Deployable Robot For Mobile Inspections

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Introduction

- The **Automated Inspection Laboratory** develops aerial and land-based robotic systems for use in inspection and maintenance tasks [Figure 1].
- Conventional inspection techniques that rely on human labor are characterized by inefficiencies, high cost, and hazards to human inspectors. [1]


Figure 1. Custom-Built Lab UAV

The goal of this project is to construct an autonomous rover, deployable from an Unmanned Aerial Vehicle (UAV), that is capable of semi-autonomously navigating its environment and can support a payload deployment mechanism.

Key System Requirements as per the NASA systems engineering design model [2]:

- The robot shall be capable of supporting a payload deployment and retrieval mechanism.
- The robot shall be capable of detecting obstacles which lie directly in its forward-facing path of travel.
- The robot shall, upon detection of an obstacle, update its path of travel according to a pre-programmed routine.

Design

Scope/Concept of Operations

- Robot was chosen to be a rover-type driven autonomously by Arduino code (C++) using Arduino Uno hardware.
- An ultrasonic sensor was chosen as the obstacle detection instrument; the subsequent course adjustment was programmed in Arduino code.
- The rover was designed to be lightweight and of small form factor, which motivated the use of 3D printing for structural components.
- A schematic that includes all the components are illustrated in Figure 2.

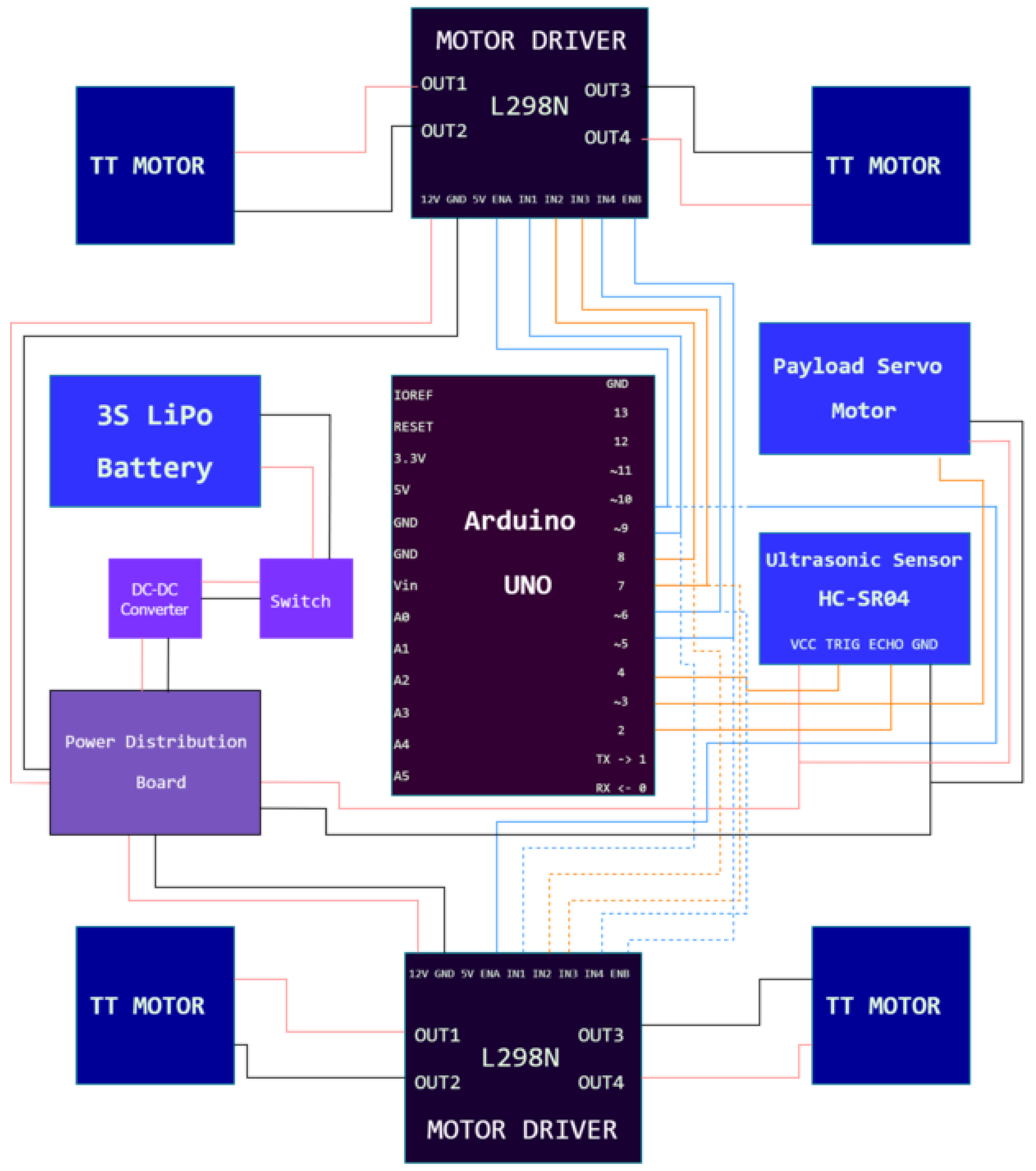

Figure 2. Block diagram of deployable rover system

Prototyping and Assembly

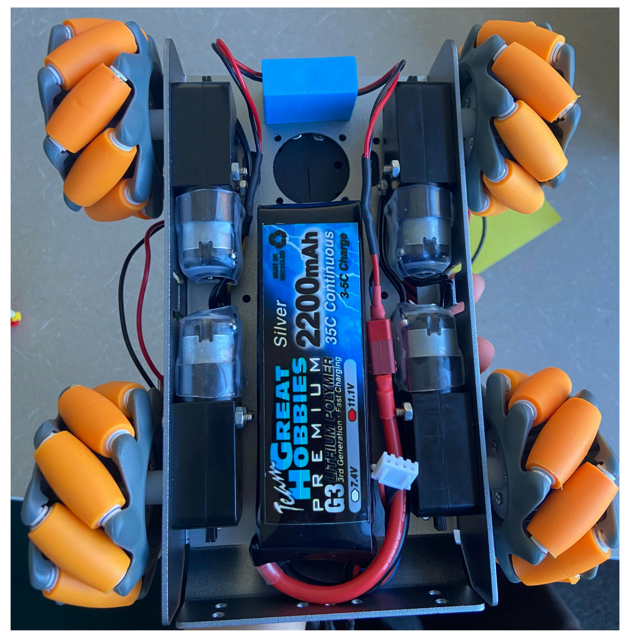
Figure 3. Battery and switch set up in the bottom of the rover

- The chassis was assembled, including mounting of the omnidirectional wheels to the motors.
- The 3S (12 V) LiPo battery was attached to the undercarriage using Velcro.
- A switch was implemented between the battery and the 5V DC-DC converter. [Figure 3].

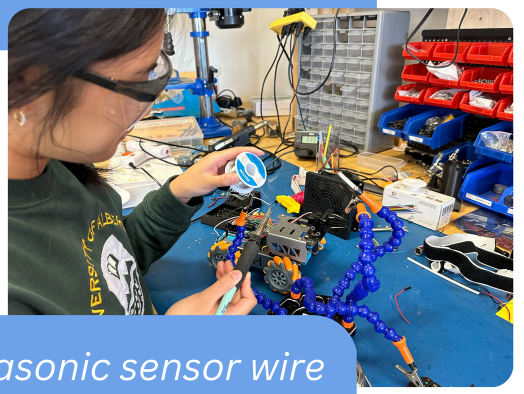
Figure 4: Soldering ultrasonic sensor wire

- All major power connections use solder joints.
- Power from the 5V DC-DC converter is distributed to all components using a power distribution board [Figure 5].
- The Arduino communicates digitally with the motor drivers.

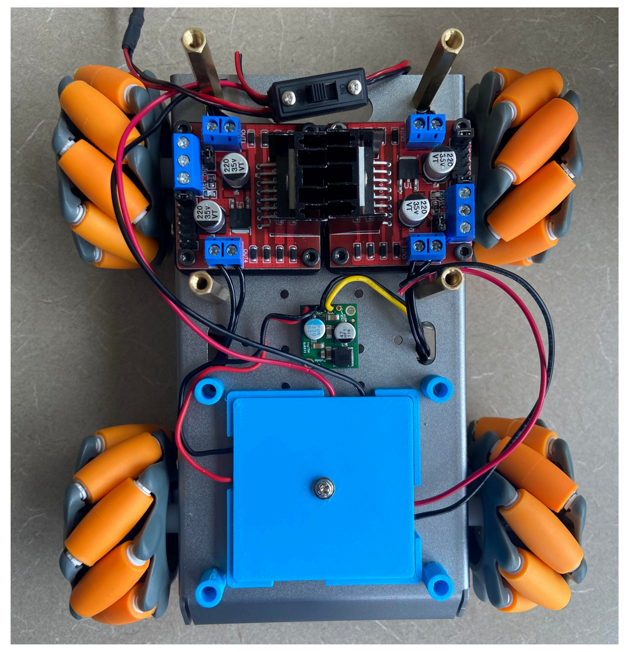
Figure 5. Aerial view of base layer of the rover

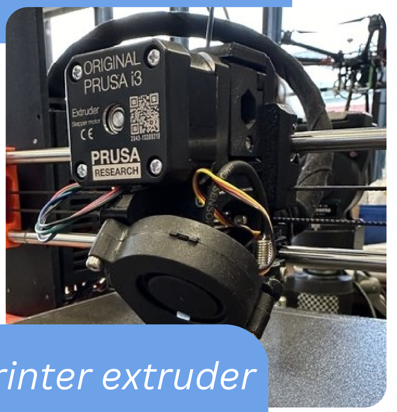
Figure 6: Prusa 3D printer extruder

- Printed components were modelled in SOLIDWORKS® and made out of PLA (polylactic acid) filament using a Prusa MK3S+ printer.
- The ultrasonic sensor was evaluated to have an accuracy within +/- 0.5 cm [Figure 7].

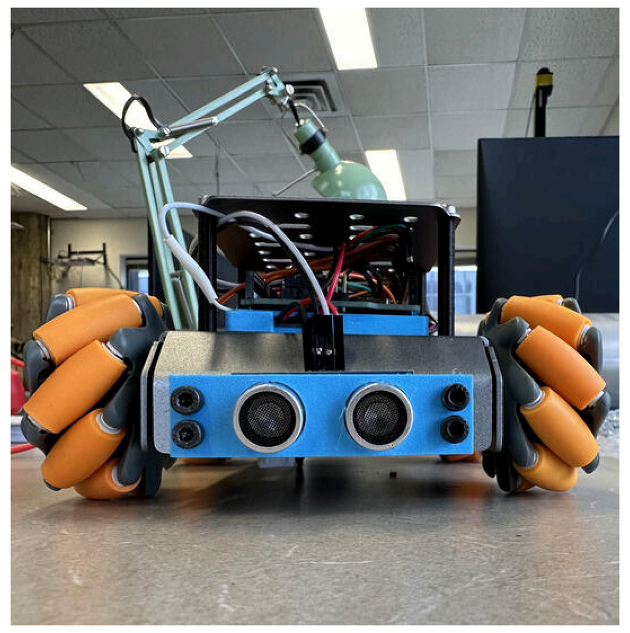
Figure 7. Front view of the rover featuring the ultrasonic sensor and its custom mount

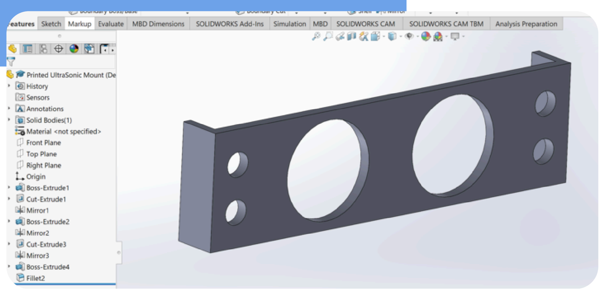
Figure 8: Render of custom sensor mount

- Coding and debugging was done in the Arduino Integrated Development Environment (IDE).
- While the whole program was around 230 lines of code, the main loop is essentially only 4 lines [Figure 9].

```
void loop() {
// start of main code

  if (check_obstacle() > TOO_CLOSE) {
    drive_forward();
  }
  else{
    drive_right_translation();
    // before restarting loop and allowing forward motion again, clear the obstacle
    // with an extra 2 seconds of right translation
    if (check_obstacle() > TOO_CLOSE){
      delay(1000);
    }
  }

}
```

Fig 9.Code snippet of main control loop

Results

Sensor Reading (cm)	9.86	19.45	29.79	39.97	49.52	59.57
Actual Distance (cm)	10	20	30	40	50	60

Table 1: Ultrasonic sensor readings against actual distance of an obstacle as measured using a measuring tape

- Sensor accuracy test proved to be within a small margin of error
- After conducting field tests, the rover is able to:
  - Traverse various terrains omnidirectionally [Figure 10].
  - Detect an obstacle, traverse until the obstacle is cleared, and continue on its path [Figure 11].
  - Grapple, carry, and release a payload at will.
- Limitations during the field tests included:
  - Detection of negligible objects led to confusion.
  - Light weight presented issues for some terrains.
  - Untuned motors caused slight non-linear trajectory.


Figure 10. Rover in woodchips


Figure 11. Rover detecting obstacle

Conclusions and Future Work

- A robotic rover, deployable from a UAV, was built that can navigate semi-autonomously and deploy a payload. The prototype met all 5 system requirements.
- An elevated and servo-actuated ultrasonic sensor could increase sensing capability. Additionally, a sensor located at the back would allow for the rover to know when to drop and retrieve the load.
- Tuning of the motor speeds to address the tendency for the rover to stray from linear path is necessary.
- Exploration of traction on different materials would allow for future adaptations.

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References

[1] S. Agnisarman, S. Lopes, K. C. Madathil, K. Piratla, and A. Gramopadhye, "A survey of automation-enabled human-in-the-loop systems for infrastructure visual inspection," Automation in Construction, vol. 97, pp. 52–76, Jan. 2019, doi: 10.1016/j.autcon.2018.10.019. Available: https://www.sciencedirect.com/science/article/pii/S0926580518303248
[2] "Systems Engineering handbook - NASA," NASA. Available: https://www.nasa.gov/reference/systems-engineering-handbook/