Pavement assisted vehicle lane keeping with passive material sensing

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Objective

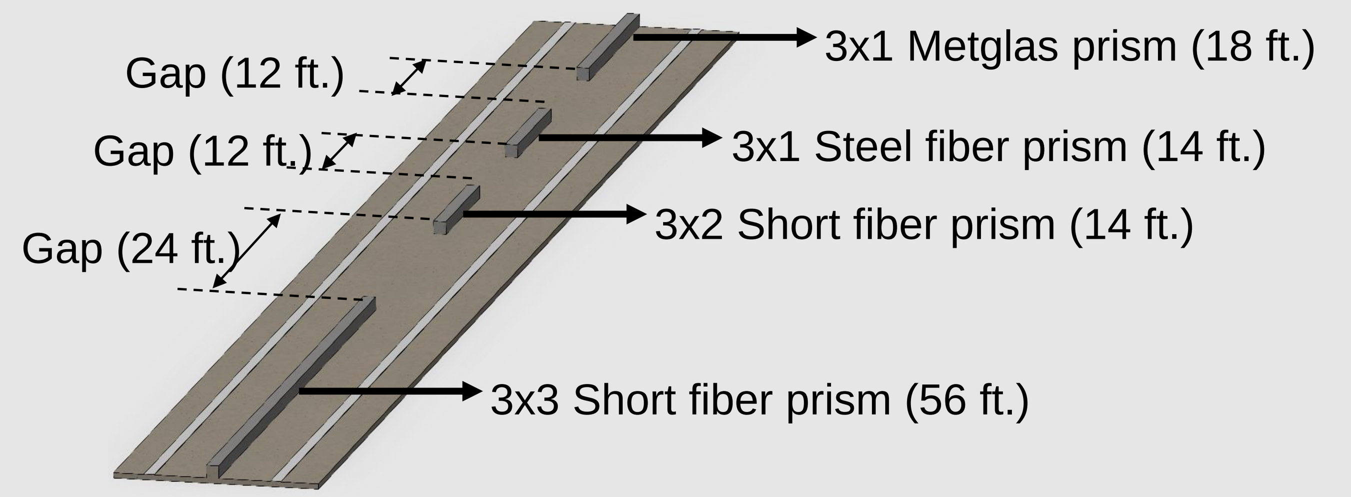
To demonstrate lane keeping of vehicles in normal and snow-covered lane by modifying electromagnetic (EM) signature of the pavement using EM modified and sensing it with custom made magnetometer array.

Motivations

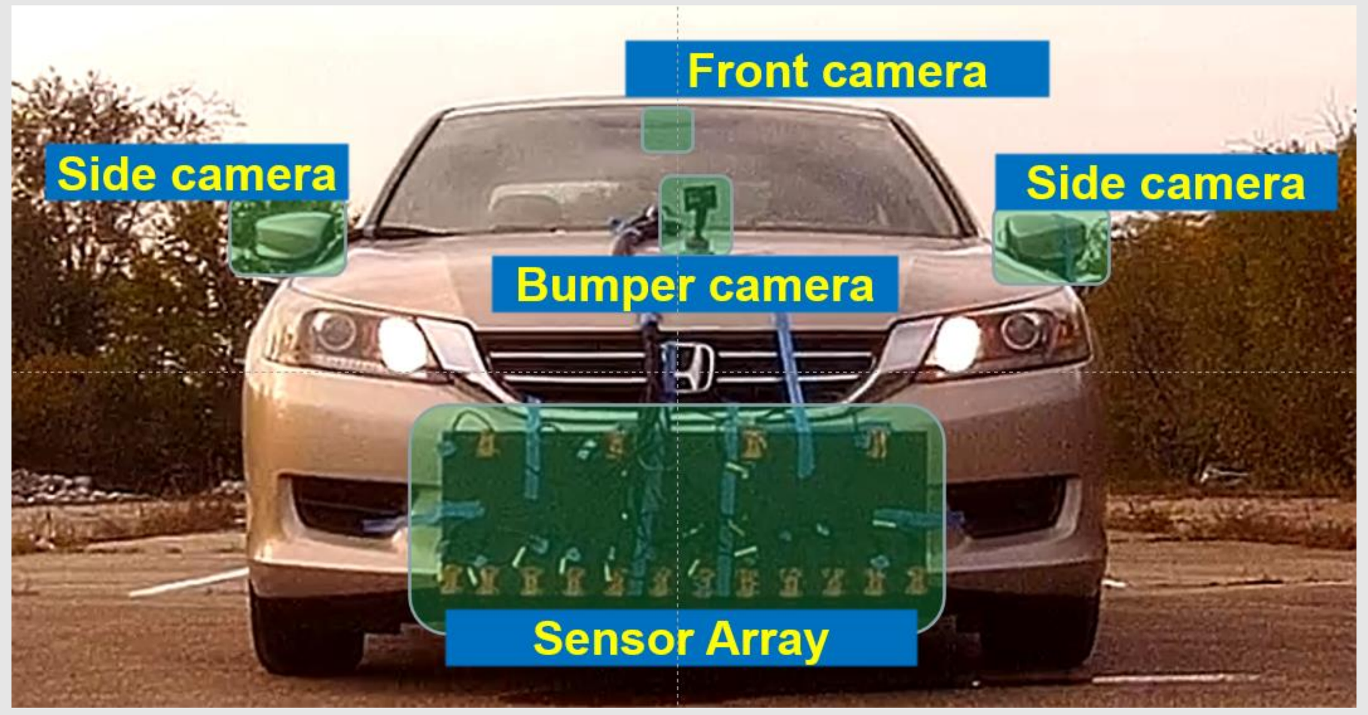
- **Adverse weather lane keeping.**
  - Autonomous vehicles and vehicles with advanced driver assistance systems (ADAS) have safety critical limitations during adverse weather conditions.
  - Sensors like GPS and camera have lower positional reliability when lane markings are obstructed by snow, water, ice, or due to shadow and varying lighting conditions.
- **Currently AVs do not interact with road.**
  - Roadway can be modified with passive materials to create a sensing system to supplement the current system and improve lateral positioning during adverse conditions.

Methodology

- **Passive Sensing: Create unique and repeatable (EM) signature on the lane.**
  - Used concrete blocks with cross section area of 3 inch x 3 inch containing metals like steel fiber and metglas.
  - Placed the concrete blocks on the surface of pavement at the center of 12 ft. wide and 150 ft. lane.



- **Sensors mounted on the vehicle**
  - The test vehicle was equipped with a custom-made magnetometer sensor array on the bumper, a front viewing camera on the rearview mirror, one camera on each side mirror, and a bumper camera on the hood.



- **Vehicle position estimation**
  - Center of vehicle at each time step was determined from two side cameras, front camera, and magnetometer sensor array.
  - Cameras used computer vision techniques of perspective transformation followed by canny edge detection algorithm and Hough line transformation to determine the lane markings. The distance be
  - The magnetometer array detected the EM signal, the peak of which corresponds to the center of the lane.

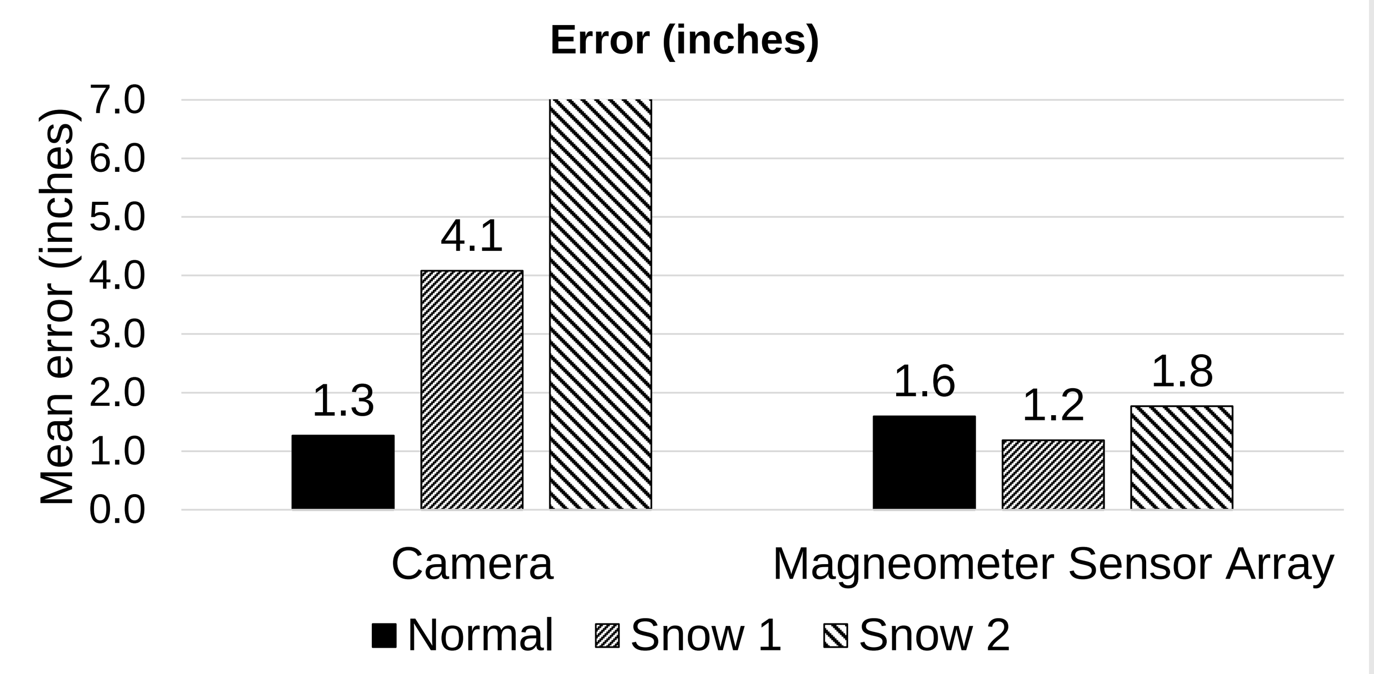
Test Results

- **Normal**

- **Snow <1 inch**

- **Snow > 2 inch**

- **Test conditions**
  - Test was performed in normal (dry surface with visible lanes) conditions and when the lane was covered by less than 1 inch of snow (partially obstructing lane marking) and more than 2 inches of snow (lane marking not visible).
- **Error estimation**
  - Vehicle's true position (ie. ground truth) was estimated by taking the average of position determined by two side cameras.
  - At any time, the error of front camera or magnetometer sensor was computed as absolute difference between the reading of corresponding sensor and ground truth.



- Average error of camera and magnetometer were comparable in normal condition.
- Partial lane marking obstruction by less than 1 in. of snow increased camera error significantly while more than 2 in. of snow made lane markings not visible to camera.
- Error of magnetometer sensor array on snow covered lane was statistically similar to the error of normal condition.

Findings

- EM signature can be used for vehicle localization in both normal and adverse conditions.
- The error of camera increases significantly with partial lane obstruction by snow and fails to perceive lane marking with > 2 in. snow.
- Magnetometer array can determine vehicle position with statistically similar error irrespective of surface weather conditions.

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