# Amith Polineni Project Portfolio

Hello! I'm Amith Polineni. This portfolio showcases several projects I have worked on, highlighting my experience in robotics, mechanical design, automation, and control systems. Each project demonstrates my ability to combine engineering creativity with technical expertise. You can explore these projects in more detail on my website: amithp.com.

### Robotic Stroller Research (Pages 1 & 2)

- Engineered a front-following robotic stroller by integrating stereo vision, LiDAR perception, and ROS-based control.
- Developed pose-tracking, dynamic replanning, SLAM, and PID motion smoothing for real-time navigation.
- Optimized mechanical systems with Onshape CAD and 3D printing, including a differential gearbox and reinforced steering.
- Applied Bayesian control logic for reliable autonomous operation at outdoor speeds.
- Designed modular electronics with a 24V network, buck converters, and safety interlocks.

Figure: Robotic Stroller

### MARS Robotics (Pages 3 & 4)

- Directed rover design, earning a 5th place finish and the Innovation Award.
- CAD-modeled a 300+ part rover in SolidWorks, applying Ansys FEA for strength vs. weight optimization.
- Presented trade studies during design reviews, refining based on engineering feedback.
- Fabricated custom components via waterjet cutting, MIG welding, machining, and 3D printing.
- Managed a $100,000 budget for robot construction, outreach, and a regolith testing arena.

Figure: MARS Bucket Drum

### Automatic Aquaponic Farm (Page 5)

- Designed an IoT-enabled aquaponics system using a Raspberry Pi with web-based monitoring.
- Automated irrigation and lighting for a 10-channel vertical farming system, optimizing efficiency.
- Operated autonomously for 10 weeks, growing and harvesting kale, lettuce, Swiss chard, and spinach.
- Applied rapid prototyping and low-cost solutions, reducing expenses by 80%.

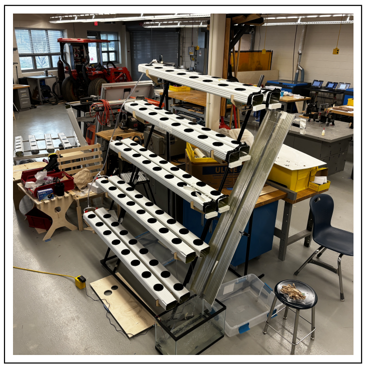

Figure: Aquaponic Farm

# 1 Robotic Stroller Research

## 1.1 Motivation

This project focuses on developing a **front-following robotic stroller** designed to operate in outdoor environments at jogging speed. Unlike traditional follow-bots, which trail behind a user, this stroller positions itself in front. The core innovation is using body pose estimation to infer human intent and generate predictive navigation trajectories.
Front-following provides critical benefits:

- The robot remains visible to the user, increasing trust and predictability.
- Elderly or visually impaired users can be guided more intuitively, as the stroller acts as a visible lead rather than an unseen follower.
- In crowded sidewalks, the stroller actively clears a path, rather than weaving through obstacles reactively.

This capability required fusing **stereo vision (ZED/ZED2i)**, **LiDAR sensing**, and **ROS-based control** to perform real-time SLAM, obstacle avoidance, and trajectory generation.


Figure 1: Overview of the stroller design with rear-wheel drive and front caster steering.

## 1.2 Mechanical Reinforcements

Initial testing revealed reliability issues in the drivetrain. The bevel gears of the differential gearbox slipped under sudden torque spikes, caused by sharp accelerations or uneven outdoor terrain. This not only produced noise but also risked long-term structural damage.
To address this, I CAD-modeled custom bracing mounts in Onshape and 3D-printed reinforcements that clamped around the gearbox housing. These reduced flex in the support structure and kept bevel gears in tight alignment. In practice, this eliminated gear skipping and allowed the stroller to sustain higher speeds with confidence.

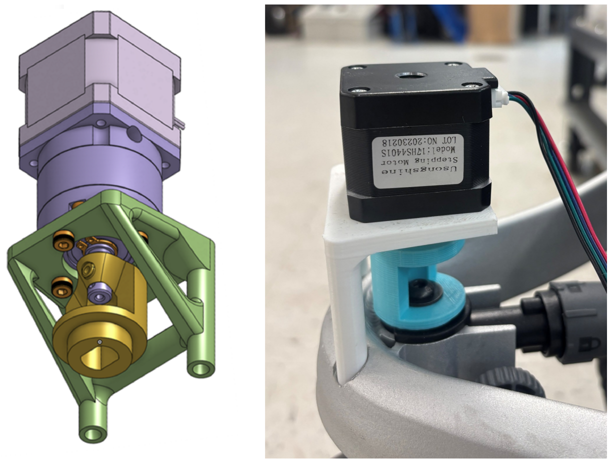

Figure 2: CAD of upgraded gearbox mount (left) and real-life support piece (right).

## 1.3 Steering and Sensing Upgrades

The front caster wheel posed a unique challenge: by default, caster wheels self-align forward, creating large resistive forces during sharp turns. To overcome this, I integrated a **high-torque motor with a planetary gearbox**, enabling the robot to hold stable steering angles even under caster-induced torque. Thicker mounting brackets were added to prevent deflection at high speeds.
The Ouster OS1 LiDAR was mounted using vibration-dampening 8020 slot inserts. These reduced jitter in point cloud data, ensuring consistent obstacle detection while the stroller navigated over sidewalks and curbs.

## 1.4 Human Following Control

The stroller's human-following behavior was implemented in ROS with multiple control layers:

- **Pose estimation**: using ZED stereo cameras for outdoor reliability, supplemented by Mediapipe on an Intel RealSense camera for shoulder landmark extraction.
- **Trajectory generation**: computing a forward offset vector from the user's shoulders, then replanning dynamically around obstacles with SLAM-informed maps.
- **Motion smoothing**: raw commands caused jerky motion, so low-pass filters and PID controllers were added to smooth both translational and angular velocities.
- **Joystick override**: a ROS teleop node was integrated for manual override, blending joystick and autonomous inputs for safety.

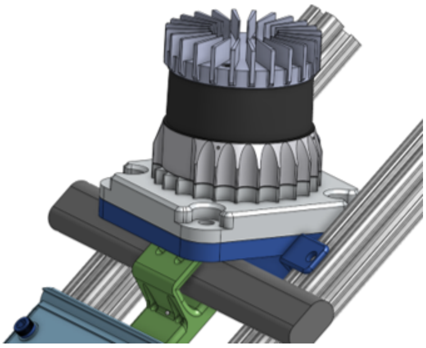

Figure 3: OS1 Lidar sensor mounted in CAD

### 1.5 Pose Estimation for Direction Prediction

Human orientation was estimated by tracking shoulder vectors. By computing a normal vector across the shoulders, the stroller could infer where the user intended to go, even before they stepped forward. This predictive behavior gave the robot more fluid, human-like motion, rather than reacting late to position changes.
Mediapipe experiments showed that even lightweight models could reliably track these landmarks outdoors. Combined with ZED's depth estimation, the stroller maintained a safe lead distance of 1.5–2 meters at running speed.

Figure 4: Pose estimation with orientation vector derived from shoulder alignment.

### 1.6 Planning and Safety Algorithms

A dynamic **around-person planner** was implemented, treating the human as a moving reference point. The stroller generated paths that stayed in front of the user while respecting:

- A circular "safety bubble" around the user,
- Velocity and acceleration limits for stability,
- Obstacle avoidance constraints from LiDAR.

This approach allowed the robot to maintain a leading position while smoothly navigating crowded or cluttered paths.

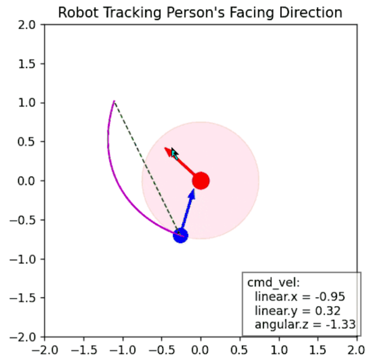


Figure 5: Simulation of robot maintaining position in front of a moving person.

### 1.7 Electronics and Power System

The stroller's electronics were designed for modularity and fault tolerance. Key features include:

- A 6S LiPo battery with **buck converters** supplying 24V, 14.8V, and 5V rails for motors, sensors, and logic.
- A distributed microcontroller system handling low-level sensor integration and motor actuation.
- A ROS laptop controller for high-level planning, communication, and visualization.
- **Emergency stop circuitry** with hardware interlocks to cut power instantly in case of fault.

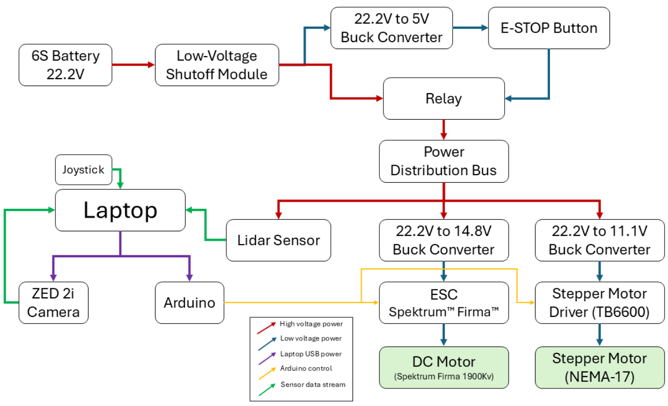


Figure 6: Electronics layout including buck converters, distributed controllers, and emergency stop system.

### 1.8 Outcomes and Future Work

The reinforced gearbox and steering upgrades allowed reliable high-speed outdoor operation. Pose-estimation-based leading made the stroller's behavior intuitive and trustworthy, while smoothing filters and PID tuning improved fluidity.

## 2 MARS Robotics Bucket Drum Development

Last year, our Mechatronics and Robotics Society (MARS) team consisted of 40 members tackling lunar excavation challenges. As a first-year member, I proposed a radical concept for a bucket drum excavation system. After multiple rounds of design reviews and trade studies, my concept was selected as the official robot design. This robot was ultimately deployed at NASA's competition, where it placed 5th out of 70 teams. As a result of this achievement, I was promoted to Vice President in my second year, leading mechanical design, systems integration, and performance optimization for the team.

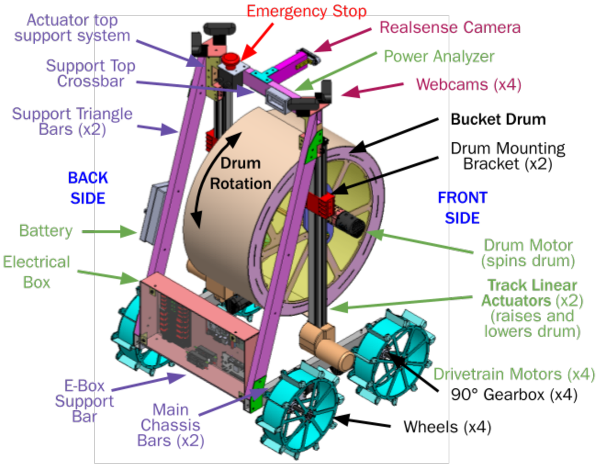


Figure 7: Labeled final configuration of robot

The bucket drum robot was inspired by advanced extraterrestrial excavation systems. It employs a rotating, baffled drum with strategically placed scoops to efficiently collect and transport regolith. Our goal was to maximize material retention, optimize torque distribution across the drum, and design a robust system capable of high reliability under dynamic operational conditions.

### 2.1 Preliminary Design Stage

During the initial design stage, the concept featured a dual drum configuration mounted on linear actuators, providing adjustable deployment height for excavation and transport. Segmented drum scoops were staggered to evenly distribute torque and reduce peak motor loads. The early focus was on proof-of-concept, with simplified mechanical modeling to validate functionality, actuation kinematics, and overall system feasibility. Real commercial actuators were used to ensure realistic motion limits and inform future integration and control strategies.

### 2.2 Intermediate Design Stage

By the intermediate design stage, the dual drum design was refined to include three regolith collection openings per drum to accelerate excavation cycles during short operational runs. Flexible thermoplastic living hinge flaps were explored to retain material, but ultimately removed to improve reliability and reduce mechanical complexity.
Structural optimization was a major focus: triangular support braces were implemented to transfer actuator loads directly to the chassis, reducing stress on individual components. The electronics enclosure was repositioned for accessibility and modular wiring, and critical joints were reinforced with gussets and precision hardware. Half-scale prototypes revealed that internal baffling was essential to retain material during drum rotation, prompting a redesign of drum geometry with two large openings to maximize storage per cycle.

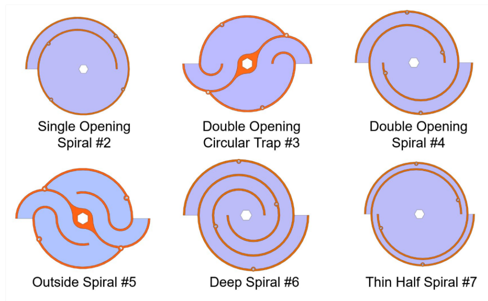


Figure 8: Variations on bucket drum geometry

#### 2.2.1 Drum Geometry and Rapid Prototyping

We conducted extensive rapid prototyping with 3D-printed subscale drums to test internal baffling and opening configurations. Designs included single-spiral, double-spiral, and circular trap geometries to analyze regolith flow dynamics, material retention, and torque distribution. Iterative testing allowed us to optimize baffle placement, opening size, and internal volume utilization while minimizing weight and simplifying manufacturing. These tests confirmed that practical fill capacity was limited to approximately half the drum volume, guiding the final drum geometry.

Figure 9: Subscale prototypes of potential bucket drum geometries with annotations after testing

## 2.3 Critical Design Stage

For the final design, the drum was scaled to the maximum allowable dimensions to optimize material capacity while remaining within competition constraints. A single-drum design enabled continuous sheet metal fabrication, improving structural integrity and manufacturability. Interlocking finger joints facilitated precise assembly and weldability. Track actuators were upgraded to larger, high-load-capacity units, reducing the number of components, simplifying control, and increasing dynamic load tolerance. Structural supports were refined, with redundant braces removed and remaining elements strategically reinforced to minimize weight without compromising rigidity.

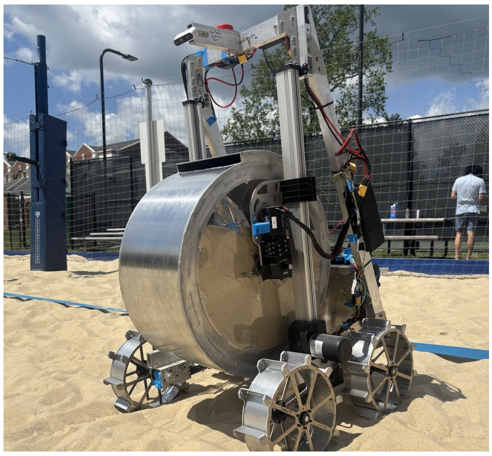

Figure 11: Bucket Drum robot at sand court testing

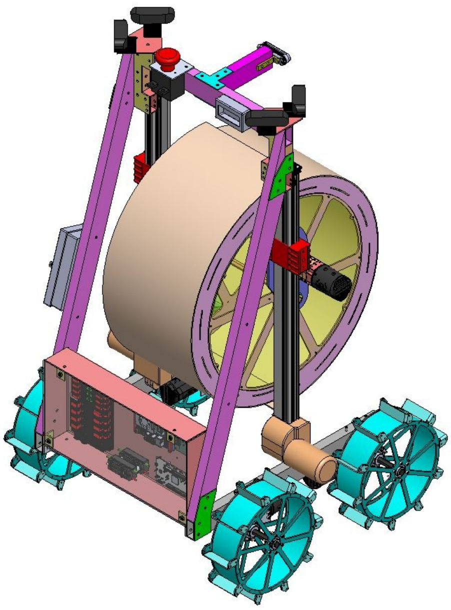

Figure 10: CDR (Feb) bucket drum robot CAD

## 2.4 Post-Manufacturing Optimization

Extensive field testing highlighted high torque demands, leading to replacement of the original belt-and-pulley system with a direct-drive motor coupled via a bevel gearbox. To meet peak torque requirements, a second motor was integrated, ensuring consistent rotational speed under load. Flexible polycarbonate side panels were reinforced with adhesive and metallic tape to prevent regolith spillage. Dust protection for gearboxes and exposed actuators was enhanced, and camera mounts were redesigned as modular, lightweight components to allow rapid adjustment and improve sensor coverage. Weight reduction and manufacturability were further addressed by pocketing non-load-bearing sections of structural supports, refining top-frame geometry, and consolidating components. This iterative approach to subsystem integration, torque management, and geometric optimization resulted in a high-performance, reliable bucket drum robot capable of excelling in a competitive lunar excavation environment.

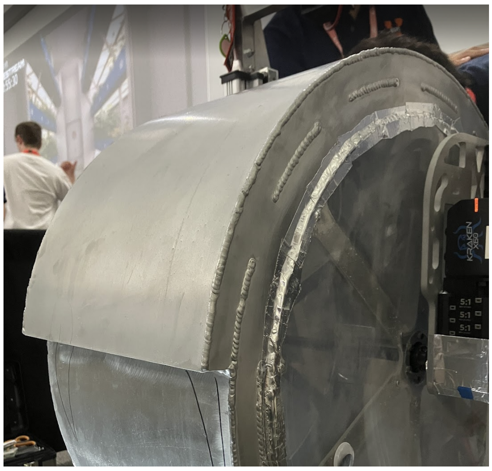

Figure 12: Drum with Aluminum Foil Tape seal

Figure 13: In the regolith area with the robot (I'm the one on the right)

# 3 Automatic Aquaponic Farm in a Greenhouse

This project involved the design and implementation of a custom Internet of Things (IoT) aquaponics system. The system was engineered to facilitate autonomous growth of leafy greens using a Nutrient Film Technique (NFT) framework, optimized for space efficiency and remote control. The primary objective was to leverage automation and cost-effective solutions to create a viable, sustainable, and remotely monitored agricultural system.

Figure 14: Me with the final prototype of the farm

## 3.1 System Architecture

The aquaponics system was designed as a 10-channel vertical farm, built to fit within a 10×3×6 ft space, though the final implementation used 8 channels to accommodate greenhouse space limitations. The skeleton was constructed from 2020 aluminum extrusions. Components like channel supports were created using a hybrid manufacturing approach: 3D printing for complex, custom brackets and laser cutting for flat components, which proved to be faster and more cost-effective.
The system utilized rectangular vinyl downpipes instead of the traditional round PVC pipes. These 3-inch by 4-inch downpipes were tilted at a 7 degree angle to ensure proper water flow and prevent pooling. Plants were grown in net cups filled with clay pebbles.
Water circulation was managed by a pump and a network of tubes. To address the issue of inconsistent flow and prevent lower channels from receiving all the water, we implemented barb valves at each level to equalize pressure across all channels. A main collection channel with bent chutes and funnels was designed to direct falling water back into the main tank, although minor leakage was still an issue.

### IoT and Automation

A Raspberry Pi served as the central control unit for the system's automation, integrated via a relay circuit. The Raspberry Pi was programmed to automate the water pump, operating on a 12-hour cycle (7 am to 7 pm) to provide nutrients to the plants. It also controlled automated grow lights to supplement natural light.
The system was designed to connect to a web server via a websocket for remote monitoring, enabling real-time data collection and display of environmental parameters such as temperature and humidity. The Raspberry Pi was programmed to send email notifications if the system lost connection with the server.
The project successfully demonstrated the feasibility of a remotely monitored and automated hydroponics system. The system was able to operate autonomously for 10 weeks, successfully growing kale and spinach.

Figure 15: Kale growing in the greenhouse

The frame and NFT channel design proved structurally sound and effective for plant growth. The autonomous pumping and lighting cycles were operational, fulfilling the core automation objective.
The project validated the potential of IoT-enabled vertical farming and provided valuable insight into the challenges of implementing such systems in a real-world environment.