

### **Project Title**

Connected Vehicle Winter Safety Improvement with Infrared Thermography Technology

### **University**

University of Utah

### **Principal Investigators**

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### **Research Needs**

Safety is the principal concern of highway transportation. Slippery roads can pose high risks of traffic collisions in snowy regions, which cover about 70 percent of road networks and population in the U.S. The USDOT FHWA safety data reported 24 percent of weather-related vehicle crashes occurred on icy/snowy roads and an average of 1,300 deaths and 116,800 injuries per year were caused by winter slippery roads. Meanwhile, more than 35 states of the U.S. experience snowstorms in winters and some states such as Utah can even have more than 5 months of winter seasons. Icy/snowy roads can significantly reduce tire frictions, lengthen vehicle braking distance, and thereby induce high risks of car crashing. Hence, if early warning could be provided to drivers before they enter hazardous locations, potential crash risks could be significantly reduced.

Conventionally, state DOTs use warning signage to alert drivers of hazardous road segments. However, slippery spots are usually hard to predict, and their locations could be changing overtime. Placing warning devices would then have limitations in addressing such dynamic situations. Recent advancements of connected vehicle or CV technology offers a new and effective solution to tackle this issue. For example, in the work with Panasonic, UDOT has already developed a Spot Weather Impact Warning application, which uses data from RWIS stations and CV information to determine the existence of potentially slippery road surfaces and then send a message to oncoming CVs.

The current Spot Weather Impact Warning application relies on ITS roadway equipment (RWIS) and partially on information from Connected Vehicles to detect the road surface temperature, moisture, icing, and other metrics to detect road slippery conditions, where the adopted sensors typically provide single-spot measurements. This project could fill the gap in augmenting or complementing the road slippery detection algorithm.

## **Research Objectives**

The objectives of this project are:

- Utilize infrared thermography (IRT) sensors to detect slippery road spots and high crash risk locations in winter seasons
- Develop machine learning algorithms to improve detection performance
- Use the detected road surface snow/ice pattern to augment or complement the Spot Weather Impact Warning (SWIW) application that UDOT has implemented
- Examine the feasibility/needs of integrating IRT sensor data in future CV control systems

## **Research Methods**

By using the IRT technology, this project will develop a convenient tool which is capable of conducting multi-lane roadway temperature mapping and road slippery condition evaluation. The obtained data can be treated as the first-hand evidence and could be used to cross-validate the detection accuracy of the current Spot Weather Impact Warning system. Moreover, the IRT technology could be potentially integrated into the CV-based traffic control loop in the future for better system performance.

## **Expected Outcomes**

The proposed research will contribute to the development of a reliable approach for roadway snow/ice detection that can output safety information for UDOT CV system. It will support an ongoing effort on the development of UDOT CV information system. And the expected outcome is to improve winter safety of UDOT CV system by developing the proposed IRT measurement technology.

## **Relevance to Strategic Goals**

The sensing technology to be developed in this proposal has a great potential for CV winter safety. Based on FHWA safety statistics, the slippery road conditions have been a major source of accident in cold regions, which covers over 60% of the U.S. states. The proposed technology based on the infrared thermography for snow detection will enable roadway snow/ice detection. More importantly, the developed algorithm will analyze the IRT data and output the information that can be fed into the CV communication system. This research aligns with the USDOT strategic goals of ‘Safety’.

## **Educational Benefits**

One Ph.D. student will be involved in the analytical and experimental work. The P.I. and the student will make presentations at national conferences, such as TRB annual conference.

## **Technology Transfer**

The main objective of this research is to develop a reliable approach for effective roadway snow/ice detection and understand the feasibility of integration with the UDOT CV system. There is a need for developing such innovative technology and the proposal addresses that need. The resulting technology will lead to sensing systems that are capable of processing IRT data and formatting the analysis results to feed into the CV system. The work will be presented at

conferences, such as the TRB annual conference. In addition, technology transfer will occur through workshops, web pages, social media, and seminars.

## Work Plan

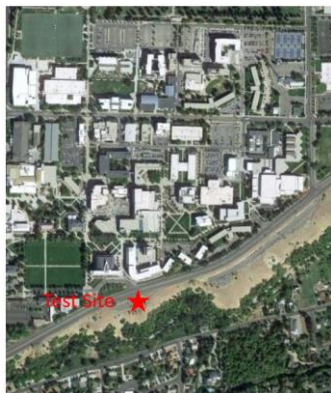
The following major tasks are anticipated:

### Task 1. Literature review – 3 months

Existing approaches involving road safety on snow detection mainly fall into three categories. The first one is to provide drivers with real-time roadway weather information. The second focus is to incorporate machine learning techniques [1] into image segmentation to segment the road images for aiding autonomous driving. The third aspect is to monitor the road surface condition via image segmentation methods [2] to provide information for road management so that necessary measures can be taken to ensure traffic safety. All three kinds of studies either involve machine learning techniques or rely on image segmentation techniques. The team will perform an in-depth review of existing literature to better understand and document the state-of-the-art.

### Task 2. IRT deployment and data collection – 5 months

To meet the objectives of the research, the team will work with our UDOT partner to deploy IRT sensor and cover areas that are currently covered by UDOT's SWIW system. Two sites are envisioned, but may change based on field conditions and/or UDOT preference: I-80 Parley's Summit and SR248 in Park City. Both of these sites have RWIS installations which will facilitate IRT camera mounting and data transmission. Two different IRT cameras will be deployed for simultaneous evaluation of camera brands/models. An exemplary IRT deployment is shown in Figure 1. The team performed field tests at a location on Highway 89, close to Utah State University, Logan, Utah. The snow detection system was installed on a portable trailer and sets of batteries connected with a solar panel were used to power the system. The infrared thermal image videos are transmitted to a Dell Latitude 5420 Rugged Laptop with the 1/25 second interval, based on which snow detection was conducted.



(a) Test site location



(b) Portable trailer system

*FIGURE 1 Previous field test site and system*

### Task 3. Algorithm performance evaluation and CV integration – 3 months

The team will use the collected data to map road snow/ice patterns, improve the interpretation of the images, and further evaluate the performance of the current Spot Weather Impact Warning application by comparing the detection of slippery roads using both systems. The team will meet with the UDOT Connected Vehicle team to define the data stream necessary for converting IRT-derived data on road condition into a format compatible with UDOT's existing CV data format.

The team has established frameworks of image processing techniques [3, 4] for roadway snow detection. An exemplary snow detection is shown in Figure 2. At daytime or with sufficient illumination, we will generally use the optical image for image segmentation. As shown in Figure 2(b), the contours of the snow regions can be correctly identified. Therefore, the snow ratio of each lane will accurately indicate the amount of snow left on the lane. The snow on the green and blue lanes is much smaller than that on the middle lane. This is because the middle lane is for left-turn, and vehicles to turn left were much fewer than those passing through this road. At nighttime or when the illumination is insufficient, the features related to the light intensity cannot serve as feature vectors. The IR images become a better candidate for image processing through the same process. The temperature difference and distribution were used and reflected as colors in the RGB image. Again, for easier comparison, both IR and optical image segmentation was shown here. And the snow ratios for each lane were noted at its left. As shown in Figure 2(e), the performance of image segmentation based on IR image outperforms the ones based on optical image.

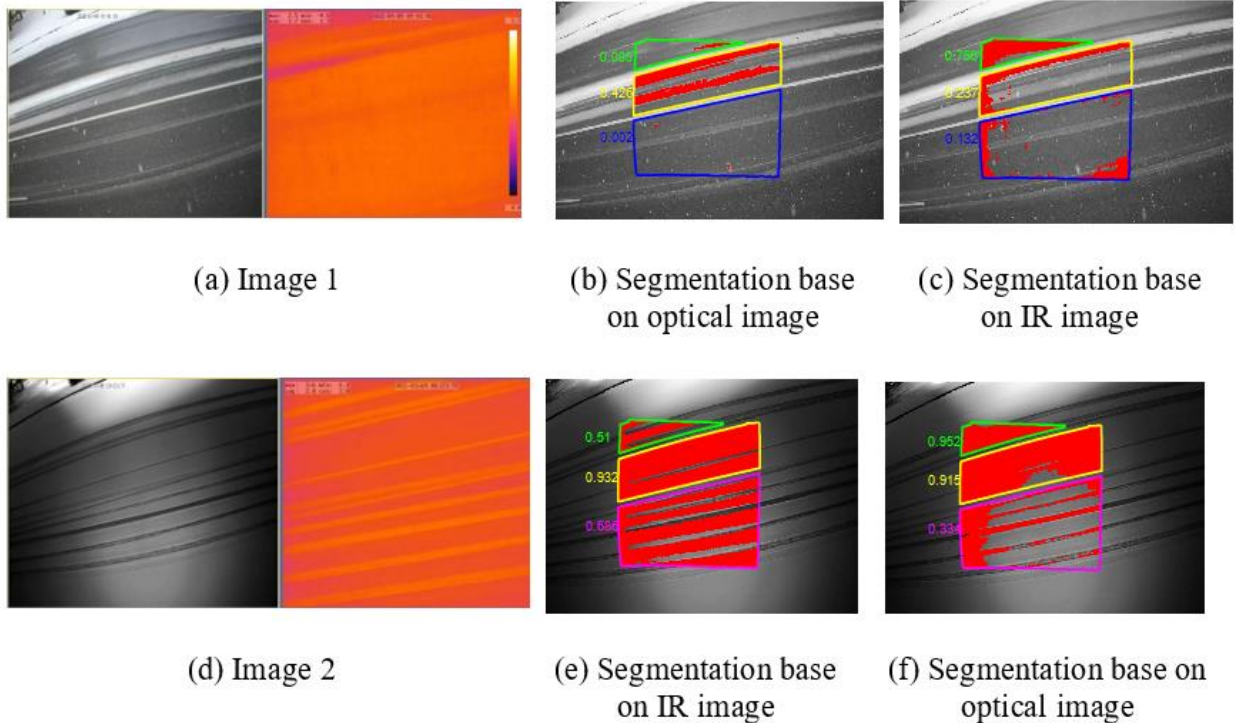


FIGURE 2 Results of the snow segmentation of images at daytime (a-c) and nighttime (d-f)

## **Project Cost**

Total Project Costs: \$90,000  
MPC Funds Requested: \$40,000  
Matching Funds: \$50,000  
Source of Matching Funds: Utah Department of Transportation

## **References**

1. Khan, M.N., Ahmed, M.M. Snow Detection using In-Vehicle Video Camera with Texture-Based Image Features Utilizing K-Nearest Neighbor, Support Vector Machine, and Random Forest. *Transportation Research Record*. 2019;2673(8):221-232. DOI: 10.1177/0361198119842105.
2. Roser, M. and Moosmann, F. Classification of weather situations on single color images, 2008 *IEEE Intelligent Vehicles Symposium*, 2008, pp. 798-803. DOI: 10.1109/IVS.2008.4621205.
3. Shapiro, L. G., and Stockman, G. C. Computer vision. Vol. 3. New Jersey: Prentice Hall, 2001.
4. Gonzalez, R. C. Digital image processing, fourth edition. Pearson education, 2018.