PRECISION VEHICLE TRACKING IN URBAN AREAS

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Introduction/GPS

- Modern vehicle positioning systems rely fully on GPS to track location.
- GPS accuracy is limited in urban, building dense areas, as satellites are harder to reach.
- GPS in cities can often be inaccurate up to 20m, depending on location.
- GPS is also unable to work in underground roadways, and vehicle position is not updated.
- Increasing positioning accuracy for vehicles can be very useful for many different situations (delivery services, rideshare, self-driving vehicle applications).

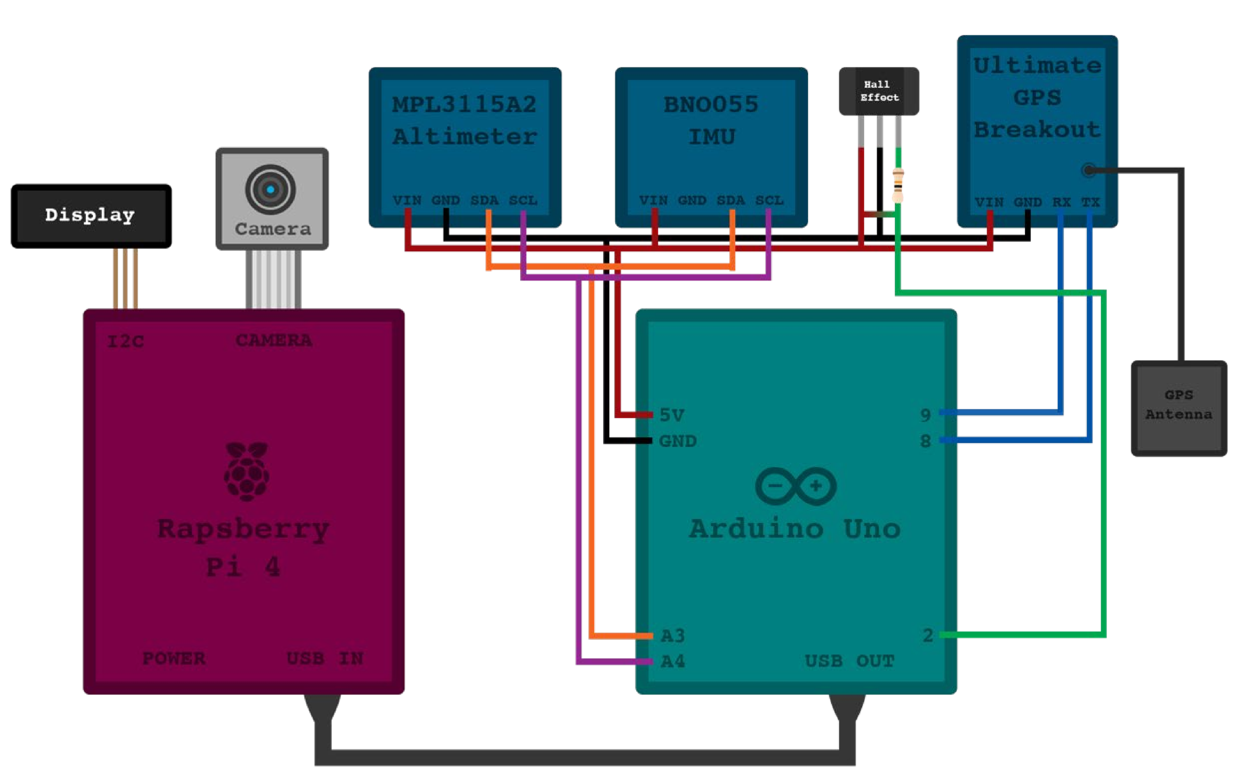
detection.

Approach and Sensor System

We are using several different sensors to create a secondary positioning system using an Arduino that will work synchronously with a GPS module to improve accuracy.

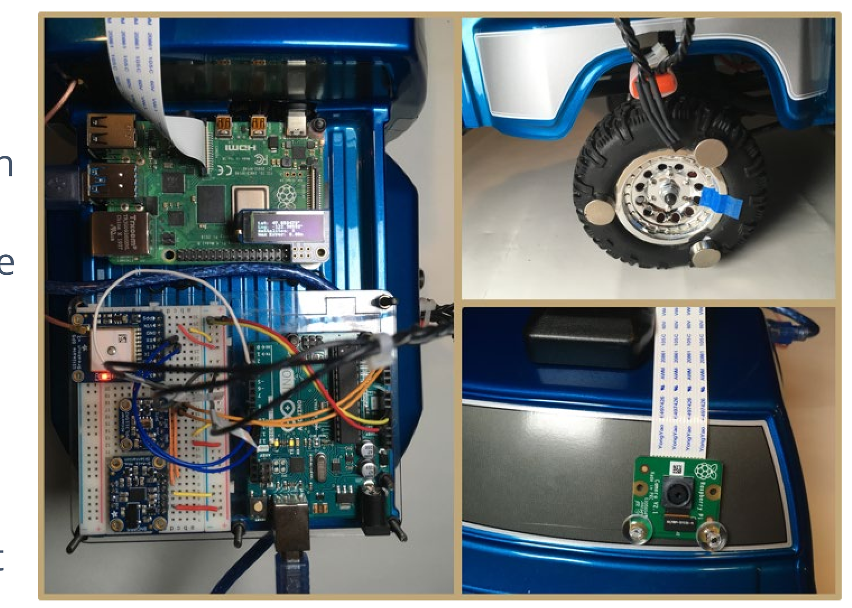
- For our secondary positioning system, we are using an IMU, altimeter, and hall effect sensor.
  - The hall effect sensor mounts above the wheel and counts wheel rotations.
  - The IMU is used to keep track of the three-axis orientation of the vehicle.
  - The altimeter is used as a secondary source for keeping track of height.
- The data received from the Arduino is sent to the Raspberry Pi via serial communications, where position is computed in real time.
  - The display on the Raspberry Pi prints the latitude, longitude, number of satellites, and max calculated error.
  - The camera connected to the Raspberry Pi works to detect markers (bus stop signs), in order to get accurate positional and orientation fixes.

Below is a schematic depicting our final sensor system setup.



Setup

- In order to conduct our testing and experiments, we used an RC truck to setup our sensors.
- The Arduino and Raspberry Pi are mounted in the bed of the RC truck.
- The GPS antenna is mounted to the top of the truck.
- The hall effect sensor is mounted above the wheel using a 3D printed mount, with magnets on the wheels.
- The camera is mounted to the windshield where it is angled upwards to properly detect bus stop signs.

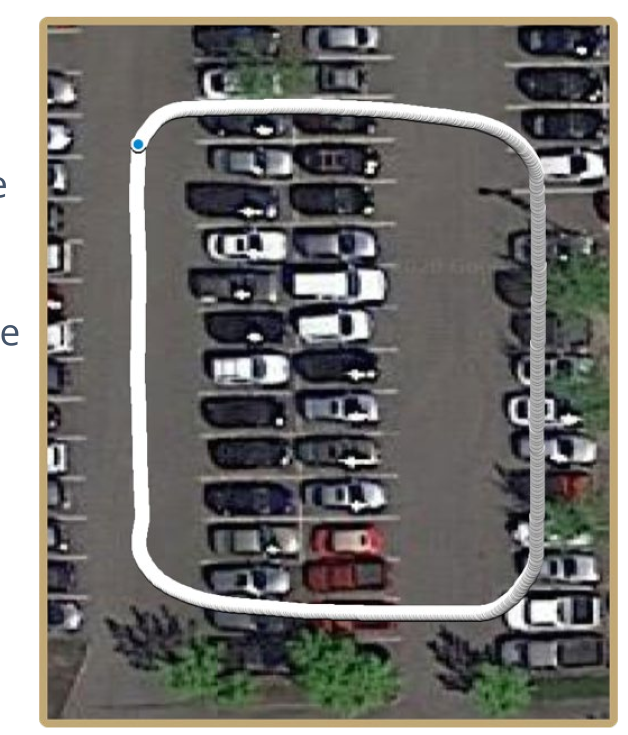


Secondary Positioning System

To create our secondary positioning system we relied on the circumference of the wheel, the heading of the car, and surrounding air pressure to determine distance traveled.

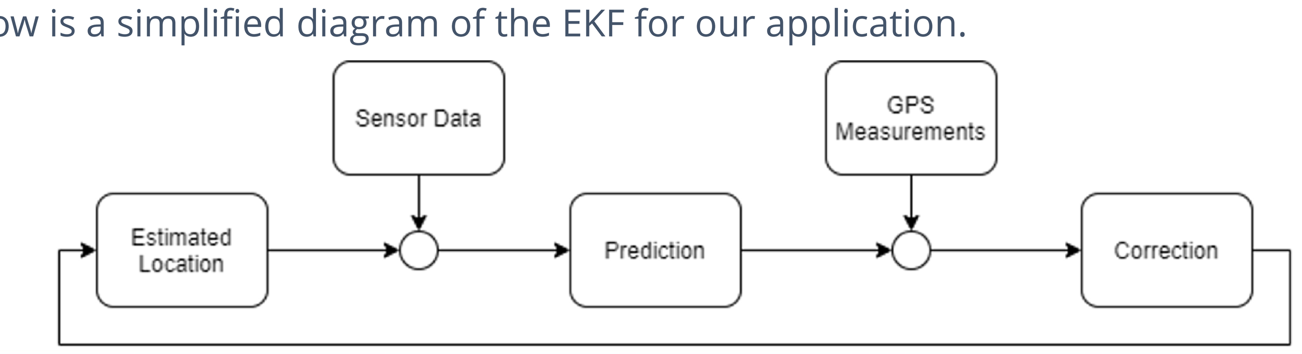
1. Every time the wheel spins 1/3 of a full rotation, the hall effect sensor detects a change in position.
2. The change in height is determined by compiling data from both the pitch of the IMU, and the change in height of the altimeter.
3. The change in height is subtracted from the total distance traveled.
4. The horizontal position is incremented by determining the heading of the car and using the calculated horizontal distance traveled.

The picture on the right shows the accuracy of the secondary system, as the car completes a loop on the parking lot.



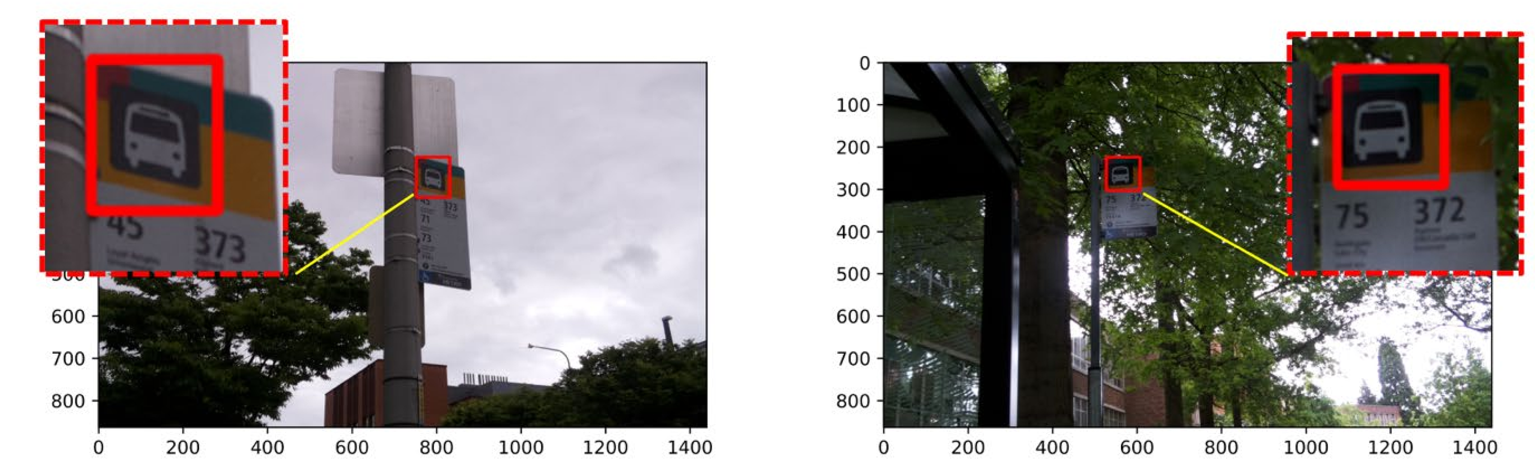
Real Time Positioning with Extended Kalman Filter

- An Extended Kalman Filter (EKF) is used to integrate the sensor data and the GPS measurements.
- The prediction step of the EKF uses the coordinates calculated from the secondary positioning system.
- The GPS data is used in the correction step of EKF.
- The EKF is the nonlinear version of the Kalman Filter and is commonly used in many professional navigation systems.
- Below is a simplified diagram of the EKF for our application.



Drift Correction with Visual Markers

- Visual markers can help reduce drift in the positioning system.
- OpenStreetMap has over 2,000 entries of location data for the bus stop signs, so we decided to use the signs as visual markers.
- A Support Vector Machine (SVM) model is trained to detect the bus stop sign.
- The image dataset is collected using Raspberry Camera Module V2.
- The results from the SVM are shown below.



Marker Detection: Performance vs. Time

- The size of the training photos will affect both the performance and the speed of the Support Vector Machine (SVM) as shown in the table.
- The SVM from large-sized images tend to provide more accurate results but require more computing time.
- The SVM from Small-sized images is much faster but less accurate.
- The SVM from images of size 720x1152 has the best overall performance.

Image Size	True Positive Rate	Avg. Decision Time (s)
1152 x 1920	0.92	15.10
1008 x 1680	0.82	10.11
864 x 1440	0.82	6.82
720 x 1152	0.82	4.29
576 x 960	0.54	2.54

Conclusions and Future Work

Conclusions:

- This system is relatively expensive compared to a simple GPS sensor, however, is much better than only GPS in building dense, urban areas.
- The amount of available markers generally determine how well the system performs, luckily there are many bus stop signs in urban areas, especially in downtown city settings.

Future work includes:

- Optimize the Support Vector Machine to improve speed while retaining performance.
- Implement Bluetooth communications via iOS and Android + integrate Google Maps.
- Decrease cost through cheaper single control unit rather than Arduino + Raspberry Pi.

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