RoboCup Junior Slovakia Open

ETC autoPrikratki

Team Description Paper

League Name:	Soccer 2:2 Lightweight
Age Group:	Secondary
Team Name:	ETC autoPrikratki
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Date:	15.1.2025.

Abstract:

This abstract provides a comprehensive glimpse into our robot's mechanical, electrical, and software designs, meticulously tailored for the upcoming Robocup Super-Regional competition 2025 in Mercersburg, PA. As novices in the Soccer Light Weight category, we've invested substantial effort to refine our robots for this challenge.

Mechanically, we've undergone significant improvements, addressing critical elements including wheel performance, motor efficiency and battery optimization. These enhancements are pivotal in ensuring our robots' peak performance during the competition.

Simultaneously, our software development efforts have yielded an advanced codebase. This code features cutting-edge algorithms, notably improving our robots' precision in line avoidance and ball tracking.

In summary, this abstract shortly outlines the purpose, methodology, and outcomes of our work, emphasizing the groundbreaking innovations we've integrated into both the mechanical and software aspects of our robots. These innovations position us competitively for the competition.

1. Introduction

Team background

We are part of ETC Varaždin in northern Croatia, dedicated to educating and preparing children for higher-level competitions.

Our team of three, including Franko, Vinka and David have been preparing since September last year. This marks our first collaboration as a team.

Together, our combined skills and experiences make us a strong force within ETC.

2. Project Planning

Overall Project Plan

Our primary objective for this competition is to achieve the highest possible score, gain new insights, expand our knowledge, evaluate our robot's performance against the competition, and identify areas for improvement in our robot design.

Our project has been a collaborative effort from start to finish. From preparation and programming to robot assembly and discussions about necessary improvements or changes, we've worked together as a team.

While Franko and David focused on designing and building the robot, Vinka made, polished, and perfected the program while the others helped by giving ideas to improve the strategy. Our overarching project plan revolves around teamwork, learning, progress, and rectifying mistakes, all of which we consider critical for our collective growth.

As mentioned earlier, teamwork is a key milestone for us, symbolizing progress, and our shared commitment to achieving our set goals. Our aim is to present ourselves as a formidable team at the global competition and establish connections with fellow robotic enthusiasts, potentially learning from their experiences.

To monitor our progress, we've outlined several project phases to reach our desired objectives:

1. Develop two functional robots capable of performing their tasks.
2. Design a functional PCB to enhance robot operation.
3. Achieve an optimal balance of power, weight, and wheel size for optimal mobility.
4. Ensure the robot adheres to the permissible weight limit.
5. Construct a robust and durable robot.
6. Showcase our strength as a team during the competition.
7. Highlight the value of our home country, Croatia, on the global stage.

Throughout this project, we've encountered various challenges and identified areas for improvement. Notable shortcomings included the subpar performance of our old X shaped line sensor PCB, which prompted us to create a circled shaped one.

Additionally, our robot's weight exceeded acceptable limits at various stages, necessary adjustments such as reducing wheel size, substituting metal screws with plastic ones, and slimming down the chassis.

These constraints and challenges have influenced our project plan by driving us to innovate and adapt to meet our goals effectively.

Interrogation plan

Our robot system is a blend of key components: the chassis for structural support, wheels optimized for traction and speed, a Main PCB for electrical connections, potent motors with motor drivers, the Teensy 4.1 microcontroller as the central processing unit, and an array of sensors including IMUs, custom line sensors, and a ball sensor. This system operates seamlessly through Arduino C++ software, which processes sensor data to enable the robot's agile ball tracking and precise line avoidance on the field.

Testing

We tested and optimized our robot's components, addressing both hardware and software concerns. Initially, we employed PLA for the chassis then we switched to PETG for better durability, and finally settled on a mixture of carbon fiber and CPE for maximum durability and minimum weight.

Wheel testing involved six designs, various rollers, and filaments to improve traction. Our transition to wheels with custom made tires enhanced grip and movement. During testing, we encountered a software issue where the robot occasionally failed to respond to specific commands.

To address this, we fine-tuned the code, implementing error-handling routines and refining the control logic. We also added a PID algorithm which helped extremely with ball following. These iterative tests ensured our robot's peak performance and compliance with weight limits while reducing potential software glitches.

3. Hardware

Our hardware design revolves around a balanced blend of simplicity and performance, culminating in a cohesive robotic system. At the beginning the parts were procured through several institutions operating in the Croatian territory: the Center of Excellence Varaždin, the Robofreak Association and the Croatian Society for Robotics. The parts were ordered according to the requirements, and we are looking for new parts from year to year and we try to look at the situation economically and use old parts from teams from previous years. Because of that we use old Joinmax, since the new ones would be terribly expensive.

We started by selecting PETG filament for chassis construction due to its durability and printability. We are slowly switching from plastic chassis to carbon fiber, but for this competition we have decided that CPE with fragments of carbon fiber will do.

The journey to perfecting our wheels led us to experiment with PLA and rubber bands, ultimately equipping our robots with wheels featuring 100% rubber tires to optimize traction and carbon fiber wheels for maximum strength and as little weight as possible.

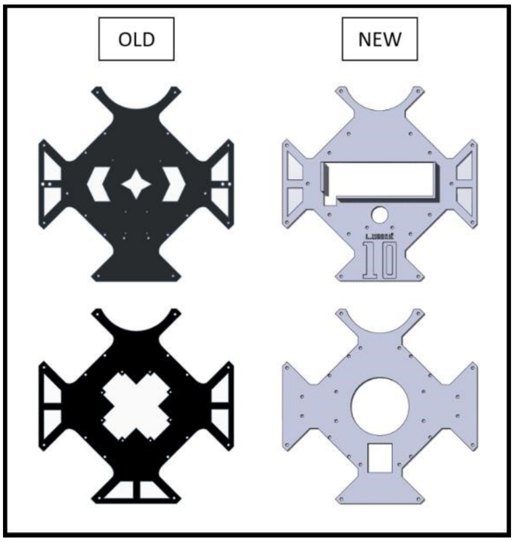
One of our pivotal hardware upgrades was the integration of a PCB to streamline functionality and resolve wiring issues obstructing the ball sensor. Our initial round PCB design encountered operational hindrances, prompting us to transition to a more adaptive shape that is the shape of the chassis itself. Additionally, we strategically relocated the orientation sensor to minimize magnetic interference from motor drivers.

Our hardware toolkit comprises robust Joinmax Motor 3561 motors, reliable ML-R Motor Driver 1x50A with reverse protection, and the versatile Teensy 4.1 microcontroller, chosen for compatibility with Arduino libraries, the OpenMV H7plus camera to better navigate the field and locate the goal, a kicker so that we can improve our attack.

For our line sensor we have engineered a custom PCB line sensors featuring a circle design with vibrant red LEDs and 32 sensors. These sensors significantly enhance our robot's line detection capabilities, ensuring precise line avoidance.

For ball tracking, we rely on the MRMS IR ball finder sensor, known for its analog output. Additionally, a voltmeter diligently monitors battery voltage during matches, ensuring consistent and reliable performance.

a. Mechanical design and manufacturing

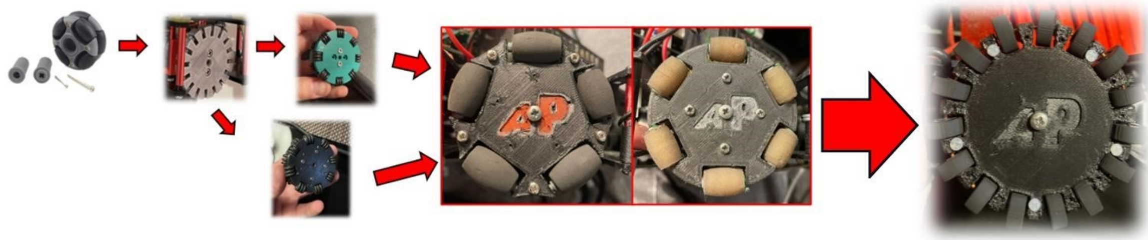


Our journey to optimize our robot's performance and capabilities has been marked by significant improvements in two key areas: the chassis and Omni-Wheels.

Our transition from PETG to CPE-carbon fiber mixture filament for chassis construction prioritized durability and printability.

Since one of our goals was to optimize the space we have, the new upper chassis has a hole for the battery, so we don't need a battery cartridge.

Our exploration of the Omni-Wheels was equally comprehensive and rigorous.

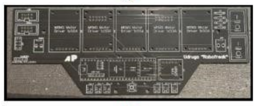


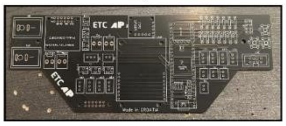
We did everything to make the best wheels possible, by experimenting with six distinctive wheel designs, three tire choices, and two filament options in pursuit of perfection. Initially, we considered utilizing pre-made wheels, only to discover their limitations. In response, we pivoted to crafting our wheels from PLA and introduced locally sourced rubber bands to augment traction. After the initial attempt, we made the second design with rubber rollers (from bought wheels) for better traction but found out at the Robo Cup Asia Pacific 2023 in Pyeongchang that our design would not work, simply because the wheels got stuck from the grass that lodged in between the rollers.

At the end, we refined our wheels to overcome issues related to slipping and getting stuck while significantly enhancing the robot's grip on the playing field. In our most recent upgrade, we adopted wheels equipped with 100% rubber tires, which was a perfect mix of everything we have work for up until this point. We also introduced a carbon fiber - CPE mix as a material for the wheels, to reduce the weight and at the same time have that essential strength.

b. Electronic design and manufacturing

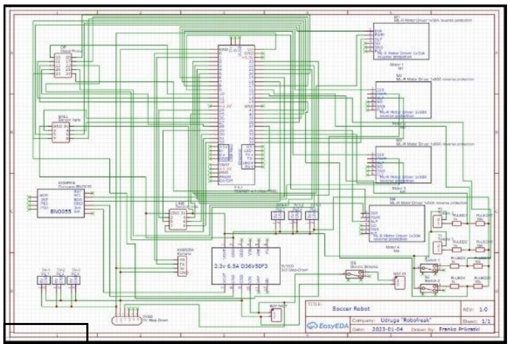
that contribute to its functionality and performance.



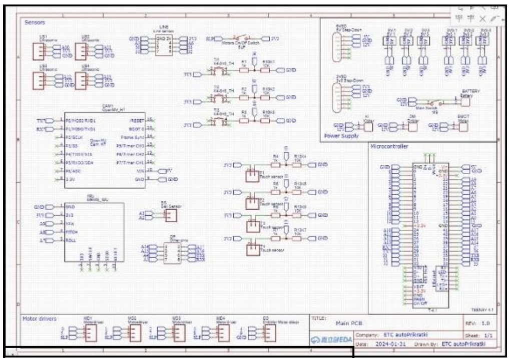


Main PCB:

We recognized the need to address issues like wiring obstructions hampering the ball sensor. Our solution involved a critical shift to a Printed Circuit Board (PCB). This innovation streamlined component integration, shedding excess wiring weight, and elevating the robot's capabilities. After initial hiccups with a round PCB design, we settled on a second, more efficient layout, creating room for potential future upgrades, such as a dribbler mechanism. For the last year, we used this PCB. We wanted to add a camera, more switches, buttons but we had now room. So, we moved the motor drivers to the bottom chassis, and we made a new PCB with everything we wanted, including JST-XH connectors. We also tactically repositioned the orientation sensor to minimize magnetic field interference from the motor drivers, a suspected cause of previous crashes. These enhancements aimed to optimize performance, reduce malfunction risks, and strengthen reliability.



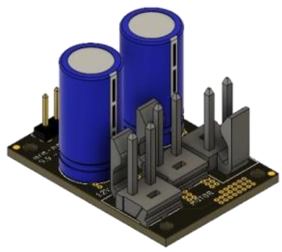
OLD



NEW-improved organization

To delve into the intricate hardware of our robot, it's essential to focus on key components

Motors and Motor Drivers: Our choice of Joinmax Motor 3561 brought strength and speed to our robot. However, their weight prompted us to strategically manage overall weight distribution. For motor drivers, we adopted ML-R Motor Driver 1x50A with reverse protection, alleviating concerns about reverse voltage.

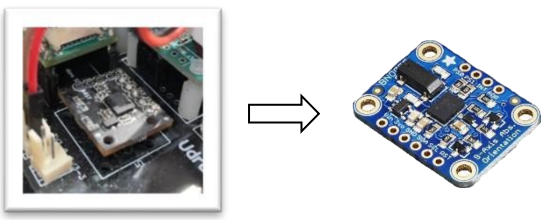


Microcontroller: At the robot's core lies the Teenys 4.1 microcontroller, a lightweight yet powerful brain. We chose it for compatibility with Arduino libraries, reliability, and the number of pins it provides.

Kicker: In addition, we've added kicker, which is made up of a very strong and heavy ZMF-2551 solenoid and a little kicking pad. Our first design was a mechanical kicker, which is made up of a simple spring which worked on the principle that the robot crashed into the ball and upon impact bended the spring, which as a result launched the ball like a kick in real football. This system worked to a certain degree, but it was simply not good enough and we wanted to add a real kicker to our toolkit.

Camera: We use the OpenMV H7plus, paired with a conical mirror so that the view is 360 degrees around the robot.

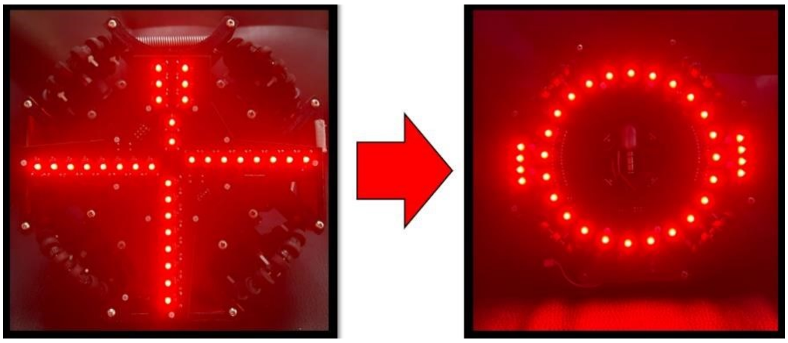
Sensors: Our orientation sensor, the Adafruit BNO055 Absolute Orientation Sensor, replaced the ML-R IMU due to performance issues. We use a complicated algorithm that calculates the distance from the original angle, and according to that distance, the motors rotate at an adjusted speed to return to the original angle.



Line sensors: We used a custom PCB line sensor, featuring vibrant red LEDs and 32-line sensors placed in a circle with extra 8 sensors to the side, since during our research, this is where the robot went out most of the time.

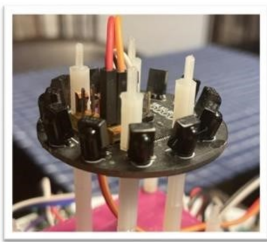
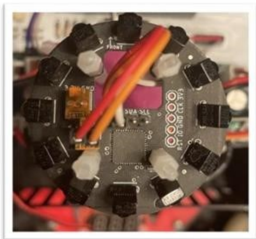
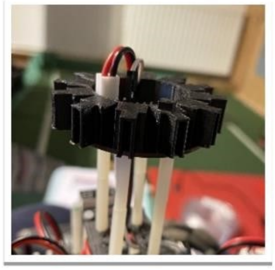
Our old design, which was basically the same, but it featured a cross shaped design, which proved to be not as good. In our last 3 competitions we had a big problem: the Sun. The lighting in the room changed very frequently and the line following needed to be calibrated often. So, to fight this problem we ordered a PCB with much stronger LEDs to hopefully fight with the lighting better.

This innovative solution enhances our robot's line detection capabilities, allowing precise avoidance.



Ball Sensor: We repurposed the MRMS IR ball finder 3, CAN Bus, I2C, analog (mrm-ir-finder3) from our surplus sensors. It provides analog values ranging from 0 to 1000, helping us locate the ball accurately.

We added protection and at the same time a guider for the sensor, so that the sensor does not get damaged and for better ball tracking.

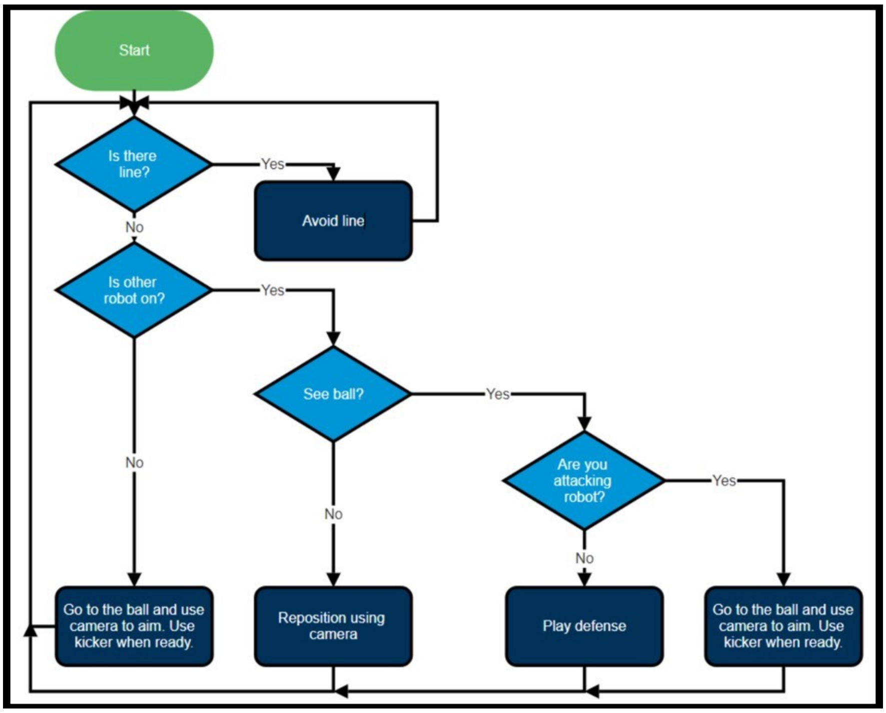




This detailed interplay of sensors, motors, and PCB innovations ensures our robot's efficiency and reliability on the field. Our commitment to continuous improvement exemplifies the spirit of innovation in the robotics community.

4. Software

a. General software architecture

Our software, written in Arduino C++, orchestrates the robot's behavior by processing sensor input and making informed decisions.



Here's an overview of its structure:

Main Loop:

1. Initialization:

The program starts by initializing the necessary components and sensors.

2. Button Check:

It checks if the button is pressed. If so, the robot starts its motors and starts moving and stops and displays the ball sensor value.

3. Line Sensor Reading:

If the button isn't pressed, the robot stops, and the program reads values from line sensors to detect the ground lines.

4. Line Avoidance Logic:

The software uses conditional statements to determine the robot's actions based on the line sensor readings. For example, if it detects a line (up, down, left, or right), the robot briefly stops and reverses its direction accordingly.

5. Ball Angle Sensor:

The program then checks the value from the ball angle sensor. Based on this value, it adjusts the robot's speed and direction to face the ball correctly, ensuring effective ball tracking.

6. Goal-Oriented Movement:

Leveraging its sensor capabilities, the robot identifies and distinguishes between two different goals on the field. Depending on the goal's position relative to the robot and the ball, it strategically moves towards the goal while maintaining ball control.

Integration:

- The software integrates solutions for various tasks, such as line avoidance, ball tracking, and maintaining heading, within the main loop.

- It continuously processes sensor data and adapts the robot's actions, accordingly, ensuring it effectively follows the ball while avoiding white lines on the ground.

This flowchart illustrates the sequential execution of the software's main loop, showing how it integrates solutions for different aspects of the robot's behavior.

b. Innovative solutions

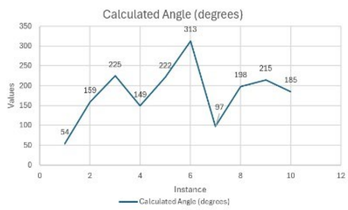
Our Arduino C++ robot control program innovatively handles ball tracking and line avoidance using sensors. It checks for a button press to start the robot’s movement and display ball data or reads line sensor values to avoid lines. Unique conditional statements adjust the robot's movement based on detected lines. The program also considers ball angle sensor data to face the ball accurately. During development, we encountered sensor data processing challenges, which ChatGPT helped address by refining our algorithms. This collaboration enhanced our robot's ability to respond to complex sensor inputs, improving its agility on the competition field.

5. Performance Evaluation (Result)

Evaluating the performance of our robot is crucial to assess its effectiveness and identify areas for improvement. Here's an overview of the performance evaluation:

1. Ball Detection and Control: Our robot has demonstrated reliable ball detection and control. The MRMS IR ball finder sensor effectively locates the ball, allowing the robot to track and approach it accurately. The ball detection and control system utilize sensor inputs to dynamically adjust the robot's orientation and movement relative to a detected ball. By leveraging constants such as **a, b, c, n,** and **n2,** the system calculates an optimal angle that guides the robot towards or around the ball. These parameters play a crucial role in determining the effectiveness of the robot's response to changes in the ball's position and distance.

Instance	Ball Bearing (degrees)	Ball Distance (units)	Goal	Heading to Maintain (degrees)	Offset Angle (degrees)	Multiplier	Calculated Angle (degrees)
1	30	50	0	0	39	0.61	54
2	90	30	1	120	90	0.76	159
3	150	20	2	22	90	0.83	225
4	210	40	3	-15	-90	0.68	149
5	270	60	1	45	-90	0.53	222
6	330	80	2	22	-39	0.44	313
7	60	70	0	0	78	0.48	97
8	120	10	3	-15	90	0.87	198
9	180	90	2	22	90	0.39	215
10	240	50	0	0	-90	0.61	185



2. Line Tracking: The custom PCB line sensor we developed has significantly improved line tracking capabilities. The robot can accurately avoid lines on the playing field, ensuring it stays on course and avoids penalties.

Line Sensors Detected	Action Taken	Comments
lineUp	Move forward with a slight left/right adjustment	Adjusts to maintain heading if no other lines detected within 300ms.
lineDown	Adjust direction based on analog sensor reading	Maps analog input to adjust direction.
lineRight	Move left with slight adjustment	Adjusts to maintain heading if no other lines detected within 300ms.
lineLeft	Move right with slight adjustment	Adjusts to maintain heading if no other lines detected within 300ms.
lineUpRight, lineUpLeft, lineDownRight, lineDownLeft	Adjust direction diagonally	Adjusts to maintain heading if no other lines detected within 300ms.

6. Discussion and Conclusion

Conclusion: Our paper highlights the journey of improving our robot's hardware design and software algorithms. We transitioned from PETG to CPE-carbon fiber filament for chassis and wheel construction, enhancing durability and printability. Customized sensors, like the PCB line sensor significantly improved line tracking. The impact of these hardware and software upgrades has been a more reliable and capable robot, contributing to our project's success.

Impact on the Project: The hardware design and software algorithm improvements have been pivotal in elevating our project. They have enhanced the robot's overall performance, making it more competitive and reliable in robotics competitions. The transition to new chassis and the innovative sensor and camera solutions have resolved key challenges, ensuring smoother gameplay.

Team's Learning Experience: Our team's learning experience has been profound. We've honed our skills in hardware design, sensor integration, and collaborative problem-solving. The process has fostered teamwork, innovation, and a deeper understanding of robotics technology. Overcoming challenges has been a valuable lesson in perseverance.

Future Work: Our plans involve adding a dribbler and communication to our robots. However, we prioritize perfecting the basics, as a strong foundation is essential for success. To enhance the strength, durability, and safety of the robot, we want to add protectors that will shield the robot from external stimuli. We are prepared for the challenges that lie ahead on our continuous journey of improvement and innovation.

7. Acknowledgements

We extend our heartfelt thanks to Centar izvrsnosti Varaždinske županije and the Croatian Robotics Association for their generous support and partnership in advancing our robotics project. Their contributions have been instrumental in our journey, providing resources, guidance, and opportunities that have significantly enriched our project's development.

Additionally, we express our gratitude to our mentors, advisors, fellow researchers, and collaborators for their unwavering support, expertise, and collaborative efforts. Together, we have achieved remarkable progress in the field of robotics.

Finally, we acknowledge the support and understanding of our family members, friends, and mentors whose encouragement and motivation have been invaluable throughout this endeavor.

This project's success is a testament to the collective efforts of these individuals and organizations. Thank you for your continued support and dedication to the advancement of our robotic achievements.