Unmanned Ground Vehicle - SIEMENS

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Sponsored By SIEMENS

Executive Summary

Underlying Need

- Urban areas are in need of efficient and autonomous solutions for litter collection.
  - Reducing manual labor
  - Reducing constant human involvement in litter collection
  - Promoting cleanliness in public areas

Project Objective

- The Unmanned Ground Vehicle (UGV) must independently and autonomously locate, retrieve, and return an empty bottle in a parking lot using a mechanical arm and clamp mechanism.
- The system must detect, retrieve, and return to the starting position in under 60 seconds for each task
- The system must not contain any adhesives in the clamp.
- The system must have a manual control override.

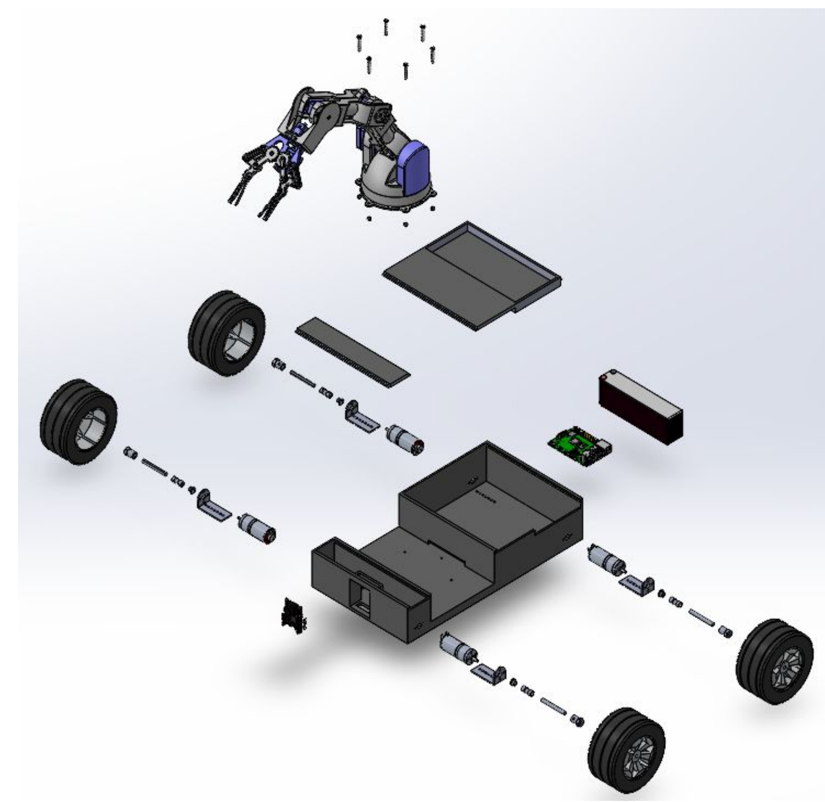
Design Solution

- The system has a 3D printed chassis housing all electronic components.
- A mechanical arm with a clamp mechanism for grasping.
- Camera-based image detection for bottle identification.
- Manual override system for user and backup control

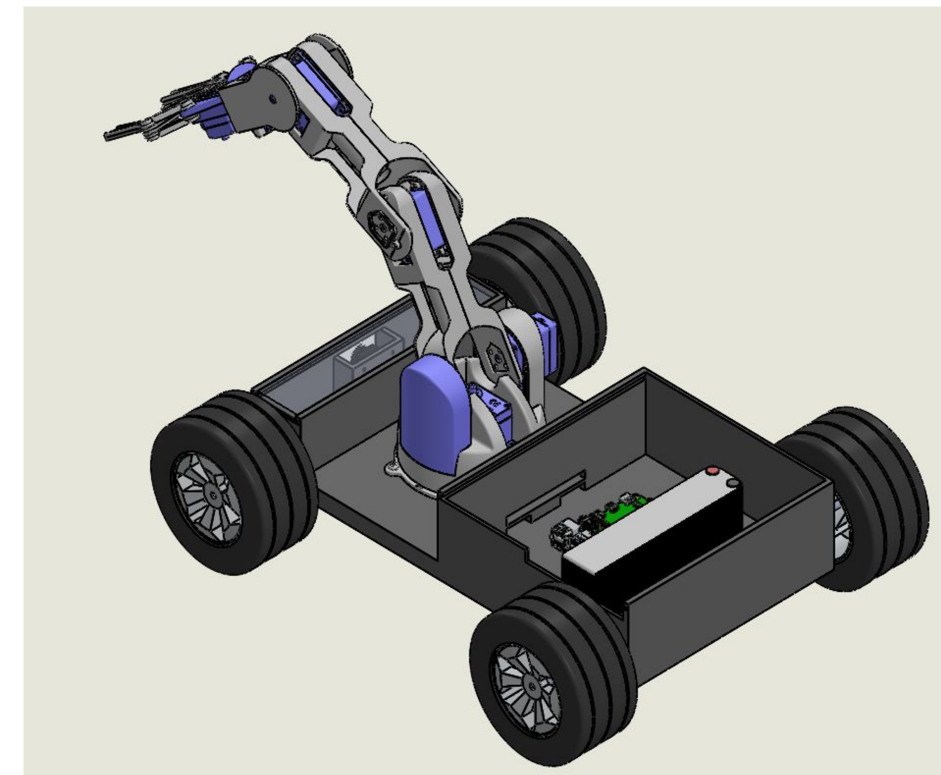
Key Features

- **Autonomous Object Detection -** Utilizes a camera-based vision system (OpenMV RT1062) to locate and retrieve bottle from up to 7 meters away.
- **Precision Gripping Mechanism -** A mechanical arm with 6DOF, 30in max reach and a 3.5in wide clamp securely maneuvers to and grasps the bottle without the use of adhesives.
- **Automated Navigation -** The UGV autonomously navigates, adjusts, and returns to the starting position all without manual intervention and in under 3 minutes total.
- **Manual Override System -** A backup control mode allows manipulation via a phone app for human intervention if needed for safety or operational adjustments.
- **Compartmentalized Design** - Structured chassis with specialized compartments to ensure ease of assembly, production, and sub-system separation.

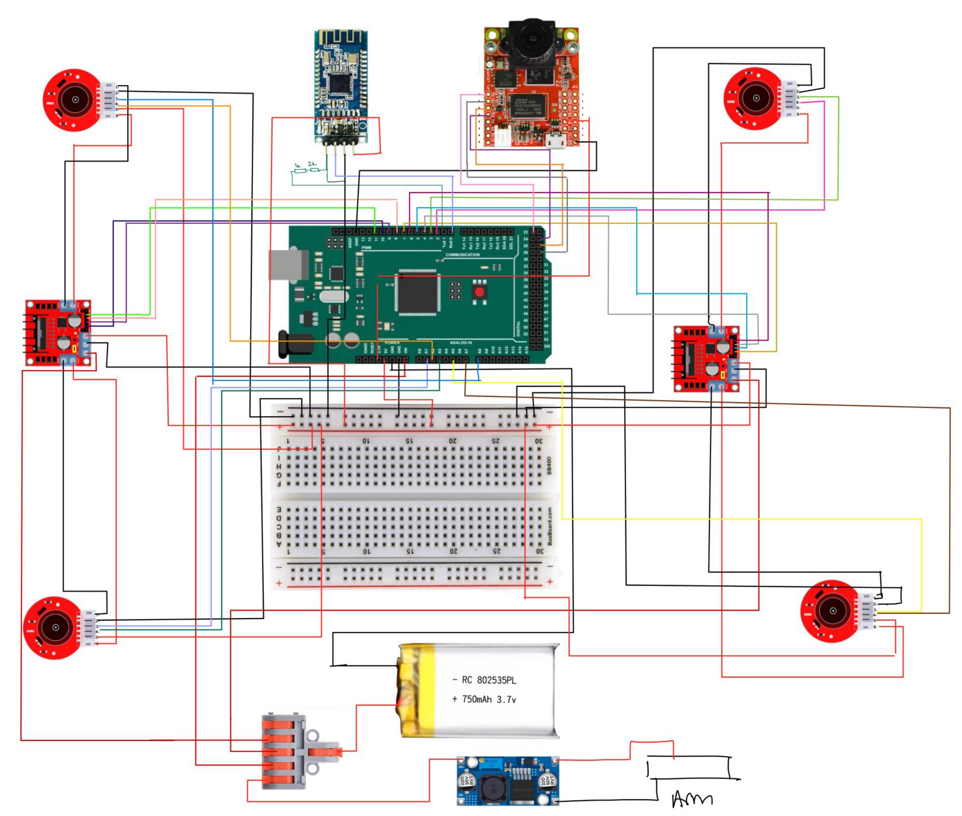
Final Design



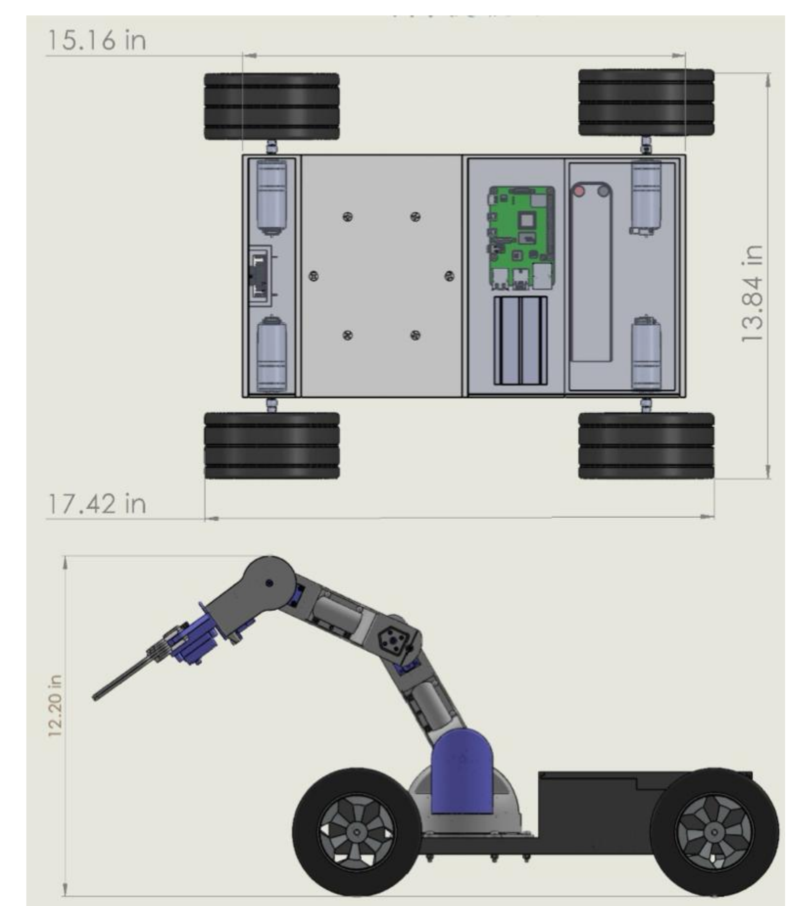
Detailed System Breakdown



Fully Assembled System

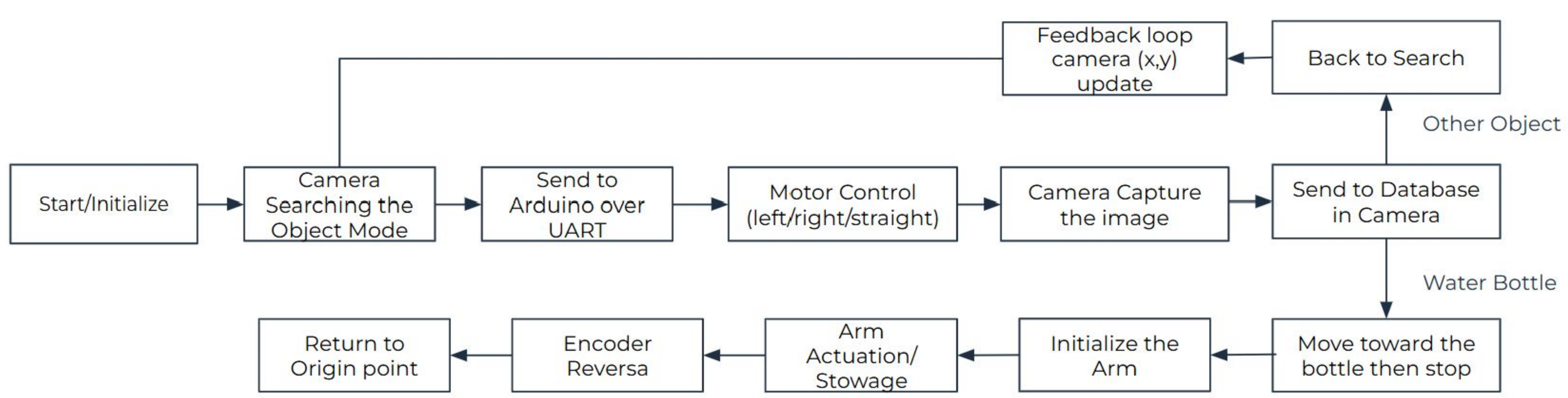


System Circuit Diagram



System Dimensions
15in x 8in x 2in

Software Logic FlowChart



Engineering Analysis

Torque:

$$T = \frac{F_r \cdot r}{\eta}$$

$$F_r = \frac{F_g \cdot \mu_r}{n}$$

$$F_r = \frac{3\,Kg \cdot 9.81\,\frac{m}{s} \cdot 0.015}{4} = 0.1475\,N$$

$$T = \frac{0.1475\,N \cdot 0.08\,m}{0.85} = 0.0138\,Nm \cdot 1.5\,(FOS) = 0.0207\,Nm$$

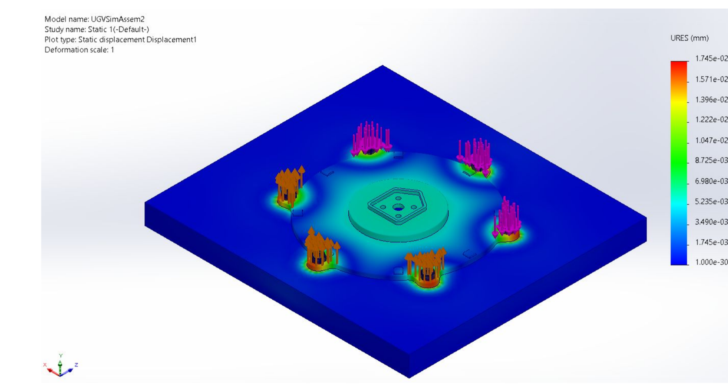
$$= 0.211\,Kg \cdot cm \text{ per motor}$$

RPM:

$$RPM = \frac{V}{\pi \cdot r} = \frac{0.7\,\frac{m}{s}}{\pi \cdot 0.08\,m}$$

$$= 167\,RPM$$

Torque Calculations



Stress Simulation

Stress Simulation - Arm Base

- Conducted Finite Element Analysis (FEA) is to evaluate the stress distribution on the arm base ensuring its structural integrity
- Identified potential deformation and stress points

Calculation - Motor Torque

- Calculated required torque and RPM necessary for UGV.
- Ensured motors are capable of handling the load of the UGV and the mechanical arm.

Acknowledgements

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Future Improvements

Increasing Detection Range

- The OpenMV camera's low resolution limits the UGV's current detection range to around 10 meters
- Adding additional sensors, like LIDAR or stereo cameras, to aid the camera's ability to detect the bottle from further ranges could help the UGV reach up to 25 meters of range.

Enhanced Gripper Design

- The current clamp mechanism has two prongs and elimited width capability.
- A more adaptive gripper that can pick up different bottle of different sizes and shapes would expand the UGV's uses.

Steering Subsystem Overhaul

- The 25mm gear motors have a minimum rpm, resulting in a minimum speed that is too fast and not precise enough
- The UGV employs skid steering to turn direction, which results in different turning speeds depending on surface friction