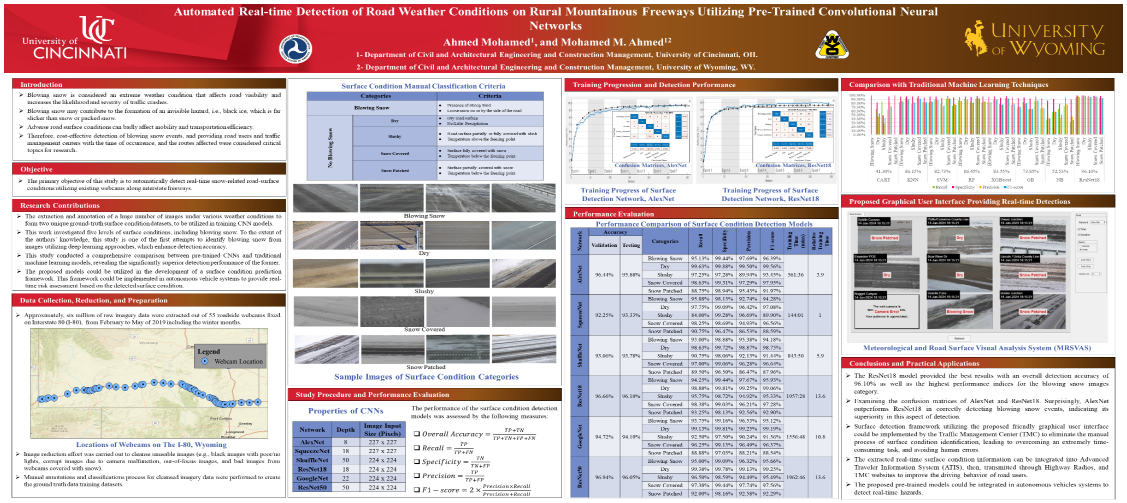
2024 Automated Vehicles & Meteorology Summit
Poster Sessions
Wednesday, 26 June
9:35-10:15 AM & 3:00-3:40 PM

Poster 1: *Automated Real-time Detection of Road Weather Conditions on Rural Mountainous Freeways Utilizing Pre-Trained Convolutional Neural Networks*

Ahmed Mohamed, University of Cincinnati, Cincinnati, OH; and M. M. Ahmed

Abstract: The main objective of this study is to improve safety and mobility of rural freeways during adverse road weather events. A first step to mitigate winter road weather is to detect real-time snow-related road-surface conditions. This was accomplished by utilizing cost-effective machine vision techniques using data collected from existing webcams along interstate freeways. Blowing snow is considered one of the most critical road surface conditions which may cause vertigo and adversely affecting vehicle performance. A comprehensive image reduction process was performed to extract two distinct ground truth datasets. The training dataset consisted of five categories: blowing snow, dry, slushy, snow-patched, and snow-covered. Six pre-trained convolutional neural networks (CNN) were utilized for road-surface condition classification: AlexNet, SqueezeNet, ShuffleNet, ResNet18, GoogleNet, and ResNet50. It was concluded that ResNet18 model achieved an optimal overall detection accuracy of 96.10%, while the AlexNet model demonstrated the shortest training time and an overall detection accuracy of 95.88%.

In addition, a comprehensive comparison was conducted between pre-trained CNNs and traditional machine learning models, with the former achieving significantly superior detection performance. Analysis of the confusion matrices revealed that AlexNet performed the best in detecting blowing snow events. A desktop application with a friendly graphical user interface was developed by implementing AlexNet and ResNet18 to automatically detect real-time accurate and consistent surface conditions in real time. The results from this study could be utilized by Infrastructure Owners and Operators to guide and update digital road infrastructure to enable a safer and efficient implementation of autonomous vehicles.



Poster 2: *Integrated Framework for Traffic Safety Assessment at Signalized Intersections: Leveraging Multi-Camera Field of Views USING CNN-Based Pose Estimation Algorithms*

Ahmed Mohamed, University of Cincinnati, Cincinnati, OH; and M. M. Ahmed

Abstract: Over the past decade, researchers have demonstrated significant interest in advancing traffic monitoring by employing diverse devices, ranging from surveillance cameras and unmanned aerial vehicles (UAV) to loop detectors and sensor fusion incorporating light detection and ranging (LiDAR). These techniques, extensively utilized for vehicle detection and tracking, have culminated in the establishment of robust safety assessment methodologies. Despite these strides, the intricate nature of pedestrian detection presents considerable challenges to traffic safety researchers, encompassing diverse motion patterns, clothing colors, partial occlusions, and varying positions relative to detection devices. However, the effective utilization of surveillance cameras, LiDAR, and microwave beams in pedestrian detection has contributed significantly to the development of resilient safety assessment methodologies. Nevertheless, the nationwide deployment of these advancements encounters challenges arising from constraints in monitoring devices, detection algorithms, and output processing. To address these limitations, this study introduces an innovative approach that integrates multiple surveillance cameras at signalized intersections within a meticulously designed framework. Leveraging two distinct Convolutional Neural Network (CNN)-based detection algorithms, this method accurately identifies and tracks road users, vehicles and pedestrians, producing reliable outputs. These outputs undergo comprehensive analysis, smoothing, and integration, facilitating a detailed reconstruction of traffic scenes at signalized intersections. The proposed framework enables the extraction of crucial traffic flow features, thereby aiding in the identification of instances of traffic conflicts. Through the synergistic integration of surveillance cameras and CNN-based algorithms, this research contributes to advancing traffic safety practices. This approach could be employed in autonomous vehicle systems to provide precise localization of human-driven vehicles and capture road users interactions.

Poster 3: *Simulating Microwave and Radar Signals in Severe Weather Conditions*

Isaac Moradi, NASA, Greenbelt, MD

Abstract: The development of radiative transfer simulators for radar and microwave signals, spanning a range of frequencies from 10 to 800 GHz, is paramount for enhancing weather forecasting accuracy, particularly for severe weather events. These tools facilitate the assimilation of microwave and radar observations into numerical weather prediction models, thereby improving accuracy of weather forecasts. Additionally, they directly simulate radar signals crucial for autonomous vehicle operation, with frequencies commonly used in radar systems such as 24, 74, 77, and 79 GHz. However, these frequencies are susceptible to weather phenomena like severe rain and snow, which can significantly impact vehicle safety and performance.

These simulation tools, including radiative transfer simulators, serve a dual purpose. Firstly, they enhance forecasts for severe weather events, contributing to autonomous vehicle safety by providing early warnings and risk assessments. Secondly, they enable the direct simulation of radar signals in autonomous vehicle driving systems, allowing researchers and engineers to evaluate radar system performance under various weather conditions.

In addition to the radar signal simulator, this abstract discusses the incorporation of advanced scattering properties developed using the discrete dipole approximation (DDA). The DDA technique enhances scattering calculations for frozen hydrometeors at microwave frequencies, thereby improving the accuracy of radar signal simulations and enabling more accurate assessments of radar system performance in adverse weather conditions.

In summary, this abstract explores the development and utilization of comprehensive simulation tools, emphasizing their significance in simulating microwave and radar signals and improving weather forecasts. Special attention is given to the simulation of radar signals at critical frequencies for autonomous vehicle sensing and navigation, addressing challenges posed by severe weather phenomena and their effects on signal propagation and detection.

Poster 4: *Road Weather Services Tailored to Autonomous Traffic*

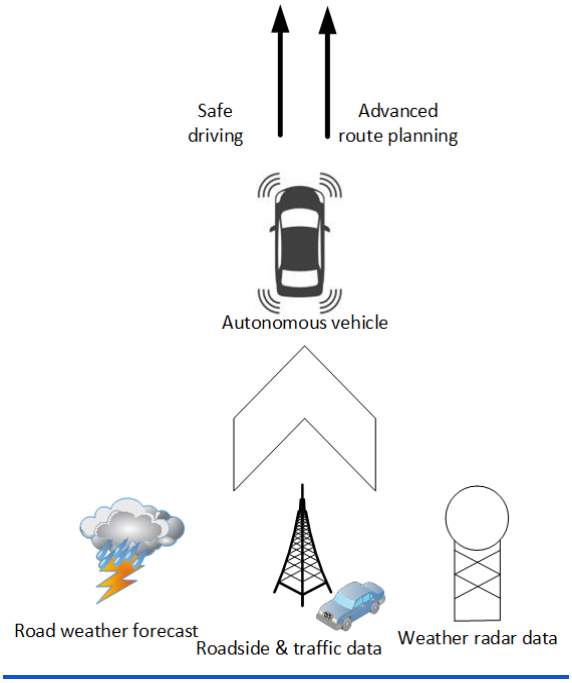
Timo Sukuvaara, FMI, Sodankylä, Finland; and V. Karsisto, H. Myllykoski, and **C. Venkatachalam**
Abstract: 6G VISIBLE project develops enhanced solutions for autonomous driving. The project's objectives include evaluation of autonomous vehicles' sensor systems sensitivity to harsh weather conditions, development of road weather services for autonomous driving and the development of precipitation nowcasting alongside the road weather services for autonomous vehicles. The resulting algorithms provide enhancements for autonomous driving in terms of driving safety and advanced route planning, as illustrated in the image below.

FMI (Finnish Meteorological Institute) produces road weather forecasts with road weather model RoadSurf that is one dimensional heat balance model for predicting road weather conditions. It uses forecasted atmospheric variables as input, and provides forecast of road surface temperature, amounts of ice, snow and water on the road, friction and road condition (wet, icy, snowy...) as output. In this project, road weather forecasts will be further tailored for autonomous vehicles. The forecasts will consider the autonomous vehicle's sensor system and its sensitivity to weather conditions to provide more sophisticated instructions (adjust speed, safety distances) in harsh weather conditions. Each group of autonomous vehicle sensors (LiDAR, vehicle camera and vehicle radar) is evaluated in different kinds of weather conditions, in order to seek vulnerabilities to different weather conditions and ultimately develop a model for their weather dependency. The forecasts will be piloted in the city of Oulu, Finland. The forecast points will be selected along major roads, and the surrounding environment's effects to radiation will be considered in the forecast via sky view factor and shadowing algorithm.

Precipitation nowcasting is produced by Pysteps, an open-source Python library. The nowcasting is based on extrapolation of radar observations along the motion field estimated from past observations. It has been studied that nowcasting based on radar extrapolation provides better results than Numerical Weather Prediction (NWP) based models on short time ranges (0-6 hours). Nowcasting models can produce reliable predictions of large scale stratiform rainfall up to 6 hours and convective rainfall up to the next 30-60 minutes. It is important to provide accurate information about precipitation for autonomous vehicles, as snowfall and heavy rainfall affect road conditions and the sensors' ability to observe the surroundings. In this project, we will develop a precipitation nowcasting web application to show results from a radar extrapolation algorithm in the Linnanmaa region in the city of Oulu. The precipitation nowcast will be also given as input data to the road weather model to produce better road condition forecasts.

Tailored road weather services to autonomous traffic are developed in the project by using the precipitation nowcasts and road weather forecasts. The developed services consist of driving mode adjustments based on road condition and supplemental information for route planning. FMI is defining the set of driving condition-based levels that can be used as driving mode adjustments in autonomous vehicles. Driving conditions are divided from perfect conditions to very poor conditions that makes autonomous driving impossible. In between there are several steps with slightly alternate driving modes, which are adjusted for different intensities of rain, snowing, icing etc. The stepwise driving conditions are defined for different sensor types individually, but the ultimate target is to adjust the driving condition levels to different autonomous vehicle models that possess different combinations of sensors. The target is to generate controlled adjustment of driving manners based on weather conditions. This allows safe autonomous driving among other vehicles and predictable driving behaviors to make human drivers more comfortable with them. The route planning element uses the information from precipitation nowcasts generated for the road/route network of the autonomous vehicle. Nowcasting information is used to pin-point the routes with harsh weather conditions in certain near-future time slots, which allows the autonomous vehicle to select an alternative route(s) and ultimately avoid decreased driving ability in the first place.

This work presents 6GVisible project's goals of producing road weather services that are tailored for each autonomous vehicle's special properties. In parallel we are also considering the possibility to exploit the vehicle sensors data as a source of additional local road weather information. This data could be used as input for road weather model or in the validation of the model's results. The 6G VISIBLE project will last until the autumn of 2026, when we expect to have our pilot services pre-evaluated and available in our test area.



Poster 5: *Discrepancy Study of Meteorological Measurements in a Climatic Aerodynamic Wind Tunnel (CAWT) Setting*

Ismail Gultepe, Ontario Technical University, Oshawa, ON, Canada; and E. Villeneuve, W. Y. Pao, L. Li, F. Hosseinnouri, M. Sadegh Moradi, E. whalls, K. Purushothama keshavan, M. Agelin-Chaab, H. hangan, and J. Komar

Abstract: The Automotive Center of Excellence (ACE) is a state-of-the-art research facility located on the campus of Ontario Technical University (OnTechU) that focuses on weather impact testing in the Unmanned Aerial Systems (UASs), automotive, and civil sector. Its Climatic Aerodynamic Wind Tunnel (CAWT) has an adjustable cross sectional test area of 7, 9.3, and 13 m^2 with a test section length of 10 m. The height, width, and length of the CAWT are approximately at 8, 30, and 30 m, respectively. It has the capacity of generating wind speeds of 250 km hr^{-1}, ambient air temperatures (T_a) ranging from +60°C to -40°C, relative humidity with respect to water (RH_w) between 10 and 100%, and various hydrometeor creation such as warm fog (WF), ice fog (IF), drizzle (DRZ), rain (RN), snow (SN), and icing (ICNG) conditions. Since its foundation in 2011, ACE has championed the execution of various industrial and academic research projects. Recent projects of note have been the development of refined ice fog generation in conjunction with ECCC (Environment and Climate Change Canada) as well as the evaluation of real-world impact of precipitation (RN or SN) on aerodynamics of passenger vehicles that was gathered during the Weather on Wheels (WoW) project.

In this work, fog, rain, and snow precipitation impact on unmanned vehicles and their advance driver assistance systems (ADAS) are investigated. Four types of precipitation rates (PR) calculations (including manual, disdrometer, visibility, and size distribution types) will be provided. Specifically, a comparison of instrument-based PR (mm hr^{-1}) from a laser precipitation monitor (LPM) for precipitation particles (RN and SN) versus physical snow depth readings gathered from laboratory testing will be summarized. Overall, measurement uncertainties, discrepancy between manual and optical measurements of the precipitation types and challenges for future work will be emphasized.

Poster 6: *How Can the Autonomous Vehicle and Meteorology Communities Help Each Other? Building Collaborations to Increase the Value of Vehicle Sensor Technologies.*

Jeffrey C. Snyder, NSSL, Norman, OK; and D. Wasielewski and N. Zemlin

Abstract: High-quality weather information is important to the Autonomous Vehicle community. In addition to the value that the weather community can bring to the Autonomous Vehicle industry, Autonomous Vehicles potentially have much to offer to the weather community. Aggregated meteorological data from aircraft have been shown to be valuable to weather warnings and forecasts. Vehicle sensors may be able to provide useful weather data and ground truth at a much greater density and at the location where weather data for the general public are, arguably, most important– the ground.

Modern vehicles (and especially Autonomous Vehicles) are already outfitted with a plethora of instrumentation, including FMCW radars, ambient light sensors, rain sensors, ultrasonic sensors, and, though less commonly, lidars. While intended for non-meteorological purposes (e.g. adaptive cruise control, forward collision avoidance, headlight or wiper control, parking assist, lane keep assist, road departure mitigation, etc.), these sensor technologies are affected by environmental conditions; therefore it is reasonable to think that valuable environmental information could be inferred from the sensor output that is already available. When these highly localized environmental observations are available at scale, data from vehicle sensors could be used by weather analysis systems to provide valuable insight for a wide variety of weather events on regional and national scales. For example, information from various vehicle sensors may be useful for identifying rain/snow transition areas, a practical benefit that can have immediate public safety benefits. In turn, this weather information may be of great interest to the Autonomous Vehicle community (and transportation industry more broadly), especially regarding navigation and logistics.

NOAA has experience fusing and assimilating data from disparate sources and from systems with potentially high measurement variance through efforts such as mPING, MRMS, and FLASH, and we have been able to effectively distribute the resultant weather products to public and private stakeholders. The burgeoning field of Autonomous Vehicles is a promising source of future symbiotic collaborations extending this legacy of connecting sensor data, weather insights, and applications.

Poster 7: *Enhancing Autonomous Vehicle Safety in Cold Climates by Using a Road Weather Model: Safely Avoiding Unnecessary Operational Design Domain Exits*

Viktoria Bogren, Klimator, Gothenburg, O, Sweden; and T. Gustafsson, G. Gulliksson, and Y. Hu
Abstract: This study investigates the use of a road weather model (RWM) as a virtual sensing technique to assist autonomous vehicles (AVs) in driving safely, even in challenging winter weather conditions. In particular, we investigate how the AVs can remain within their operational design domain (ODD) for a greater duration and minimize unnecessary exits. As the road surface temperature (RST) is one of the most critical variables for driving safety in winter weather, we explore the use of the vehicle's air temperature (AT) sensor as an indicator of RST. Data from both Road Weather Information System (RWIS) stations and vehicles measuring AT and road conditions were used. Results showed that using only the AT sensor as an indicator of RST could result in a high number of false warnings, but the accuracy improved significantly with the use of an RWM to model the RST. ROC-curve analysis resulted in an AUC value of 0.917 with the AT sensor and 0.985 with the RWM, while the true positive rate increased from 67% to 94%. The study also highlights the limitations of relying on dashboard cameras to detect slippery driving conditions, as it may not be accurate enough to distinguish between, for example, wet and icy road conditions. As winter maintenance often prevents slippery roads, the vehicles often measured wet or moist roads, despite RST < 0°C. Our calculations indicate that the vehicle should be able to detect 93% of slippery occasions but the rate of false warnings will be as high as 73%, if using a dashboard camera along with the AT sensor. There are clear benefits of using a RWM to improve road safety and reduce the risk of accidents due to slippery conditions, allowing AVs to safely extend their time within their ODD. The findings of this study provide valuable insights for the development of AVs and their response to slippery road conditions.