ZG24ROBOTICS

TEAM

We are ZG24Robotics, a team of high school and university students from Zagreb, Croatia. Guided by our mentors, Ivica and Ivan Kolarić, we are passionate about robotics, technology, and innovation.

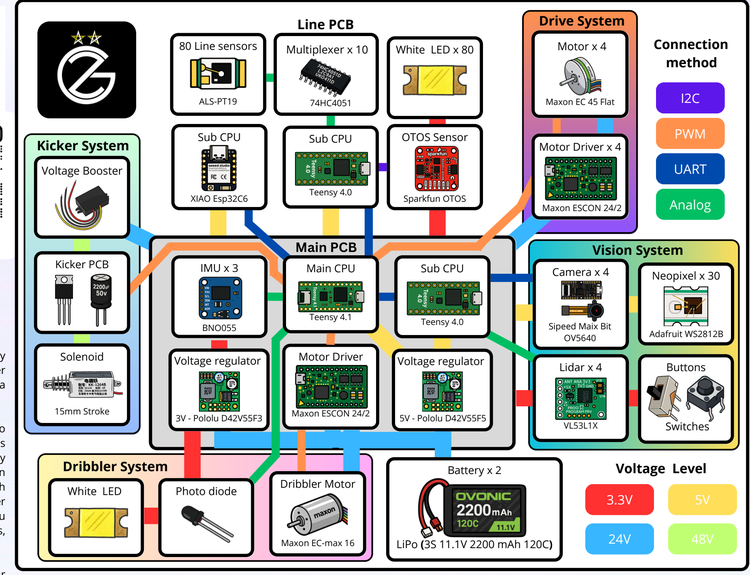
Our team members:

- Borut Patčev (CTO) – Team Captain, Lead Programmer, Electrical Design
- Ivan Matošević (CEO) – Mechanical Design, Materials and Manufacturing
- Ivan Perko (CFO) – Electrical Design, Camera Vision Systems, Sponsorships
- Dino Furjan (COO) – Hardware Assembly, Testing & System Integration

We have proudly represented Croatia at numerous RoboCup Junior competitions, including World Championships in Sydney, Bangkok, Bordeaux, and Eindhoven, and European Championships in Guimarães and Bari.

Our goal: to design advanced autonomous robots for the Soccer Open League, push the limits of technology, and promote STEM education worldwide.

ZG24ROBOTICS



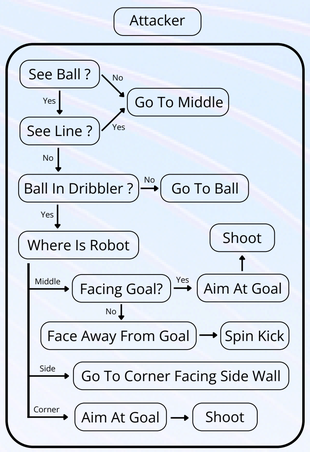
PROGRAM

"Efficient Software, Smarter Decisions."

Our robot is programmed in C++ using the Arduino IDE. The software is designed to be as simple and efficient as possible to ensure reliable performance during matches.

Multiple Teensy 4.0 microcontrollers process data from cameras, line sensors, lidars, buttons, and other onboard sensors. These microcontrollers communicate with the main Teensy 4.1 controller, which manages motor control and decision-making.

The robot operates in two play modes: goalkeeper and attacker. During the game, robots dynamically switch modes depending on their distance to the ball.



TOOLS

maxon

Fusion 360 · KiCad · ARDUINO

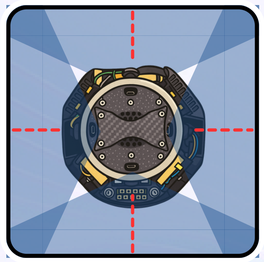
VISION SYSTEM

"Advanced Vision. Smarter Play."

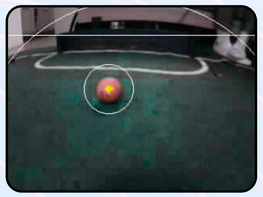
Our vision system is an innovative solution for the Soccer Open category, providing full 360° field coverage. The robot uses four Sipeed Maix Bit cameras positioned at the front, back, left, and right, each equipped with OV5640 image sensors. Three cameras have 140° lenses, while the front camera features a wider 170° Foxeer FPV lens for enhanced clarity.

All cameras are tilted at 45° angles to maximize field visibility and minimize distractions from above. This setup allows the robot to detect the ball and goals from any direction, almost all the time.

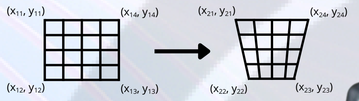
The cameras run a custom color blob detection algorithm in MaixPy (Python), filtering out objects above the field. Once a ball or goal is detected, the cameras send the coordinates via UART to the Slave Teensy 4.0 microcontroller. The Teensy processes the data, adjusts the angles based on the camera position, and calculates the precise ball location—even in complex cases where multiple cameras detect the ball simultaneously



Camera coverage and blind spots



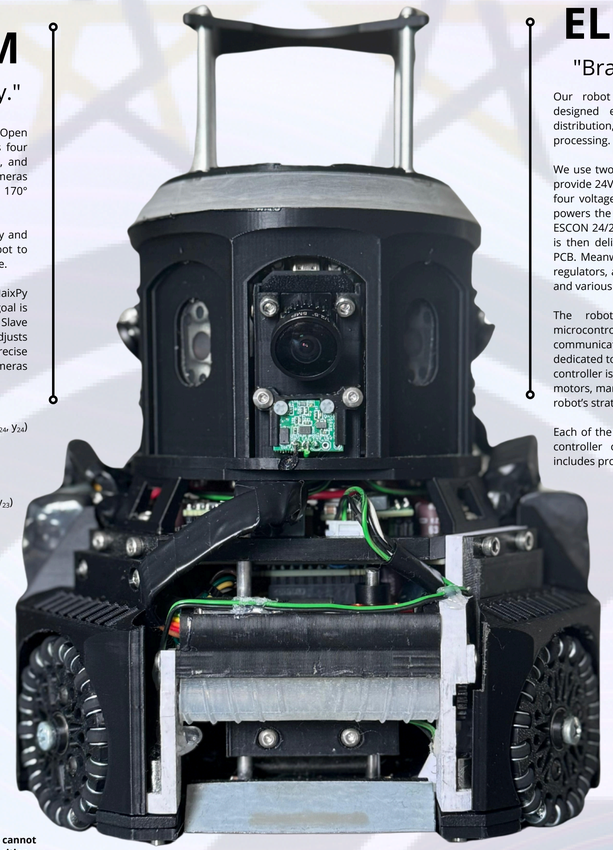
Robot POV



Homographic transfomation

Since the camera captures the field from a first-person view and the image is further distorted by the wide-angle lens, we apply a simple homographic transformation to correct the perspective.

This allows us to approximate the true position of the ball relative to the robot.



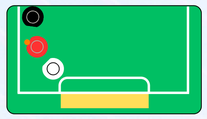
COMMUNICATION

"Stay Linked. Play Smarter."

The robots use a Seeed Xiao ESP32-C6 module to communicate wirelessly. They exchange their current state (attacker/goalkeeper), their distance to the ball, and, if the ball is visible, its coordinates on the field.

The receiving robot uses this shared information to estimate the ball's position even if it cannot detect it directly.

This capability is especially useful for the goalkeeper: when the opponent hides the ball, the goalkeeper can position itself closer to the opponent robot to maximize the chance of blocking a goal.



The goalkeeper knows where the ball is even if it cannot see it directly, because the attacker sends its position.

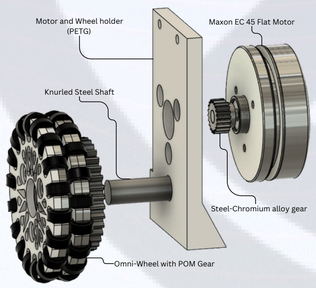
DRIVE SYSTEM

"Precision Driving. Maximum Control."

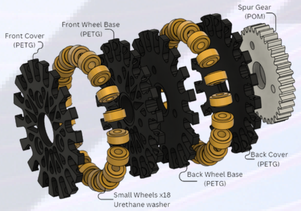
Our robot features a unique 4-wheel omni-directional drive system with motors placed in a custom configuration: the rear motors are set at 90° and the front at 120°. This setup creates more space for the dribbler and kicker, while ensuring excellent speed, maneuverability, and balance.

Inspired by Small Size League designs, our system includes custom-made gears, wheels, and holders. We use compact Maxon EC 45 flat brushless motors (24V) mounted on 3D-printed PETG holders, allowing more space for internal components like the kicker and electronics. Each motor has a custom steel-chromium alloy gear, epoxy-glued to the shortened shaft for torque transmission.
The wheels are fully custom dual-layer omni-wheels, combining 3D-printed parts, rubber rollers, and metal washers for smooth, low-friction movement. Each wheel also features a POM gear for power transmission. The wheels rotate on strong, knurled steel shafts, securely mounted with epoxy, which eliminates stress on the motors and increases durability.

Thanks to this innovative spur gear reduction drive, we achieve high torque, consistent driving force, and superior performance — setting a new standard in RoboCup Junior Soccer Open.



Exploded view of our Drive System and Transmission



Exploded view of our Custom Dual-Layer Wheel

We also developed fully custom dual-layer omni-wheels. Each layer consists of two 3D-printed parts that securely clamp around small 3D-printed cylinders. Inside each cylinder is a small rubber roller, positioned between two metal washers to minimize friction between the rollers and the wheel frame, ensuring smooth and efficient movement.

Drive Transmission (Fusion 360)

Drive Transmission (Real)

ELECTRONICS

"Brains Behind the Game."

Our robot features a highly integrated and carefully designed electronic system, delivering efficient power distribution, precise control, and robust sensor data processing.

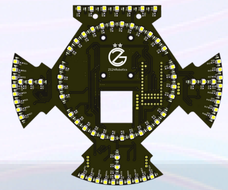
We use two 11.1V (3S) LiPo batteries connected in series to provide 24V. From the main PCB, power is distributed across four voltage levels: 24V, 48V, 5V, and 3.3V. The 24V supply powers the motors, dribbler, and motor controllers (Maxon ESCON 24/2). A voltage booster raises the 24V to 48V, which is then delivered to the kicker through a dedicated kicker PCB. Meanwhile, 5V and 3.3V voltages, generated by Pololu regulators, are used to power the microcontrollers, sensors, and various electronics throughout the robot.

The robot's control system is built around four microcontrollers. A Seeed XIAO ESP32C6 handles wireless communication between robots. Two Teensy 4.0 boards are dedicated to collecting and processing sensor data. The main controller is a Teensy 4.1, which is responsible for driving the motors, managing the dribbler and kicker, and executing the robot's strategy and decision-making.

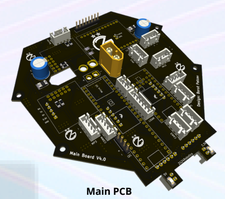
Each of the four Maxon motors is driven by its own ESCON controller on a custom Motor Driver PCB, which also includes protective diodes and fuses.

Navigation relies on 4 analog LIDAR sensors, a BNO055 compass, odometry, and line sensors to determine the robot's position and orientation on the field.

The custom Line Sensor PCB includes 80 ALS19 sensors and 80 white LEDs managed via 10 multiplexers and a Teensy 4.0. This circuit detects field lines and transmits processed data to the main controller via UART.



Line Sensor PCB



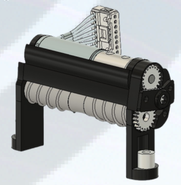
Main PCB

DRIBBLER

"SSL-Inspired, ZG24-Perfected."

Our dribbler is the most complex part of our robot, developed over six months. Inspired by Small Size League (SSL) teams, it features a custom design focused on precision and reliability. The dribbler body is 3D-printed from PETG and uses a 1:1 gear transmission with three custom PAHT-CF gears and a four-rod suspension system for smooth vertical movement. The motor, a Maxon EC-max 16, is mounted parallel to the roller and controlled by an ESCON Module 24/2 servo controller, powered by 24V from the batteries. Power is transmitted via a 2mm-to-4mm shaft coupler, connecting the motor to a custom steel shaft with a PAHT-CF gear. Additional PAHT-CF gears transmit power to the roller, which rotates on custom-made shafts supported by high-quality bearings. The roller itself is molded from soft A45 silicone and features a spiral shape that centers the ball for better control. The dribbler also includes an LED and a photodiode beneath the roller, allowing the robot to detect ball possession. All components—gears, shafts, and roller—are custom-made, while bearings and couplers are sourced from specialized suppliers.

Dribbler Custom Gearbox



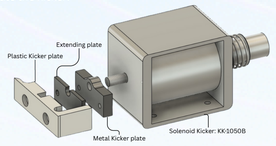
Dribbler System

KICKER

"Every Shot Counts."

Our kicker uses a standard 48V solenoid with a 15mm stroke, powered by a voltage booster and controlled by a custom-made kicker circuit. Although we originally planned to build a fully custom kicker, time constraints led us to purchase a ready-made solenoid from Aliexpress. However, we designed a custom two-part kicker plate for better performance. The first part is a CNC-machined metal plate (made by JLCCNC) that screws onto the solenoid shaft. The second part is a 3D-printed plate, allowing easy adjustment of the kicker's stroke length by changing its thickness.

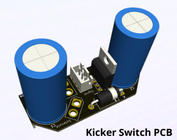
The kicker is controlled by our dedicated kicker PCB, which includes an N-type transistor (IRF3415), protection diode, two 2200µF capacitors, and a 3.3V-to-5V level shifter (74HC125D). When activated, 24V from the main PCB is boosted to 48V and sent to the kicker PCB. The Teensy microcontroller sends a PWM signal to the level shifter, which amplifies it to 5V to trigger the transistor and activate the kicker.



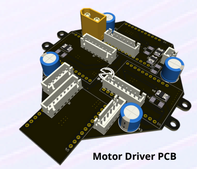
Exploded view of the Kicker System

HARDWARE

"Engineered for Reliability. Designed for Victory."



Kicker Switch PCB



Motor Driver PCB

All of our robot's mechanical parts were designed using Fusion 360, while EasyEDA and KiCad were used for PCB design. Inspired by Small Size League (SSL) teams, our goal was to create a robust and reliable robot equipped with advanced features for maximum performance during matches.

From the start, we focused on combining key features such as brushless motors, a gear-driven drive system, an effective dribbler, a powerful kicker, 360° vision, and a reliable electrical system. Each component was carefully selected based on performance, cost, availability, ease of use, and long-term reliability. Throughout development, we continuously refined our design to improve functionality and durability.

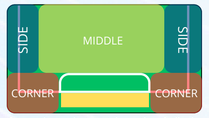
For production, we relied heavily on 3D printing using two Bambu Lab P1S printers. One was modified with a hardened steel nozzle and extruder gears to handle carbon fiber-reinforced filament (PAHT-CF), which we used for high-strength parts like the dribbler gears.

Metal gears and components for the drive system were manufactured using a gear hobbing machine and finished on a CNC lathe, while the POM (polyoxymethylene) gears were also produced with precision gear hobbing.

STRATEGY

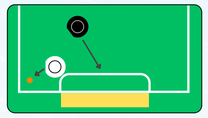
"Dynamic Strategy for Maximum Impact."

ZONES ON THE FIELD



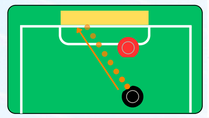
Once the robot catches the ball, he switches to a specific case depending on his position on the field, which is determined by the odometry sensor.

SWITCH BETWEEN MODES



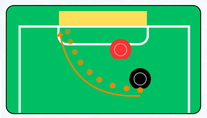
If the ball is close to the Goalkeeper, and the Attacker is far away, the Goalkeeper switches to the attacking mode, and the Attacker becomes the Goalkeeper

CASE: **MIDDLE**



If the robot is facing the enemy goal, he heads towards the goal while slowly aiming at it. Once the goal is in front of him, he kicks the ball.

CASE: **MIDDLE**

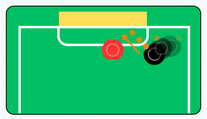


If the robot is away from the enemy goal, he goes in front of the goal while facing away from it. Once it gets near the goal, it performs a spin-kick.

CASE: **SIDE**

The robot drags the ball near the side line while facing the wall, to hide the ball from other robots. Once it reaches the corner, it transitions to the corner case.

CASE: **CORNER**



The robot goes towards the middle of the field while slowly turning towards the goal. Once the goal is in front of him, he kicks the ball.