Implementation Report

Icy Road Forecast and Alert (IcyRoad): Validation and Refinement Using MDT RWIS Data

https://www.mdt.mt.gov/research/projects/safety/icy-road-rwis.aspx

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Introduction and Purpose

State Departments of Transportation (DOTs) need road ice condition forecasts in order to arrange anti-icing/de-icing activities and to enhance public safety and awareness. Icy road fatalities account for 3.6 times more deaths than all other weather hazards combined (USDOT, 2001). The relative risk of vehicle crashes significantly increases given the presence of winter precipitation. Applying anti-icing materials on the roads, has been reported as having a cost reduction of 30%-90% compared to de-icing after road ice forms. In order to help improve public safety this research was divided into two focus areas, Development of IcyRoad Model and Validation of the Ice Formula.

Development of IcyRoad Model

For Montana DOT (MDT), a statewide IcyRoad model has been developed, tested, and refined during winter 2020-2021 using Montana Road Weather Information System (RWIS) measurements.

This product is demonstrated at https://sg-weather.com/INTERNAL/Icyroad3/. The MDT IcyRoad project identified the most accurate forecast algorithm for Montana (IcyRoad3), which assimilated RWIS hourly historical observations into a weather model forecasting temperature, clouds, rainfall information, and the SpringGem road-surface physical scheme for road surface layer turbulence and heat transportation. IcyRoad project achieved several milestones, including developing an online automatic RWIS validation tool, and developing an in-depth understanding of the formation of road ice. The overall hourly road ice forecast accuracy improved from an averaged 62% to 82%.

Though progress on road ice formation mechanisms and forecasting capabilities has been made, research on black ice was very limited due to a lack of black ice identification and funding availability. More development on model forecast schemes for black ice formation is also needed.

Validation of the Ice Formula

Validating and refining the IcyRoad scientific algorithm, in particular the black ice algorithm was conducted during the project period spanning July 2020 - July 2021, progress was made investigating technologies, particularly the use of hyperspectral imagery, to identify black ice formation on road surfaces. Black ice mechanisms are one of the most meteorologically challenging processes to model and more observations are needed to understand black ice forming meteorological conditions, locations, and timing of events in order to forecast it well.

An ice sheet, thin or thick, has spectral reflectance ($r\lambda$) significantly different at near infrared bands. By using the combination of visible bands and near-infrared bands (NIR), a thin ice-covered surface may be differentiated from road surfaces. Theoretically, for snow and ice, $r\lambda$ reduces from RED to NIR and thus θ is negative; while for asphalt surfaces, $r\lambda$ increases from RED to NIR and thus has a positive θ. As a result, icy roads can theoretically be detected using a combination of Red and NIR bands. (Road Ice Index θ = (NIR-RED)/(NIR+RED)).

There is evidence of hyperspectral cameras with visible and near infrared capabilities (0.4 – 1 µm) being used to identify road defects but no one has yet attempted to distinguish road surface conditions using hyperspectral cameras. Therefore, the team has been developing a drone-based remote sensing technology to detect black ice via hyperspectral camera launched on an unattended aerial vehicle (UAV). This project used several hyperspectral cameras, a Pika L that covers the spectral range from 0.4 – 1 µm and a Pika NIR-320 that covers the spectral range from .9-1.7 µm. Additionally, a spectrometer with a range of .35–2.5 µm was also utilized.

Results within a controlled laboratory setting indicate promise for detecting ice versus dry asphalt using hyperspectral cameras but discerning black ice from other ice is not promising using the ice index formula with this current dataset. Another analysis method using a common method for processing and interpreting hyperspectral data with principal component analysis (PCA) was also explored. This study demonstrated that the PCA technique is capable of identifying, water, and snow in comparison to dry asphalt.

Stepping up to a UAS based collection platform there is a noticeable decrease in data resolution, due to sensor to target distance, subsequent accuracy decreases compared to the laboratory and field-based data.

Implementation Summary

MDT plans to test and evaluate the IcyRoad3 forecast system in a pilot program that will involve one web based user and six application users for the coming winter season. The pilot program will enable the end-users to provide feedback on the forecast system and possible implementation into MDT's operations and procedures. SpringGem will provide MDT with a detailed estimate of the services requested further consideration of services.

Utilizing an unattended aerial vehicle (UAV) is not the proper platform to collect road ice data due to cost, equipment, and regulatory restrictions that make it cost prohibitive in application.

Results from the Road Ice Index θ = (NIR-RED)/(NIR+RED) was not as definitive as expected for determining ice vs black-ice, but validated when detecting, snow, ice, water and bare surfaces, using hyperspectral sensor and PCA methods. Additional research is needed to determine the sensor needed to define ice vs black-ice.

Implementation Recommendations

Recommendation 1:

Implement the use of IcyRoad3, from SpringGem into the MDT operations and workflows.

MDT Response:

MDT will consider a short-term pilot program to use of IcyRoad3 on limited access, to include one web based and six application users, for evaluation by end-users and possible implementation.

Recommendation 2:

Multi-rotor UAS is not the desired platform for data collection along long stretches of roads and corridors to gather data for road ice detection due to the following limitations: FAA regulation, inclement weather, platform flight duration, ice formation on UAS, volume of data collected, platform specific training, equipment cost, increased workforce and workload.

MDT Response:

MDT concurs with recommendations due to mentioned limitations and implementation would be cost and labor prohibitive.

Recommendation 3:

Further research into correct sensor type for detecting black ice with active sensors and possible incorporating static hyperspectral sensors into the current RWIS stations.

MDT Response:

MDT will consider implementing the hyperspectral sensor into one or two selected RWIS sites for further evaluation if deemed feasible, considering the limitation of the sensor. These limitations: durability, connectivity, lighting requirements and cost, will have to be addressed prior to installation.

References

[1]USDOT, 2021: Winter Driving Statistics. https://www.thezebra.com/winter-driving-statistics/

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