A Reflected-Laser Black Ice Detection System for Autonomous Vehicles

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Background Info

• Temperatures warmer than the surface cause moisture on the ground to freeze promptly and attach itself to the pavement.
• Changes in temperature usually occur after winter storms, which cause snow to melt and therefore create ice on roadways.(Erie Insurance, 2014)
•When snow or light rain falls on still-frozen concrete it turns into ice upon contact. This rapid and sudden freezing gives Black ice it's thin layer.(Erie Insurance, 2014)
• The most common locations for the emergence of black ice are overpasses because of their ability to freeze quickly(http://www.maine.gov).
• In the 2008-2009 winter there were 477 deaths due to the icy road conditions (http://icyroadsafety.com).
• 154,580 crashes on icy pavement occur annually (http://americanpreppersnetwork.com).
• 70% of winter weather deaths in the USA are caused by icy road accidents (http://icyroadsafety.com).
• More than 400 accidents were reported in the beginning of 2015 January's icy road conditions in New Jersey (hctv, 2015).
•Ice's reflectivity is greater than that of water or a road surface. However snow is more reflective than ice(https://nsidc.org/cryosphere/seaice/processes/albedo.html).

Engineering Goals

The goal of this Research project is to build a system that can detect ice on roadways from a moving vehicle. The detection system will consist of an Vernier Infrared Thermometer, a Vernier Light Sensor and a laser. It is expect that ice will cause a detectable increase, compared to regular asphalt, in light intensity if light is reflected onto it. This difference should be able to be picked up by the Vernier Light Sensor which will be able to send the information to a DCU. The diffused laser will be shined on a roadway, reflected back to a light sensor sending information to a programmed DCU. When ice is detected, the DCU will process the input and output a signal slowing the test vehicle.

Methods

Experimental Phase Ⅰ : Bench Tests

- **Part A) Indoors in Dark Hallway:** A SparkFun Vernier Arduino Interface Shield was attached to an Arduino Mega, a digital control unit. A Vernier Light Sensor was then connected to the Vernier Arduino Interface Shield through the analog 1 input. The Vernier Light Sensor and a diffracted green 5mW class III laser (with a 532 nm±10 wavelength) were mounted on two ring stands approximately one meter away from each other and were angled towards each other at approximately a 90º angle. The Arduino was then programed to measure the light intensity and display it. A sample of asphalt was then half treated with ice and placed between the laser and the phototransistor. Data was recorded as the laser reflected off the untreated asphalt into the phototransistor and then as the laser reflected of the ice covered asphalt into the phototransistor
- **Part B) Outdoors in sunlight:** The same test in Part A was again commenced outdoors in sunlight. The phototransistor and laser were set up in the exact same manner and data was again recorded with the half ice covered sample of asphalt; the only difference being that the main source of light was the sun.

Experimental Phase II: Field Tests

- **Part A)** The Arduino system, discussed in the first phase, was then mounted to a car. The Arduino was programmed to read the data from the phototransistor and display it. A 30x30cm sheet of titanium was slid under the detection system and the Arduino recorded the changes in light intensity.
- **Part B)** The Arduino system, as discussed in part A, was mounted to a car. The Arduino was programmed to read the data from the phototransistor and display it. A 30x30cm sheet of titanium was placed on the asphalt as a stand-in for ice. The car then drove over the sheet of titanium at a speed of 5mph and the Arduino recorded the changes in light intensity.
- **Part C)** The Arduino system, as discussed in part A and B, was mounted to a car. The Arduino was programmed to read the data from the phototransistor and display it. The road was wetted to ensure the phototransistor was capable of differentiating between a wet and ice-covered road. A thin sheet of ice was placed on the wet road to represent a real-life demonstration. The car then drove over the sheet of ice at a speed of 5mph and the Arduino recorded the changes in light intensity.

Experimental Phase III: Lego Mindstorm

- A Vernier Light Sensor was connected to a Lego Mindstorm EV3 with Vernier's NXT Sensor Adapter. Various surfaces, such as asphalt, a sheet of ice, and a sheet of metal were set up. A Lego Mindstorm then drove over these surfaces to determine how the surfaces affected the phototransistor readings. Then the average increase in light intensity due to the presence of each substance compared to the floor tiles was calculated which allowed the Mindstorm to be programmed to autonomously slow down when it drove over the more reflective surface.

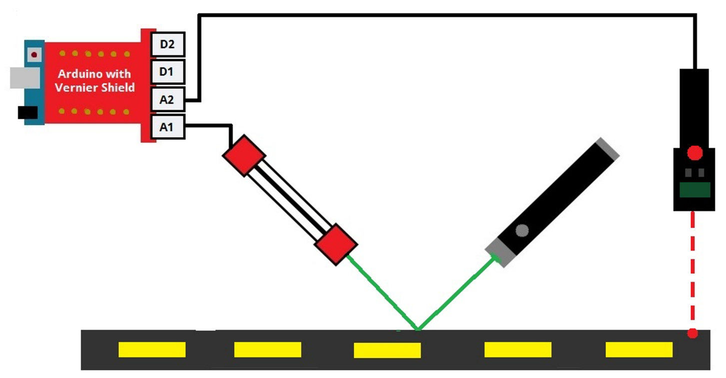


Fig. 1. A diagram of how the sensors connected to the Arduino Mega and the angle placement of the laser

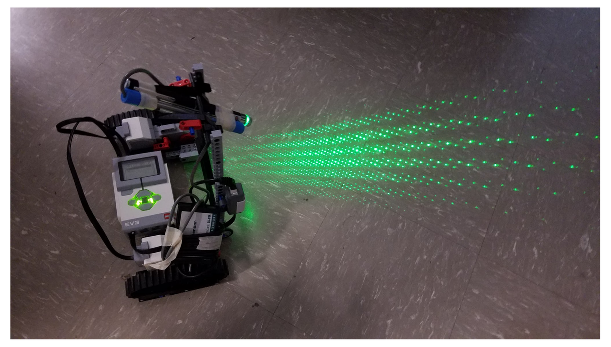


Fig. 5. Picture of how the device was connected onto a Lego Mindstorm and the diffraction grading of the laser.

Figs. 6 & 7. Pictures of how the sensors were attached onto the vehicle. The light intensity was measured while the vehicle drove over the shown sample of ice.

Results

Our hypothesis was supported because the light sensor paired with the laser was successfully able to detect ice due to an increase in light intensity.

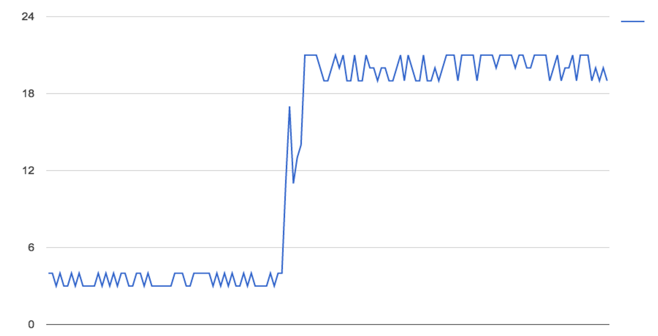


Fig. 2. Half of the surface of a sample of asphalt was covered in ice and the other half was left untreated. First the laser was recorded pointing at the section without ice, then the section with ice. both data sets were recorded indoors with the laser.

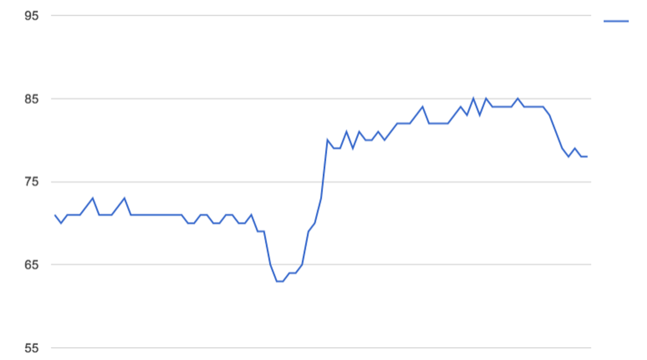


Fig. 3. Half of the surface of a sample of asphalt was covered in ice and the other half was left untreated. First the laser was recorded pointing at the section without ice, then the section with ice. Both data sets were recorded outdoors and with sunlight.

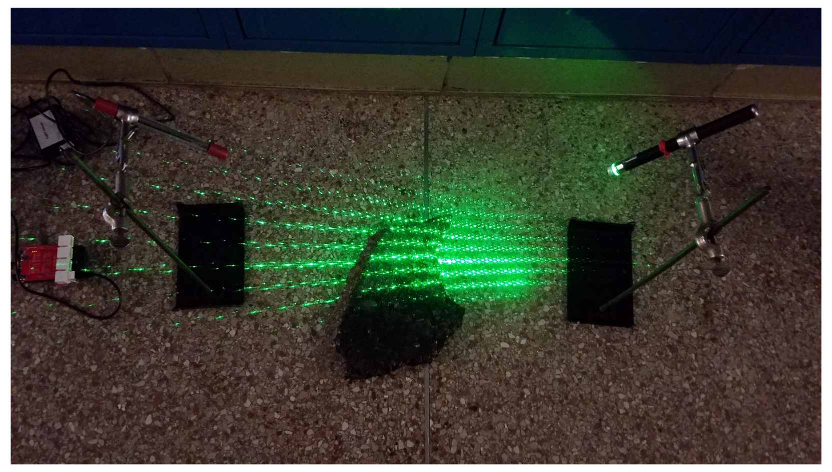


Fig. 4. Picture of the setup we used to record the data in figure 1. The same setup was used to record the data data in figure 2, however, everything was set up outdoors where the primary light source is it sun.

Fig. 8. Sensors were attached onto a stationary vehicle. First the light intensity was recorded of the the road surface. Then a sheet of metal was slid under the sensors.

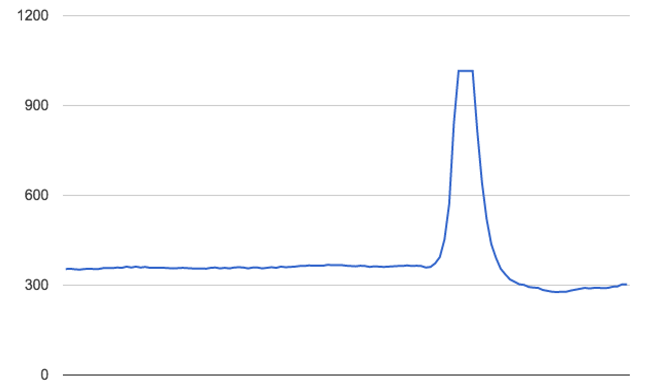
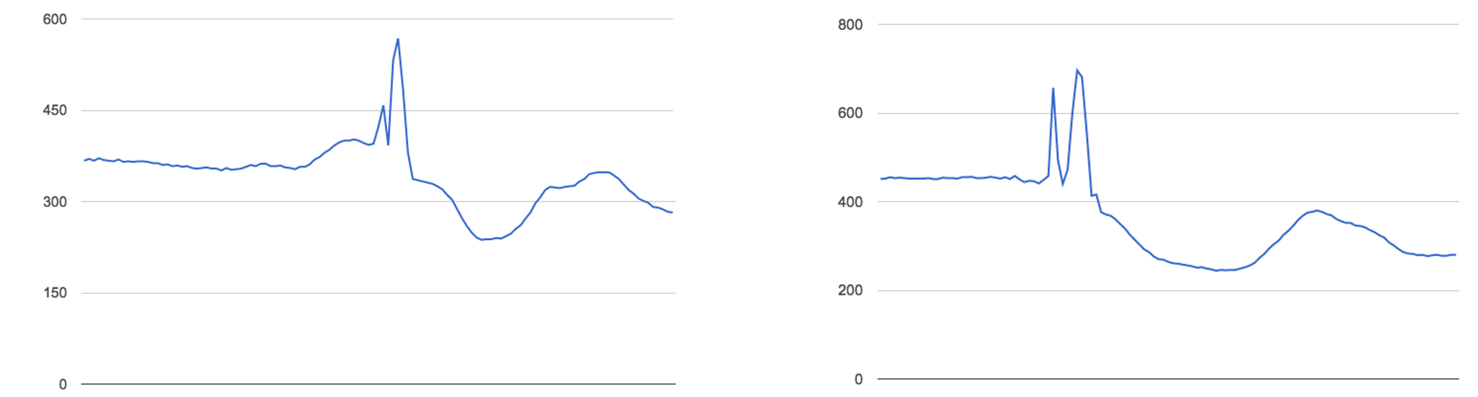


Fig. 9. Sensors were attached onto a vehicle. The light intensity was measured while the vehicle drove over the sheet of metal .



Figs. 10a &10b. Sensors were attached onto a vehicle. The light intensity was measured while the vehicle drove over a sample of ice. The first spike on the graph is due to the ice while the second spike is due to a white road marking

Discussion

Although we did not engineer a way to slow an autonomous vehicle when driving over ice, we showed that it was was possible to do so with a laser and light sensor. Our tests showed that there is a detectable increase in light intensity between ice and asphalt both during the day and night. Using a digital control unit, the increase in light intensity can be taken in as an input and produce an output such as slowing down a vehicle. The tests with the Lego Mindstorm further prove this by showing that it was possible to slow down a self driving robot using only a light sensor and laser.

Limitations
- The accuracy of the light sensor we had used
- Due to the warmer temperatures this winter we were not able to test our device outside in freezing conditions
- Response time of the light sensor
- Weak laser

Possible application
- These results can be use to develop a fully functional system to alert drivers of black ice. Engineers can also use this steady the steering wheel and slow autonomous vehicles to a safe speed.

Future experiments
- Using devices other than Vernier equipment
- Higher intensity laser/ light source.
- More experiments to test percent increase of light intensity due to ice
- Developing code that can better account for changes in sunlight and road conditions
- Applying a conductivity sensor

Literature Cited:
"Black=Danger." Maine BGS: Risk Management. N.p., n.d. Web. 06 Feb. 2016.
Hctv. "Black Ice Storm Causing over 400 Accidents in NJ." Hudson TV. Hudson County, 19 Jan. 2015. Web. 06 Feb. 2016.
"How Do Weather Events Impact Roads?" - FHWA Road Weather Management. N.p., 12 May 2016. Web. 13 Nov. 2016.
"Icy Road Fatality Statistics." Icyroadsafetycom News. Web. 05 Jan. 2016.
"Introduction." Arduino and Vernier Sensors Engineering Education Vernier Software & Technology. Web. 07 Jan. 2016.
"Light Sensor." Light Sensor Vernier Software & Technology. N.p., n.d. Web. 13 Nov. 2016.
"National Snow and Ice Data Center." Thermodynamics: Albedo | National Snow and Ice Data Center. N.p., n.d. Web. 07 Mar. 2017.
"Roadway Icing and Weather: A Tutorial." Roadway Icing and Weather: A Tutorial. Web. 04 Feb. 2016.
"Snow & Ice." Federal Highway Administration. N.p., 12 May 2016. Web. 13 Nov. 2016.

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