Graduate Research Plan Statement -
Advanced Vehicle-Weather Applications using Edge Computing

Background: Microclimates suffer a serious impact on driving. This includes snow, ice, heavy rain, and other kinds of inclement weather that create rapidly changing road conditions. Dynamic road conditions require the vehicle's driving assistant system to react accordingly to ensure efficiency and safety. For example, a drone can be more energy efficient if its route planning algorithm considers real-time wind vector data, and a car should adjust its braking control system parameters to drive safely on snow-asphalt joint pavement[4].

Problem: There lacks an effective method to sense microclimate in a realtime fashion. On one hand, existing sensors on smart vehicles are vulnerable to weather conditions and provide low accuracy under adverse weather conditions [5]. On the other hand, the traditional approach for sensing microclimate by weather stations and satellites suffer from high processing latency and cannot provide useful information to drivers or autonomous vehicle systems fast enough to be considered real-time. As a result, one of the most critical issues in the development of autonomous vehicles and driver assistance systems is their poor performance under adverse weather conditions, such as rain, snow, fog, and hail[3].

Unique Insight: The system I propose to build will benefit from our latest insight concerning the fusion of data from different *types* of sources, which can provide high-accurate microclimate data with a high enough QoS that realizes real-time responses (i.e., adjusting the necessary stop distance). By surveying research literature, I found that different sensors provide their own distinct perspective on microclimate. For example, smart road sensors can be used to provide accurate observations on some microclimate parameters; some car-mounted sensors (i.e., camera, radar, temperature sensor) provide direct information about the weather, while other car-mounted sensors provide indirect information that can be used to infer the weather (e.g., the braking system parameters and the motion sensor readings can be used to infer road slipperiness); and mobile sensors provide information about the driver's concentration levels, which can also be used to infer weather conditions.

Research Question:

How to adapt to dissimilar execution environments? Cars are moving fast on road neworks, which brings high resource dynamicity to the proposed system (i.e., number of nodes in a network, types of sensor data provided). However, the driving assistant applications require a real-time degree of QoS (i.e., latency, reliability, accuracy) to provide the required functionality. *Hence, how can we translate all heterogeneous inputs into a homogeneity to guarantee the necessary QoS for a real-time weather application?*

Approach and Methods:

1. Understand the requirements: Collect information from engineers working on autonomous driving (Ford, GM, other Detroit-area automotive companies) to gain an understanding on the requirements on latency, accuracy, and granularity for autonomous/assisted driving vehicle systems.

2. Build an emulator testbed in order to**: a)** *Define data collection methods***, b)** *Collect data under different weather conditions to create a dataset* **c)** *Apply data processing algorithms on the edge server.*

3. Design and build and test a system that works best for most scenarios: Build a system and adapt the data analysis algorithm to work with all tiers (cloud, network core, edge) and with all types of sensor data so that a weather application will function for a vehicle system and meet the latency, granularity, and accuracy requirements. See figure 1.

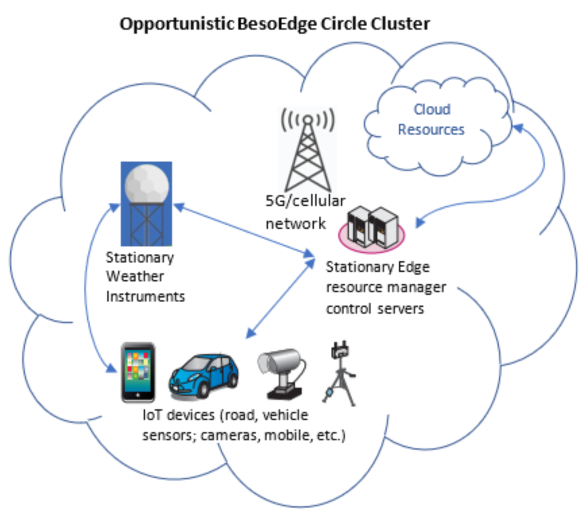

Figure 1

Logistics and Support: State-of-the-art CIS and Engineering research facilities at the University of Michigan-Dearborn (UM-D) including: The Engineering Lab Building (newly completed in 2022) which contains multiple CIS and engineering laboratories; Institute for Advanced Vehicle Systems building (IAVS); Edge Computing researchers: Dr. Zheng Song, IEEE best paper[1] on edge computing (2019). He runs Edge Computing courses and collaborates with graduate and undergraduate students on his research and manages an edge-computing user experience and testbed framework.

Intellectual Merit

For decades, the IoT has not reached its true potential for one simple reason: We have not leveraged heterogeneous data provided from all devices. We need to work towards the solution of creating homogeneity among the diversity of devices and data. This will help to incorporate and advance the field of Artificial Intelligence, which can be used to decide how to incorporate different kinds of data so that we can leverage different sensor data to complete the same tasks (such as weather applications). Overall, research in vehicle-weather applications will enhance the state-of-the-art of edge computing and the broad IoT. My research involves building a collaborative testbed for emulating sensor data in inclement weather to be used by autonomous driving; as such, other researchers in the scientific community (meteorologists, physicists, autonomous vehicle engineers, network engineers) will be able to leverage my work and advance their respective fields.

Broader Impacts

Research in edge computing in vehicle networks with weather sensor data can specifically keep drivers safe and advance the development of autonomous vehicles. This project involves the IoT, which is relied upon by the whole of humanity; therefore, there is no way such an undertaking can be done effectively without involving students and everyday users from all backgrounds. In the future, we can realize a world where there is essentially always internet connectivity for all users - a world where there are so many devices that are all securely connected in a web that does not only rely on the internet core, but where every device (buildings, cameras, cell phones, smart watches, satellites, etc.) is always contributing its own data and computation and making so many applications possible - like safer driving. That is the vision for edge computing. As long as enough people are nearby, connectivity is practically guaranteed. Automotive companies in the Detroit area can take advantage of my work to produce safer vehicles. City planners can know that investments in technology for road projects means investing into the future of connectivity and safety. This project also promotes the future of education: it can be used to train students how to process sensing data and provide hands-on project opportunities to undergraduate students like myself. Lastly, it promotes the next generation of weather forecasting. Meteorologists will be able to utilize the same framework of edge computing weather applications in vehicle networks to gather and analyze more local data and improve their forecast accuracy and warning times. The ultimate outcome of this project would stimulate safety and connectivity for our future.

References

[1] Z. Song and E. Tilevich. “A programming model for reliable and efficient edge-based execution under resource variability”. In 2019 IEEE International Conference on Edge Computing (EDGE), pages 64–71. IEEE, 2019.
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[4] Wang, Xinqun, et al. "Development of AEB control strategy for autonomous vehicles on snow-asphalt joint pavement." International Journal of Crashworthiness (2021): 1-21.
[5] Vargas, Jorge, et al. "An overview of autonomous vehicles sensors and their vulnerability to weather conditions." Sensors 21.16 (2021): 5397.