MAKER PORTFOLIO

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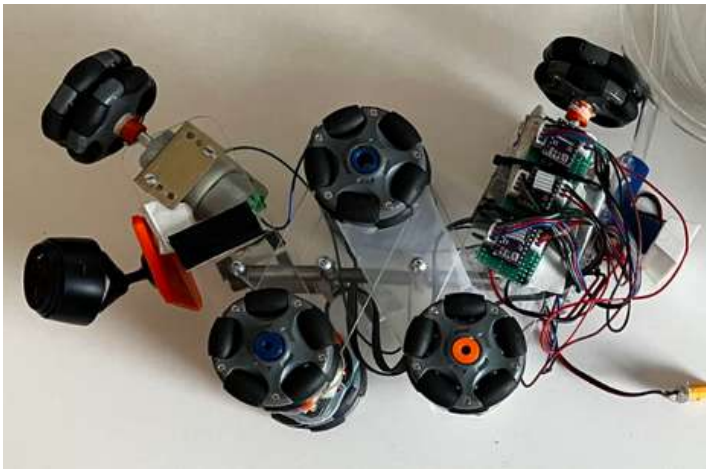
FlexiPipe

Grade 9, 2022



PROBLEM STATEMENT

- Indoor air pollutants within HVAC ducts can be 2–5× higher than outdoor levels due to accumulated dust, lint, and toxins.
- Traditional cleaning requires 6–8 hours of manual labour, with entire hospital or office floors shutting down.

What sets FlexiPipe apart?

Unlike typical systems, that typically lack in one or more areas, FlexiPipe a**cheives all:**

- **Maneuverability**: Fits any 10–35 cm duct, climbs vertically, & clear complex geometries: 90° elbows, reducers,

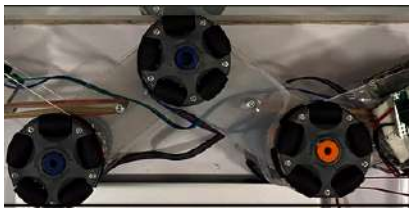
Physical Design:

Stability through **both circular and rectangular** geometries.

- **Torsional Spring Pivots** at module axes deliver passive, per-module height adjustment;
  - Self-expands or contracts for a tight fit.

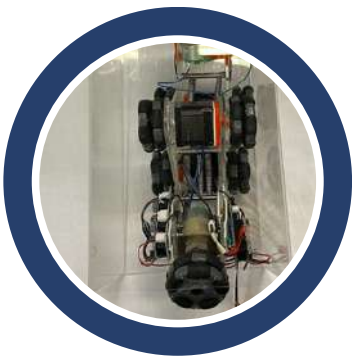
- **Perpendicular Omni-Wheel Configuration:** Controlled slip on one axis, traction on the other, enabling forward roll in round ducts and yaw turns in rectangular corners.

- **Bipolar stepper motors:** Calibrated step-count subdivision (1.8°/step) yield precise 90° reorientation.
- **3D-printed bushes & free-axle joints:** isolate dummy wheels & drive torque, stabilizing the chassis under asymmetric loads.
- **Vacuum diffuser** (high-RPM coreless motor, dual-filter path, tapered nozzle) concentrates suction and prevents fiber entanglement at the fan.



Electrical/PCB Design:

- Arduino Pro Mini firmware implements a state-based motion layer with Bluetooth command mapping (HC-05) from a **custom MIT App Inventor** controller.
- Unused channels enter driver sleep to cut idle draw (~0.3 A).
- Wi-Fi camera with IR provides live, low-light navigation and post-clean validation.



Advantages

- FlexiPipe merges passive mechanical adaptability with precision stepper control and serviceable electronics to clean the hardest-to-reach sections of HVAC networks.

- Wire-free, operator-light, and validation-ready—turning a full-day manual job into a targeted, continuous process.

PowerPlay Surge – FTC India

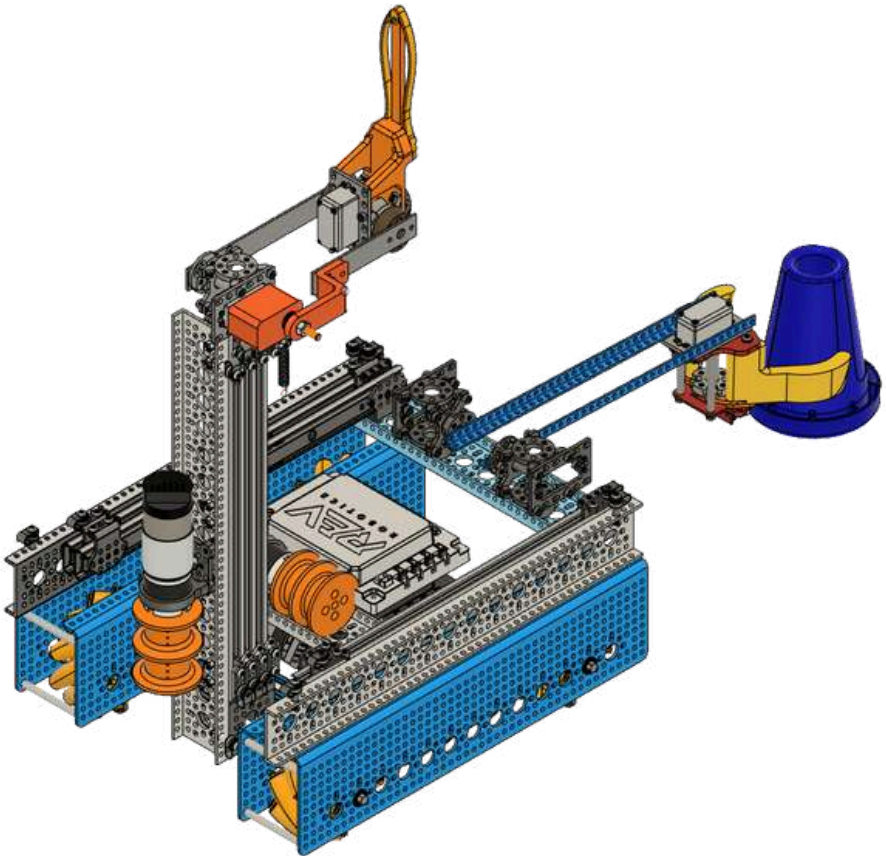
Grade 9, 2022-23

OVERVIEW

Designed for the FTC India Nationals for the PowerPlay Season 2023. Integrated holomonic drivetrain for omni-directional motion, autonomous controls using odometry and motion profiling for high accuracy during driver and pre-programmed periods.

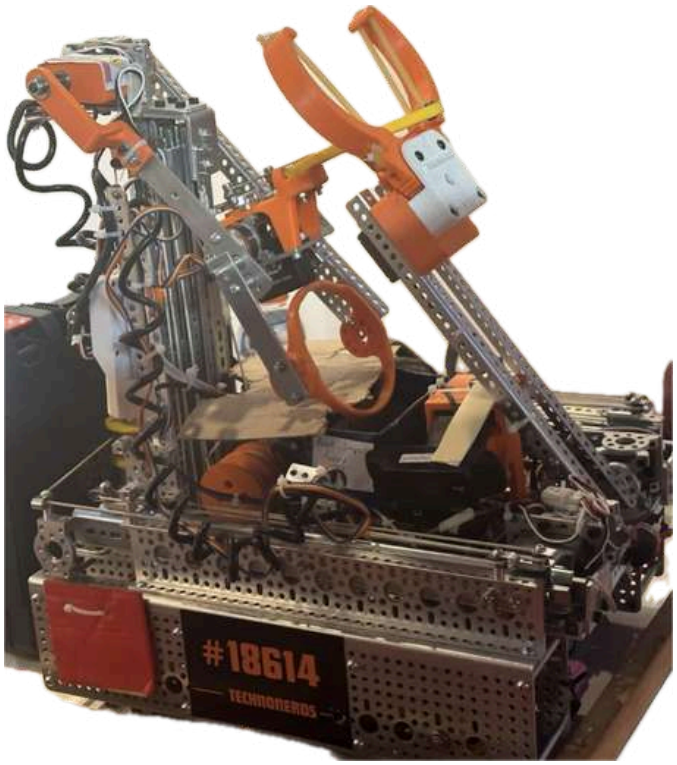
What sets Surge apart?

Unlike conventional FTC drivetrains, Surge optimized odometry calibration and feedforward gravity compensation, creating a both a mechanical and programme efficient system built for repeatable automated cone placement and scoring.



DriveTrain:

- Mecanum drivetrain: Enabled full planar translation using an H-shaped chassis that housed motors midway between side plates to lower the center of gravity and simplify encoder mounting.
- Dual-stage linear slides: Belt-coupled lift reduced backlash and maintained synchronous extension under asymmetric load.
- REV UltraPlanetary DC motor (3:1 + 5:1 gearboxes) delivered controlled torque at 48 RPM, measured by a REV potentiometer for precise lift height feedback.
- Failsafe handling, where slide velocity and current draw were monitored to detect jams or cone misalignment, triggering recovery subroutines through sensor feedback.



Control Systems:

- **Independent PID loops** - stablise turrer, slide position, drivetrain heading.
- **Feedforward compensation** balanced gravitational torque on the slides for uniform velocity during extension.
- **Three-encoder odometry** supplied translational and rotational feedback for localization, and data converted from ticks to

Motion Profiling and Trajectory Optimization

- Implemented a trapezoidal motion profile with acceleration, cruise, and deceleration phases to minimize jerk and mechanical oscillation.
- Paths generated through RoadRunner's Bezier-curve model allowed precise waypoint transitions with dynamic heading correction.

PowerPlay Gridlock – FTC APOC

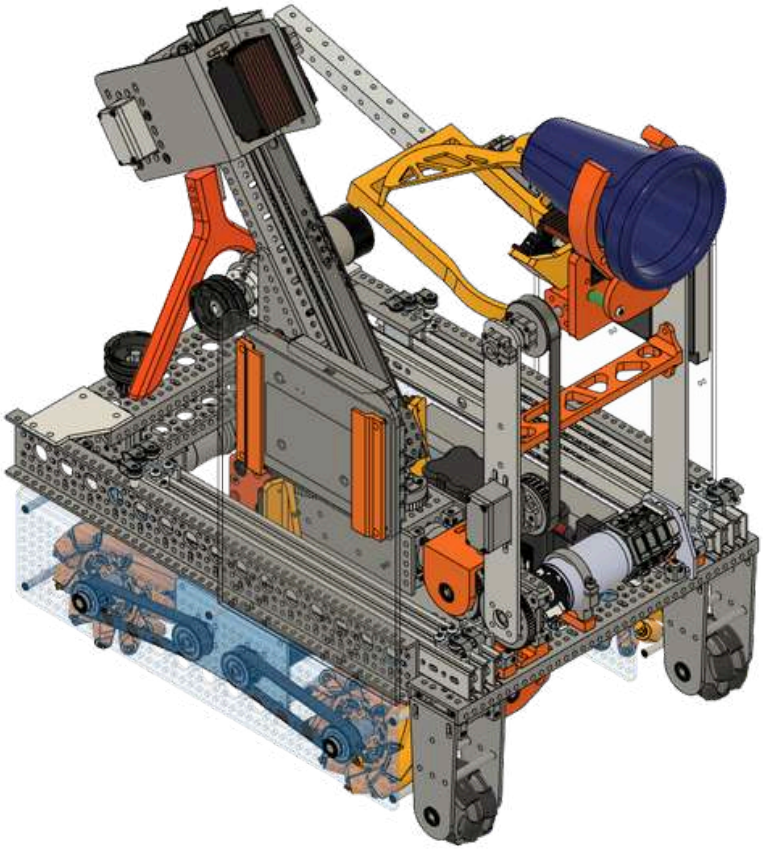
Grade 9, 2022-23

OVERVIEW

PowerPlay Gridlock expanded upon Surge by introducing perception-driven autonomy. A 360° turret coupled with a camera pipeline allowed automatic cone localization and alignment through hybrid vision-sensor feedback, amongst other innovations.

What sets Surge apart?

Gridlock's defining feature was its **vision-synchronized turret system**—a combination of OpenCV detection, feedforward + PID angular control, and IMU–encoder fusion. This helped acheive camera-guided alignment/scoring under shifting field conditions.



Turret Control:

- The 360° turret, driven by a high-torque stepper motor, was controlled via a feedforward + PID feedback hybrid loop for smooth and accurate alignment.
- Real-time angular velocity adjusted dynamically to minimize cone offset error.

Vision & Perception Systems:

A custom OpenCV pipeline powered Gridlock's visual autonomy:

- HSV segmentation with adaptive thresholds isolated cone markers under variable lighting.
- Centroid extraction converted pixel displacement into angular deviation relative to the robot's heading.
- Camera calibration matrices and focal-length corrections enabled distortion-free, real-world mapping.
- Depth inference was derived from cone size scaling, supporting precise approach and placement.

Motion Profiling and Trajectory Optimization

- Temporal frame filtering reduced noise from transient visual artifacts using a moving average of recent detections.
- Angular velocity clamping prevented overshoot in turret rotation by constraining output acceleration relative to feedforward predictions.
- Adaptive PID tuning recalibrated proportional gains depending on cone proximity, allowing smoother motion during close-range adjustments.
- Latency compensation accounted for frame delay between camera processing and turret actuation through time-based interpolation of predicted offsets.

CrescendoBot – FRC 2024

Grade 10, 2023-24

OVERVIEW

CrescendoBot was engineered to meet the challenge of rapid, dynamic movement and precision scoring across a full FRC field. The system features a true swerve-drive architecture for full translational and rotational freedom, an intake/shooter subsystem capable of variable trajectory launch.

Electrical Innovation:

Linear CAN topology with clearly defined node order to reduce reflection and frame-drop risk under load.

Power Distribution: Centralized REV PDH architecture with line protection based on measured stall currents from drivetrain and shooter.

Mechanical Architecture

Swerve Drivetrain

- 4 independent COTS swerve modules with absolute azimuth encoders (hard-zero on boot).
- Short-wide wheelbase to lower yaw inertia and keep bumper gap minimal for ground intake.

Ground Intake → Centering → Indexer

- Poly-belt indexer with one-way backdrive path; throat geometry prevents double-feed.

Dual-Wheel Hooded Shooter

- Independent wheel velocities to trim spin axis; steel-hub flywheels for inertia.

Stage Climber: Two-stage telescoping tubes with constant-force springs (rapid deploy).

Motion Profiling and Trajectory Optimization

- Flywheel speed maintained by voltage feedforward + proportional velocity control; feedback tuned using on-field velocity logging.
- Electrical draw balanced between shooter and drive to prevent brownout during full-field shots.
- Swerve Steering Synchronization
- Azimuth position calibrated through absolute encoders at boot, removing need for mechanical homing.
- Combined current sensing and encoder feedback ensured no desynchronization under transient loads.
- AprilTag alignment (PhotonVision/Limelight class): tag yaw + range select pre-characterized shooter table(RPM/hood set).

AquaDetect

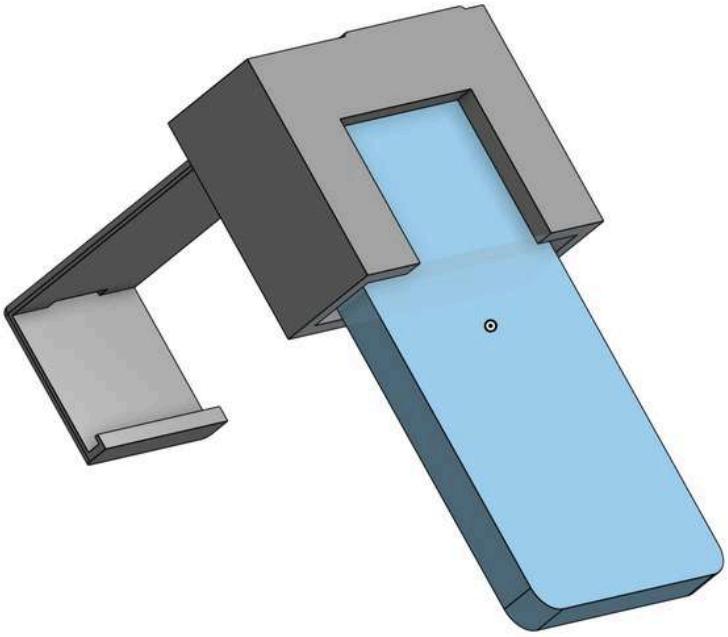
Grade 11-12, 2025

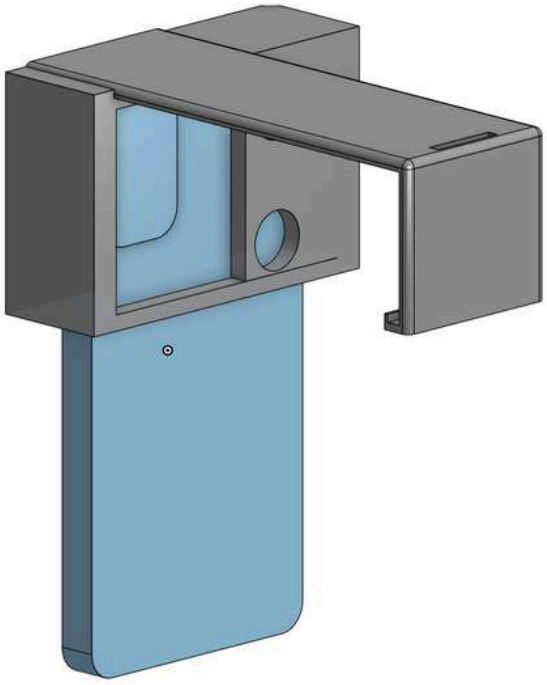
OVERVIEW

AquaDetect transforms simple reagent strips into digitally interpretable data, using a hybrid mobile-AI pipeline that performs image calibration, chemical color comparison, and context-specific recommendations — all through an API-secured multilingual app.

Problem Statement

- Access to clean drinking water remains unequal in rural and low-income regions.
- Conventional heavy-metal testing kits are costly, require lab instruments, and rely on visual interpretation, making them inaccessible to non-specialist users.





Key Features:

Colorimetric Analysis:

- Normalized RGB values of reagent zone mapped to reference dataset for heavy metals: Pb, As, Hg, Cd, and pH scale.
- Output compared against WHO safety limits, generating contamination classification and next-step guidance.

Sample Reagent Interface:

- Custom tray with hydrophobic coating prevents contamination between tests.
- Guides users to insert strip in a fixed optical path for reliable region-of-interest detection.

Accessibility:

- Results displayed with **bilingual text** (English + 2 local language).
- Text-to-speech: verbal report for users with limited literacy.
- Supports offline fallback, caching the last five tests and queued API calls for transmission once a network connection is available.

Software and API Workflow:

- Image data is sent via secure HTTPS POST request to a GPT-4o endpoint using a unique API key generated per user device.
- The server pipeline performs two sequential passes:
  - White-Balance Correction Pass – GPT-4o applies image-domain normalization using a calibrated gray reference.
  - Analytical Color Matching Pass – (ROI) corresponding to the reagent pad is vectorized into RGB values.
- The model uses ΔE2000 color difference metrics to compute the nearest match and determine safe/unsafe.