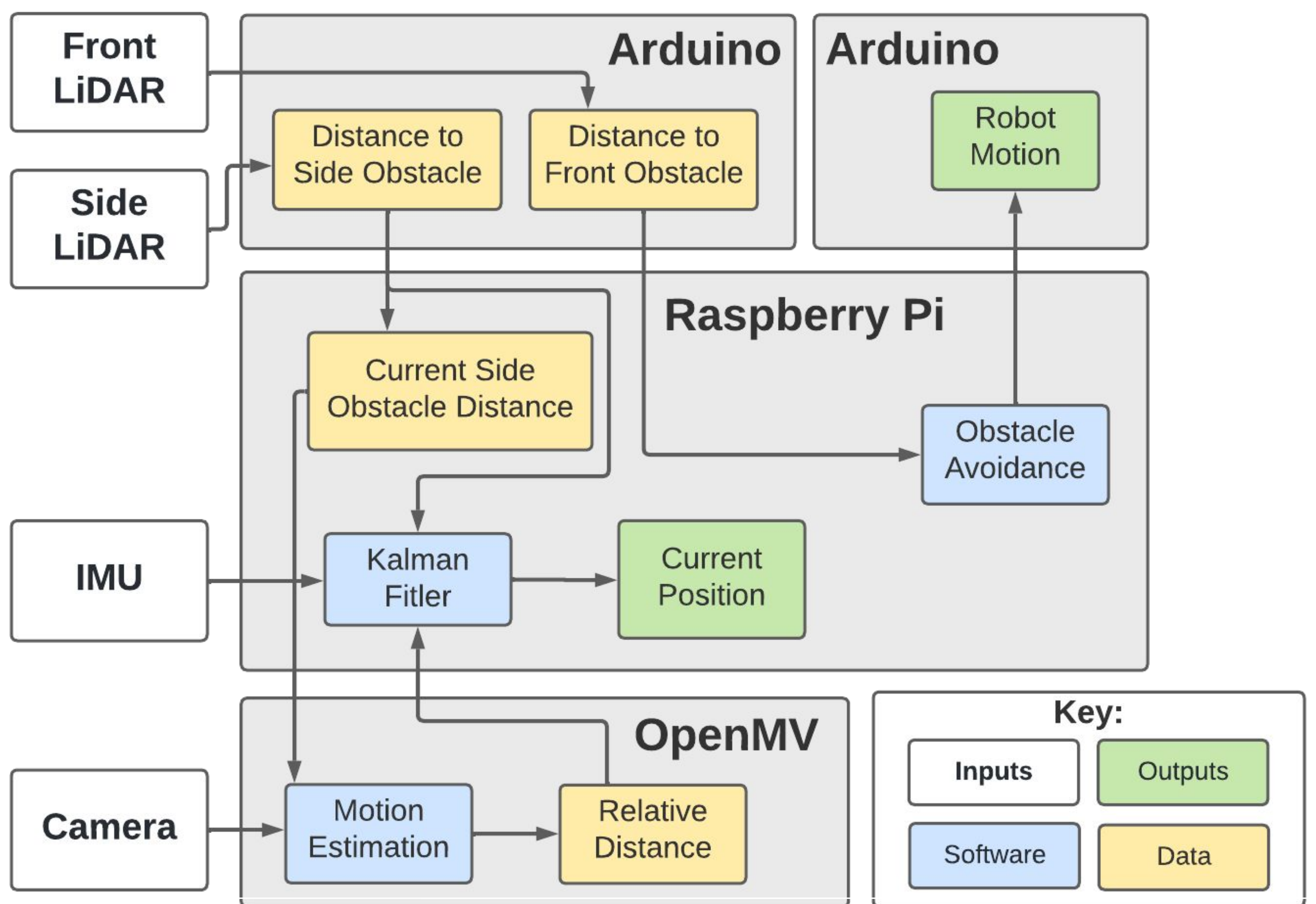
Hazard Detection & Positioning System for Asteroid Navigation

Team Outer Space: Anoushka Alavilli, Jack Batchelor, Jack Freeman, James Lai, Keenan Rhea, Rebecca Skantar

The Problem

While most navigation systems rely on access to GPS or prior mapping of the environment, these are not typically available to systems that explore remote environments such as asteroids. In these cases, navigation and localization must be performed using other methods.

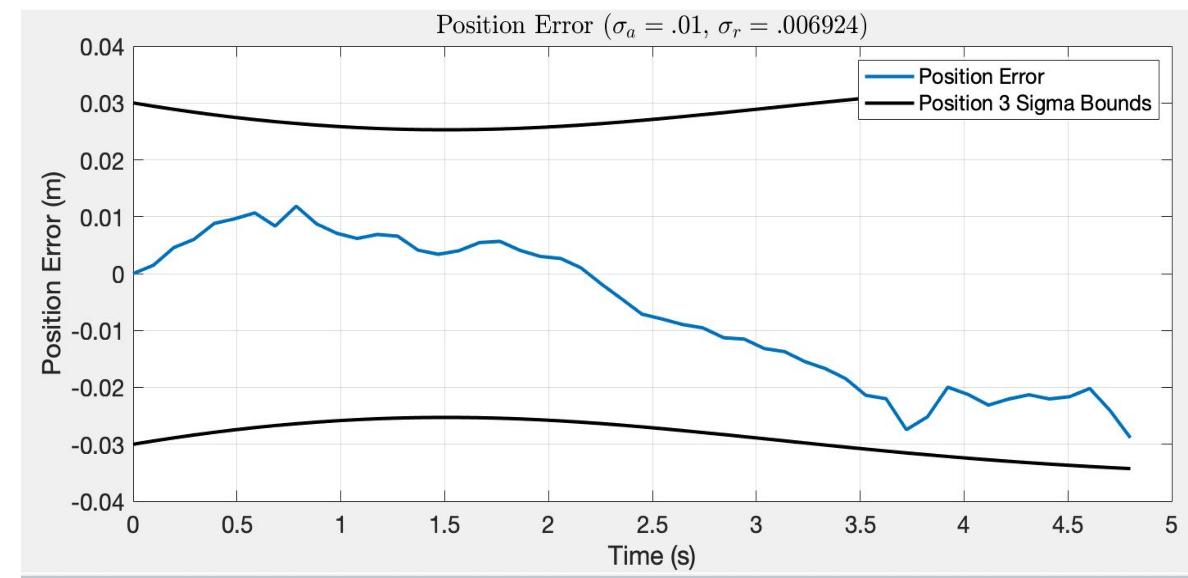


This system diagram details the hardware and software used to accomplish our goals of (1) knowing the current position of the robot and (2) navigating forward safely.

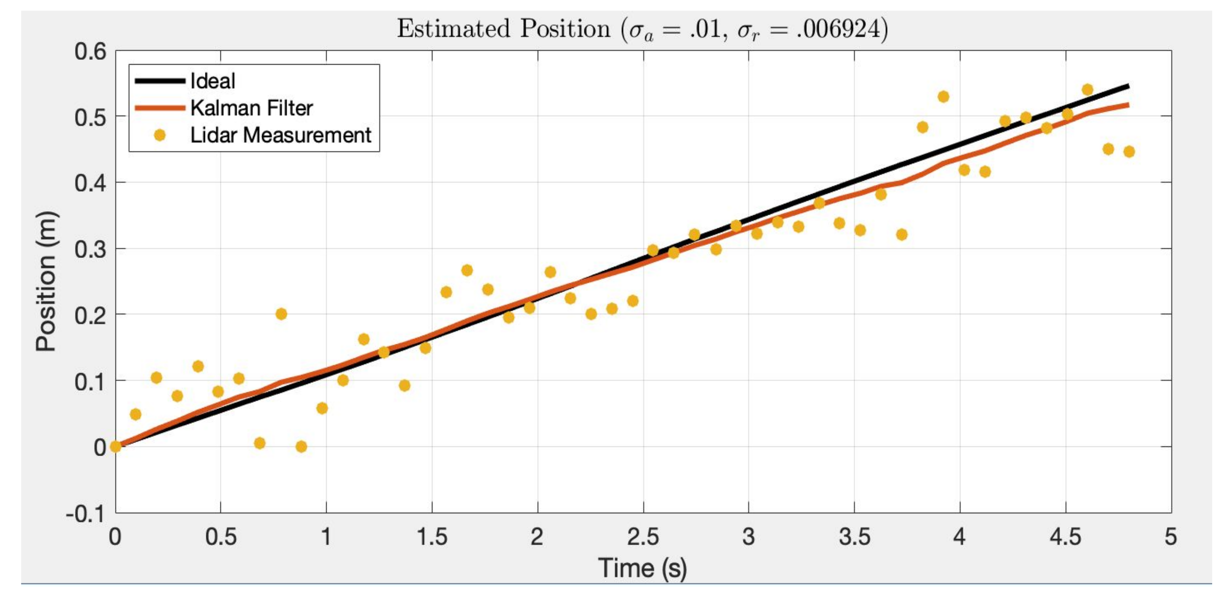
Challenges

- Reliable detection of different types of obstacles (rocks vs craters) is complicated with only one LiDAR sensor available.
- Relative position localization can lead to significant build up of errors in the final result.
- Re-scoping of the project was necessary to ensure a completed product by the deadline.

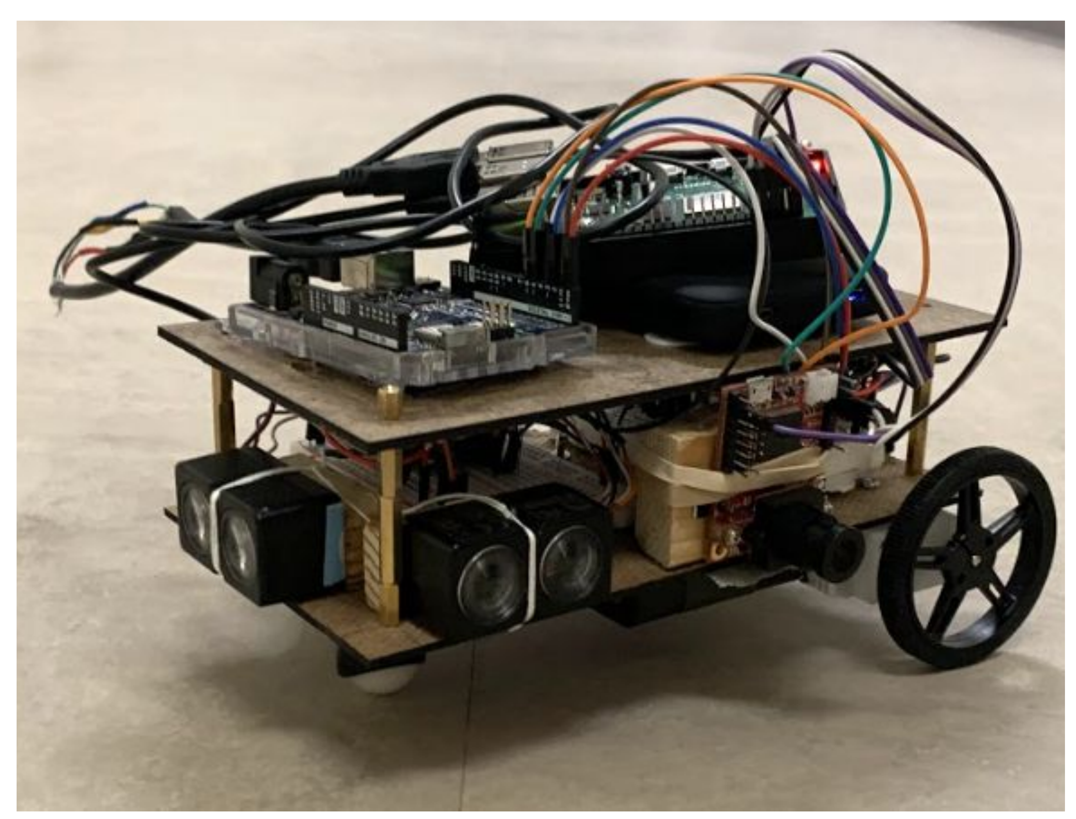
These plots show the behavior of the Kalman filter over time during a one-dimensional motion trial (where the robot moved in a straight line in the x-direction).

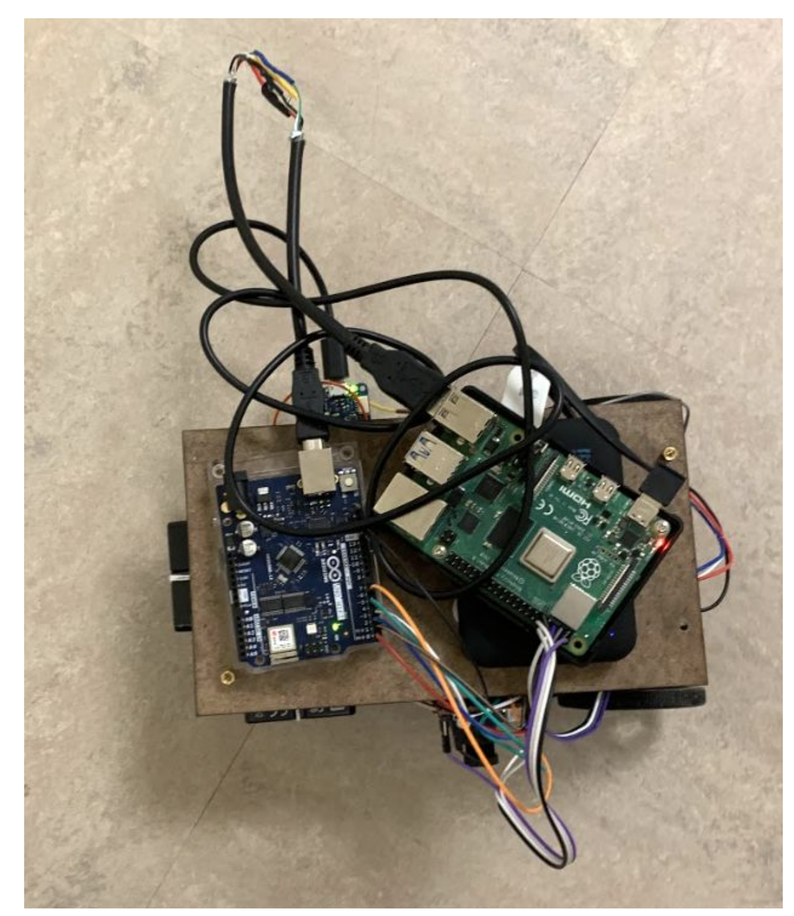


The top plot shows the position error over time (blue), while the bottom plot shows the Kalman filter position estimation (orange) along with the expected robot position (black) and raw LiDAR measurements (yellow).



The Kalman filter estimation is significantly smoother and more accurate than the raw sensor data.





Results

We mounted all components on a fully operational robot that can safely avoid obstacles and localize itself relative to its starting position using LiDAR, camera, and IMU data. In one-dimensional trials, our system had a maximum error of 5.7% over a total distance of 0.53 meters.

Our Solution

- LiDAR: detects the distance to obstacles in front of and next to the robot.
- Camera: uses optical flow techniques to determine relative distance traveled.
- IMU: detects the acceleration and orientation of the robot for use in the Kalman filter.
- Obstacle avoidance: uses environment data to determine how to move the robot forward safely and avoid potential hazards.
- Kalman filter: integrates all sensor data to generate a position estimate relative to the starting position. By continuously comparing its predictions with real measurements, it ensures that our system produces the best current position estimate with the minimum possible variance.

Future Improvements

- Mount additional sensors to collect more detailed environment information.
- Upgrade equipment (wheels, motors) so robot motion is more predictable.
- Add a path planning algorithm that finds the shortest path to the destination.

Acknowledgements

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