

Engineering the Future

Projects and Prototypes **by Keegan Castro**

Building ideas, one bot at a time.



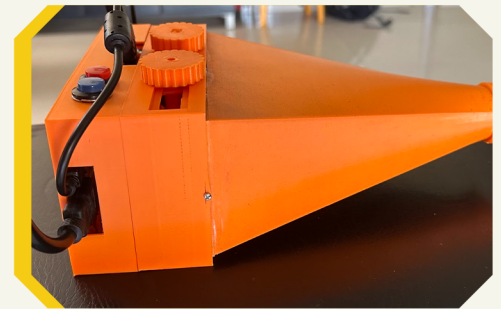
INNOVATED

Vision Guardian: Low-Cost Retinal Disease Detection Device

Optical Coherence Tomography (OCT) devices are extremely costly and often not portable, which makes them difficult to use in rural or resource-limited areas. Due to budget constraints, many laboratories in these regions cannot afford such equipment, resulting in limited access to advanced diagnostic tools needed for the early detection and monitoring of retinal diseases.

Project Overview:

This project aims to build an affordable and portable solution for the early detection of 45 retinal diseases, including diabetic retinopathy, glaucoma, and age-related macular degeneration. Detecting these conditions in their initial stages is crucial, as timely treatment can prevent irreversible vision loss. By combining AI with low-cost hardware, this device makes advanced eye screening accessible to rural and underprivileged communities.



How it Works:



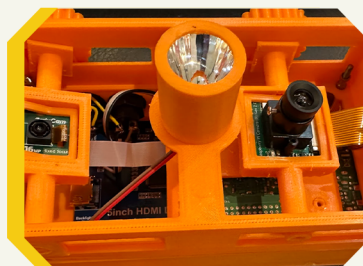
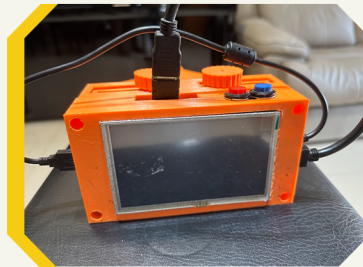
The device integrates a Raspberry Pi 5 with HD vision and IR imaging cameras.



IR images are automatically overlaid onto HD retinal images to enhance the visibility of blood vessels and retinal structures, creating a structured dynamic image that closely resembles output from an OCT device.



These enhanced images are then analyzed by an EfficientNet deep learning model, trained on Kaggle's retinal disease dataset to classify 45 diseases.



Key Features:



Affordable & Portable:

Built with Raspberry Pi and low-cost imaging hardware.



AI-Powered Analysis:

EfficientNet model trained on 45 retinal diseases.



Enhanced Imaging:

Automatic IR-HD overlay for improved visibility of retinal features.



User-Friendly:

Minimal training required for operation.



Real-Time Results:

On-device predictions for immediate screening.

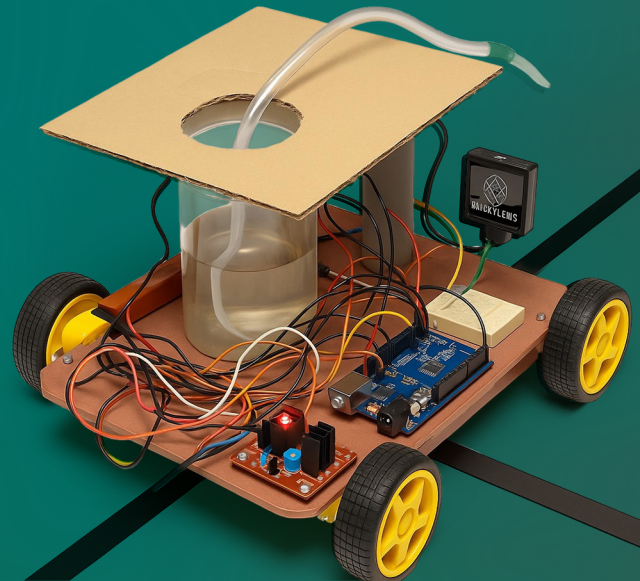
Results and Impact:

Currently, the model achieves 94% accuracy on training data. Predictions are generated in real time, allowing screenings to be conducted beyond hospital settings, including in remote regions. The total system cost is ₹19,451, dramatically lower than standard Optical Coherence Tomography (OCT) instruments, which typically exceed ₹2,050,000. This solution brings early detection of retinal diseases to schools, villages, and community health camps.

Autonomous Line-Following Irrigation Robot

– Arduino Mega 2560
& HuskyLens

Independently designed and developed an autonomous robot capable of navigating across multiple terminals and performing intelligent irrigation tasks. The system combined line-following techniques with AI-based visual recognition, making it both adaptive and scalable for agricultural or controlled garden environments.



Motion & Navigation

The bot's mobility was driven by four BO motors, managed through L298N motor driver modules. An HC-SR04 ultrasonic sensor was mounted at the front to provide continuous real-time distance measurements, enabling dynamic obstacle detection and avoidance.



AI-Based Detection

The HuskyLens AI vision module was integrated to detect plants at each terminal. Leveraging its onboard machine learning capabilities, the robot was able to distinguish between plant presence and absence in real time.



Automated Irrigation

Once a plant was identified, the system triggered a relay-controlled 5V mini water pump to deliver precise watering at the correct location, ensuring efficient water use.



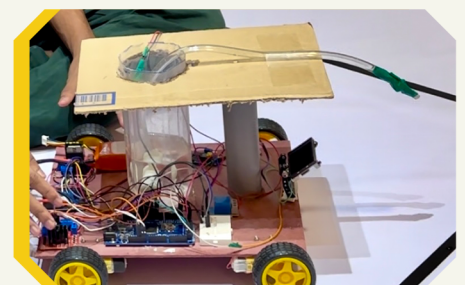
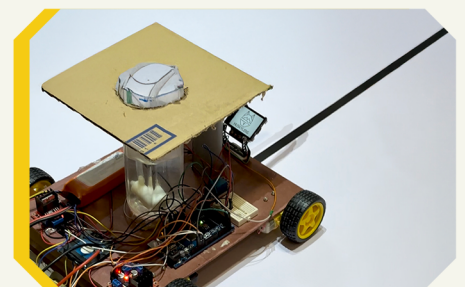
Hardware Optimization

Implemented a PCB to streamline current distribution across all subsystems, reducing wiring complexity and improving electrical reliability. This enhanced system robustness and simplified integration of motors, sensors, and actuation components.



Centralized Control

The Arduino Mega 2560 microcontroller served as the central hub, coordinating navigation, detection, and irrigation tasks. Its versatile processing capabilities enabled seamless integration between motion, AI vision, and actuation.



Community Impact

This project demonstrates how low-cost robotics and embedded **AI can be applied to smart agriculture**. By combining automated navigation with machine learning-based plant detection, the system enables targeted irrigation, **reducing water wastage and increasing efficiency**. With further scaling, similar solutions could be deployed in community gardens, small farms, and urban agriculture projects, **empowering growers with affordable automation tools**.



WORLD ROBOT OLYMPIAD™

2024 Robot

Gold Medal (1st place) & Robot Design Award (Nationals)

For the World Robot Olympiad (WRO) 2024 Senior Category, I designed and built a robot using the LEGO Mindstorms EV3 platform to complete competition-specific challenges with precision and efficiency. The robot was equipped with multiple subsystems to enable reliable intake, navigation, and task execution on the field.



Block Handling Mechanism:

An active intake system, powered by a medium motor, efficiently collected blocks from the playing field. These blocks were then stacked using a dedicated outtake mechanism, ensuring accurate placement.



Navigation & Sensors:

Precision movement was achieved through an ultrasonic sensor that enabled wall-following behaviour along the field boundaries. In addition, dual colour sensors mounted at the base facilitated consistent line-following, ensuring dependable navigation across zones.



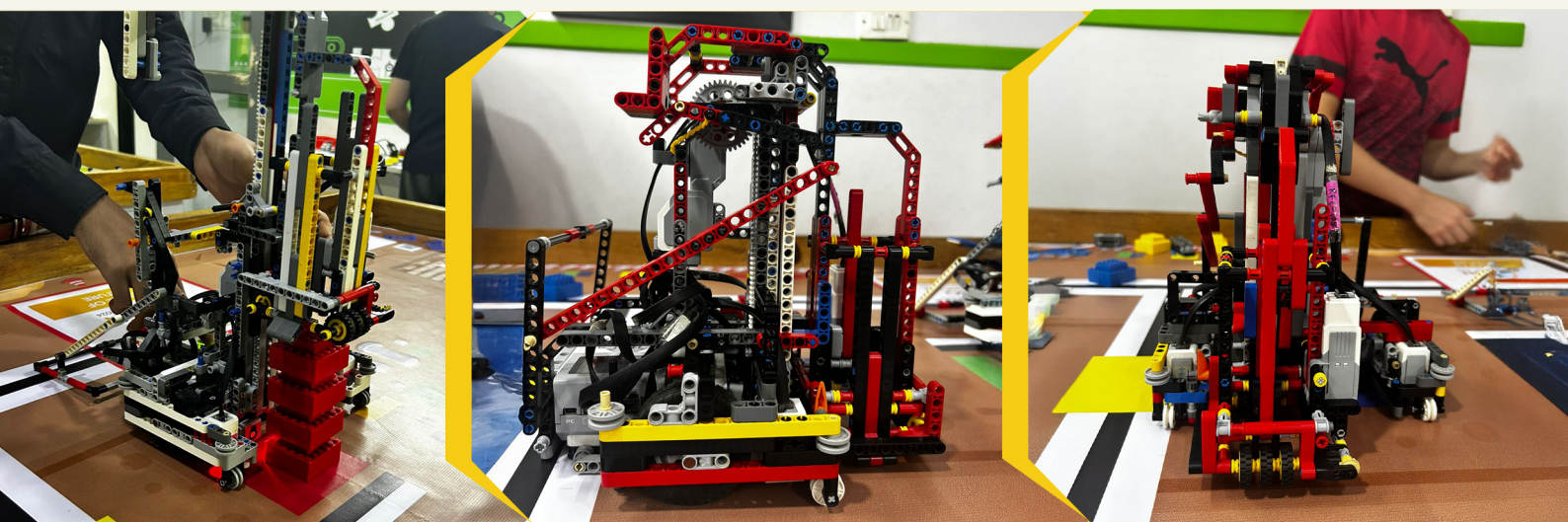
Drive System:

The robot's primary drive system was powered by two medium motors, offering both speed and stability during high-mobility tasks.



Custom Rear Mechanism:

A press-actuated cage system was developed and mounted at the rear. This mechanism allowed the robot to collect debris and perform controlled deposition at designated target areas, a key scoring



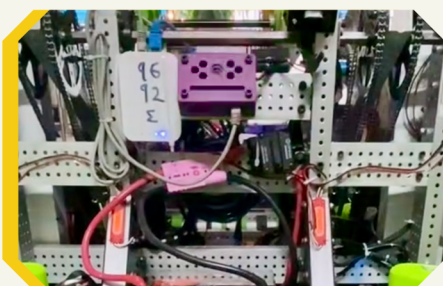


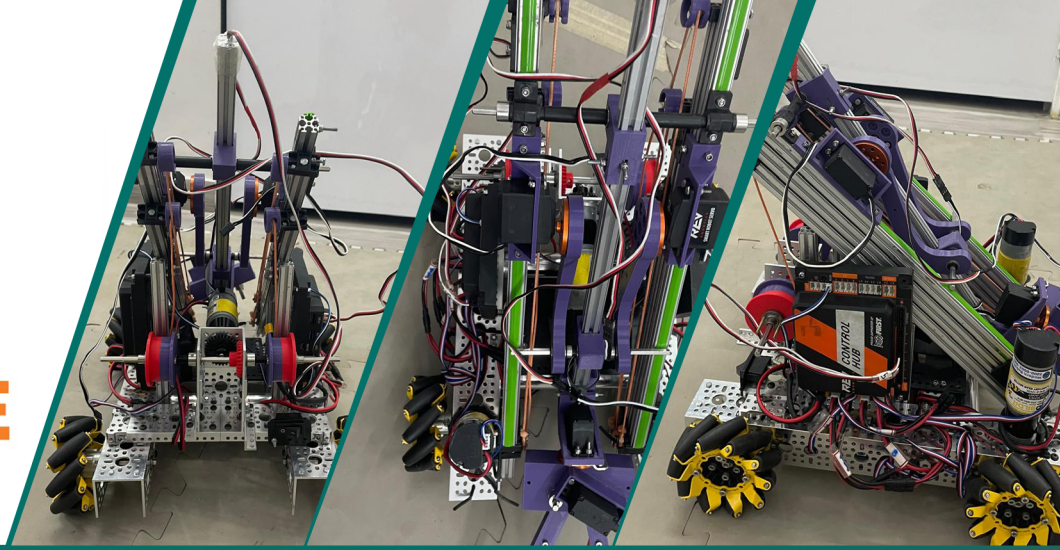
FIRST **ROBOTICS** **COMPETITION**

Robot (2024)



- **In my rookie FRC season with Team Sigma (#9692),** I played a key role in the end-to-end development of our competition robot. The design began with SolidWorks and Onshape CAD modeling, where we iterated multiple chassis concepts before finalizing a swerve drive drivetrain to provide high maneuverability on the Crescendo field. I collaborated on mechanical sub-systems including the intake, shooter, and climbing mechanisms, applying principles of gear ratios, load distribution, and structural optimization.
- **On the electrical and control systems side,** I helped integrate a RoboRIO-based architecture with PDH, PDP, CAN bus motor controllers (Talon FX, Spark MAX), encoders, and NavX IMU sensors. Pneumatics were deployed for actuation, with solenoids controlled via PCM modules. The entire system was wired with attention to safety, redundancy, and efficient troubleshooting.
- **Programming was executed in Java using WPILib,** where I contributed to both autonomous and tele-operated modes. This included implementing vision tracking pipelines with Limelight and OpenCV, sensor fusion for precise odometry, and closed-loop PID control for drivetrain stability. Tele-op controls were optimized for driver ergonomics through joystick mapping, while autonomous routines combined trajectory generation with real-time feedback from encoders and gyro sensors.
- **The integration phase required significant debugging and iterative testing.** I participated in driver practice and system validation, ensuring seamless coordination between hardware and software subsystems. By competition time, our robot was not just a machine but a demonstration of cross-disciplinary engineering, combining mechanical design, CAD, electronics, pneumatics, sensors, and control algorithms into a single cohesive system. This hands-on experience has been pivotal in shaping my understanding of applied robotics engineering at a competitive level.





- **In our rookie FTC season with Team Vortex (#22920)**, I co-developed the competition robot, contributing to its design, build, and programming alongside my teammates. Entering as a new team, we knew that achieving both mechanical reliability and programming precision would be critical. We began with a mecanum wheel chain-drive chassis, which gave us early mobility but proved difficult to maintain under competition conditions. Learning from that experience, the team transitioned to a more robust GoBilda-based chassis that offered greater stability, easier maintenance, and better weight distribution. My role in this stage included CAD modeling in Onshape, 3D printing custom components, and assisting with the physical assembly and integration of subsystems, ensuring that our digital designs translated smoothly into the working robot.
- **The robot's primary scoring system combined a linear slide**, a prismatic joint, and a grabber-flipper mechanism, designed to efficiently place cones on junctions of varying heights. Through prototyping, CAD refinements, and on-field testing, we improved each iteration for speed, stability, and accuracy. The use of lightweight 3D-printed parts allowed us to reduce load on the slide while maintaining durability. I contributed to integrating these mechanisms with the chassis and troubleshooting alignment issues during testing, giving me hands-on exposure to both the mechanical and electrical build process.
- **On the software side**, I worked with the programming team to implement Java-based autonomous and tele-op control, first in OnBot Java and later in Android Studio. The autonomous system combined multiple technologies: dead wheel odometry for precise positional tracking, through-bore encoders for measuring distance, an IMU sensor for orientation, and a TensorFlow-based vision pipeline to detect our custom signal sleeve. This allowed the robot to navigate reliably, place cones with accuracy, and park consistently during matches. In tele-op, we optimized control mappings for faster cycling and smoother driver handling. Debugging sessions and iterative field tests were an essential part of my contribution, helping to bridge the gap between hardware and software performance.
- **Beyond the robot itself**, the team committed heavily to outreach and impact. Over the course of the season, we mentored more than 300 underserved students through robotics workshops at NGOs, worked with differently-abled learners, and established three fully functional robotics labs equipped with sustainable resources. We also showcased our robot at large-scale events such as STEM expos, education fairs, and community carnivals, collectively reaching over 32,000 people and raising awareness about FIRST and robotics as a pathway to STEM careers.

Autonomous Garden Junk Bot

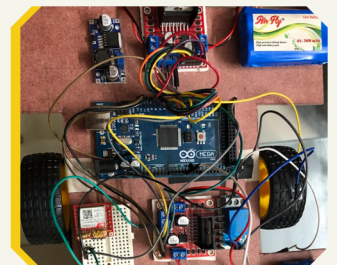
– Arduino Mega 2560

Independently conceptualized, designed, and built an autonomous garden robot that combines smart irrigation with safety monitoring. Powered by the Arduino Mega 2560 microcontroller, the bot integrates multiple subsystems to achieve real-time autonomy.



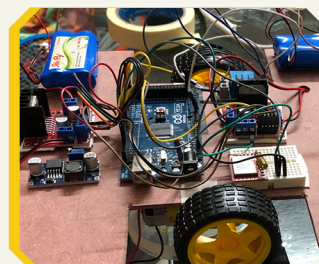
Motion & Navigation

The bot's mobility was driven by four BO motors, managed through L298N motor driver modules. An HC-SR04 ultrasonic sensor was mounted at the front to provide continuous real-time distance measurements, enabling dynamic obstacle detection and avoidance.



Automated Irrigation

To assist with plant care, the bot was programmed to recognize plants and activate a 5V mini water pump through a relay module. This ensured targeted watering without manual intervention.



Snake Detection & Communication

A critical safety feature was integrated using the SIM800L GSM module. When a snake was detected, the Arduino issued AT command instructions to the GSM module, which automatically placed calls and sent SMS alerts to designated recipients. This real-time warning system enhanced the safety of garden spaces.



Power Regulation

A buck converter was included to step down and stabilize input voltages for sensitive components, particularly the SIM800L module, ensuring reliable and uninterrupted operation.

Community Impact

The Autonomous Garden Junk Bot **addresses two pressing community needs**, efficient use of water resources and safety in green spaces.

Automated irrigation **helps reduce water wastage**, making it highly valuable for community gardens, small farms, and urban green projects where manual watering is difficult or inconsistent.

The integrated **snake detection and alert system** provides an additional layer of protection in rural or semi-urban areas where snakes pose real threats to residents.

By combining technology with social benefit, this project demonstrates how **low-cost robotics can directly improve sustainability**, safety, and quality of life for local communities.