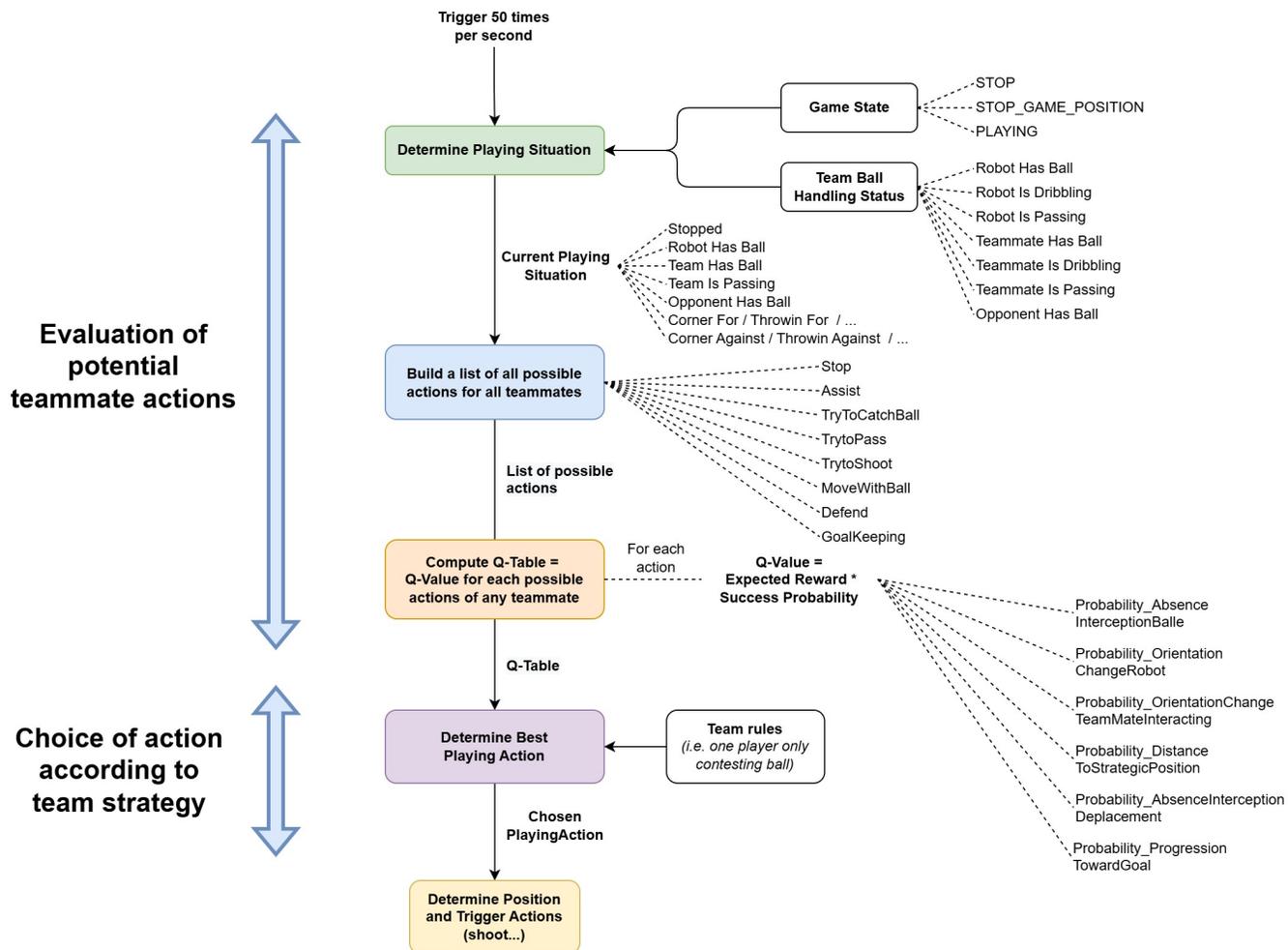


Fig. 6. Decentralized Partially Observable Markov Team Decision (DPOMTD) algorithm

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

2.6 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. 7) 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.

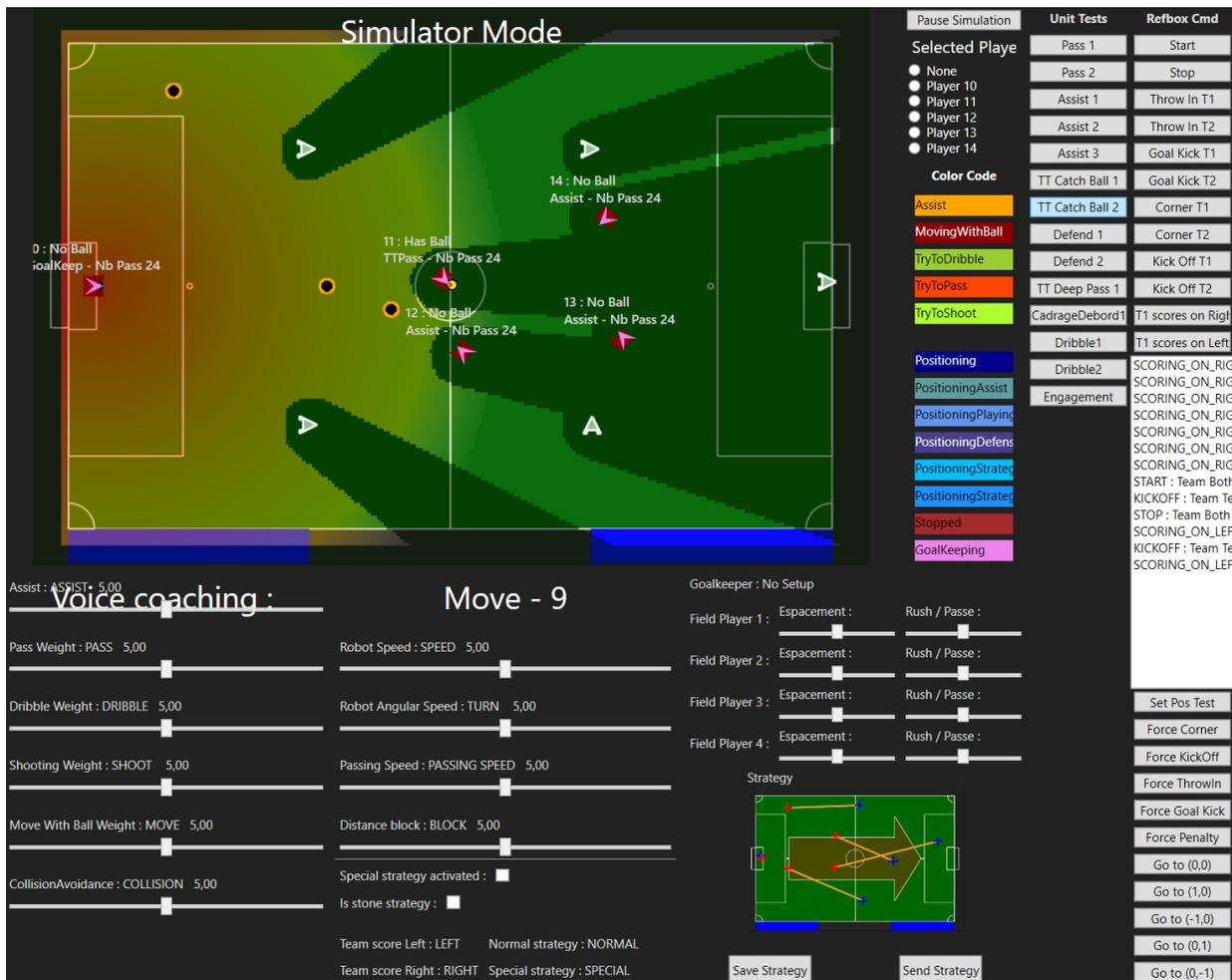


Fig. 7. RCT team simulator

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 for 3 years.

3.2 MSL Workshop 2025 organization

This year, 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. 5. 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 following link :

https://github.com/iutgeitoulon/MSL_Vision/

5 Conclusion

Participating in the RoboCup is a wonderful challenge for our team. A strong emphasis was put on strategy this year as well as on mechanics for goal keeper and swerve drive. Our challenge this year is to be able to develop our strategy during a game and to be able to adapt our strategy in real time depending on the opposing team.

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 2025 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.