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High-Speed Pavement Texture Measurement Prototype

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- Illinois Department of Transportation, Federal Highway Administration
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- ICT research engineers
- ICT students and staff

Introduction

United States

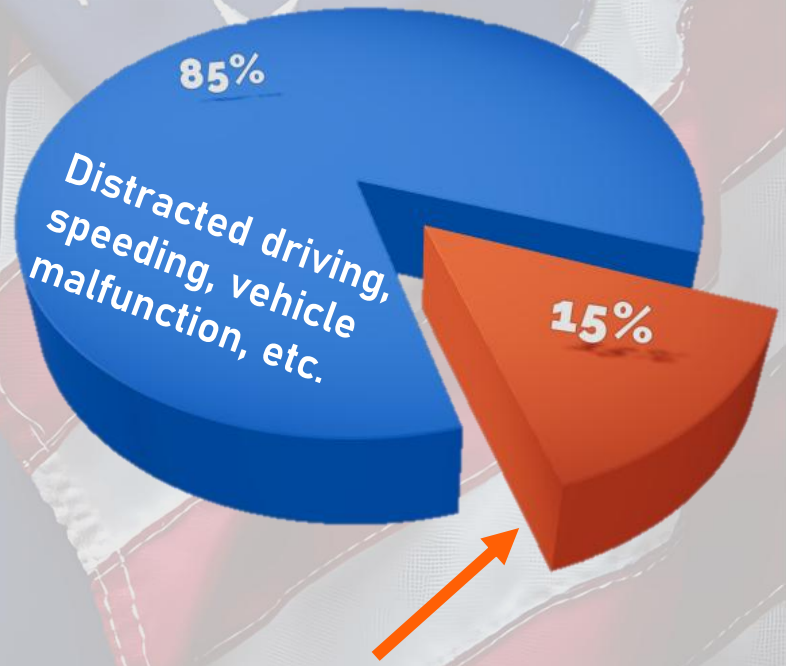
6 Million crashes annually

- ~40,000 fatalities
- $1.37 Trillion is societal harm
- $340 Billion in economic damage

Illinois

- 1177 fatalities in 2024
- $2 Million in economic damage per fatality

Crash Causes



Insufficient friction

Maintaining adequate friction on roads is critical for traffic safety.

Friction Measurement

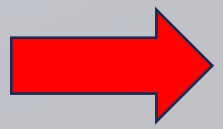
Locked Wheel

Fixed slip

Side-Force

Limitations:

- **Relatively expensive to own and operate**
- **Affected by test tire properties**
- **Require extensive training**
- **Spot/sporadic measurements**



Alternative methods are needed.

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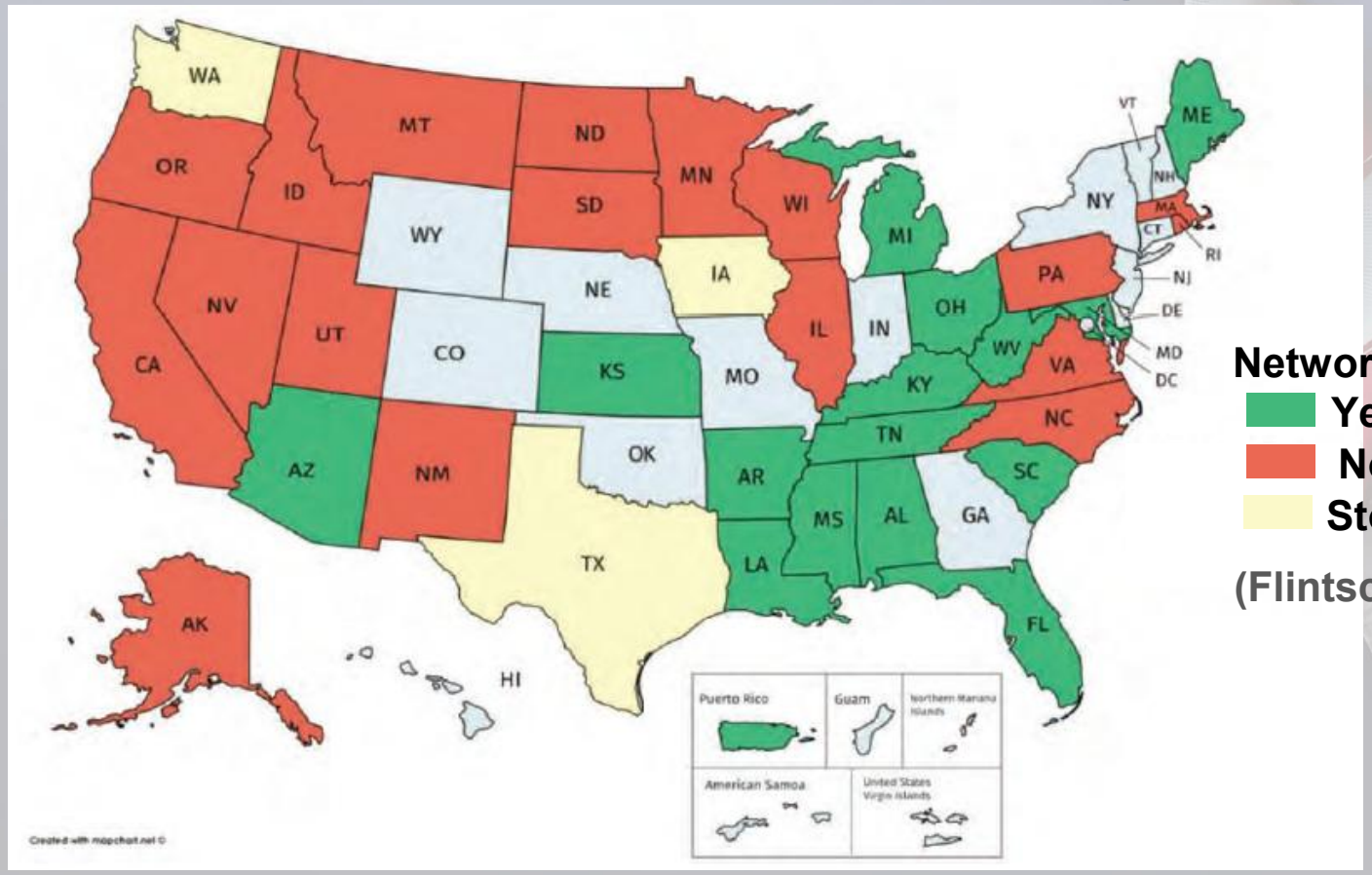
Pavement Texture

Pavement texture is a major driver of friction, yet only 15 states and Puerto Rico conduct network measurement of pavement texture due to the high cost of network-level laser scanning.

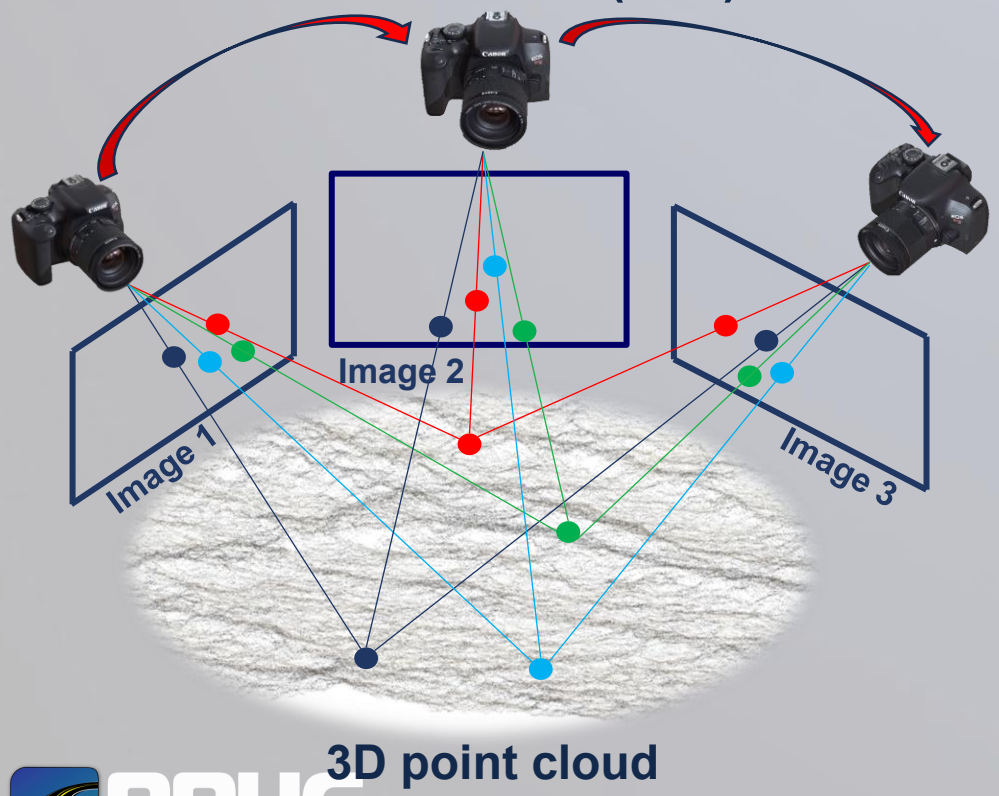


(Flintsch et al, 2021)

Emerging Technologies

Computer vision techniques can be utilized to recover 3D information from 2D images.

Photogrammetry/Structure from Motion (SfM)



Advantages:

- Inexpensive equipment
- Comparable or higher quality data
- Less complex technology

The technology must be scaled for measurement at speed.

SfM Vehicle-Mounted System

High-resolution 3D surface

Overlapping images

High-resolution cameras

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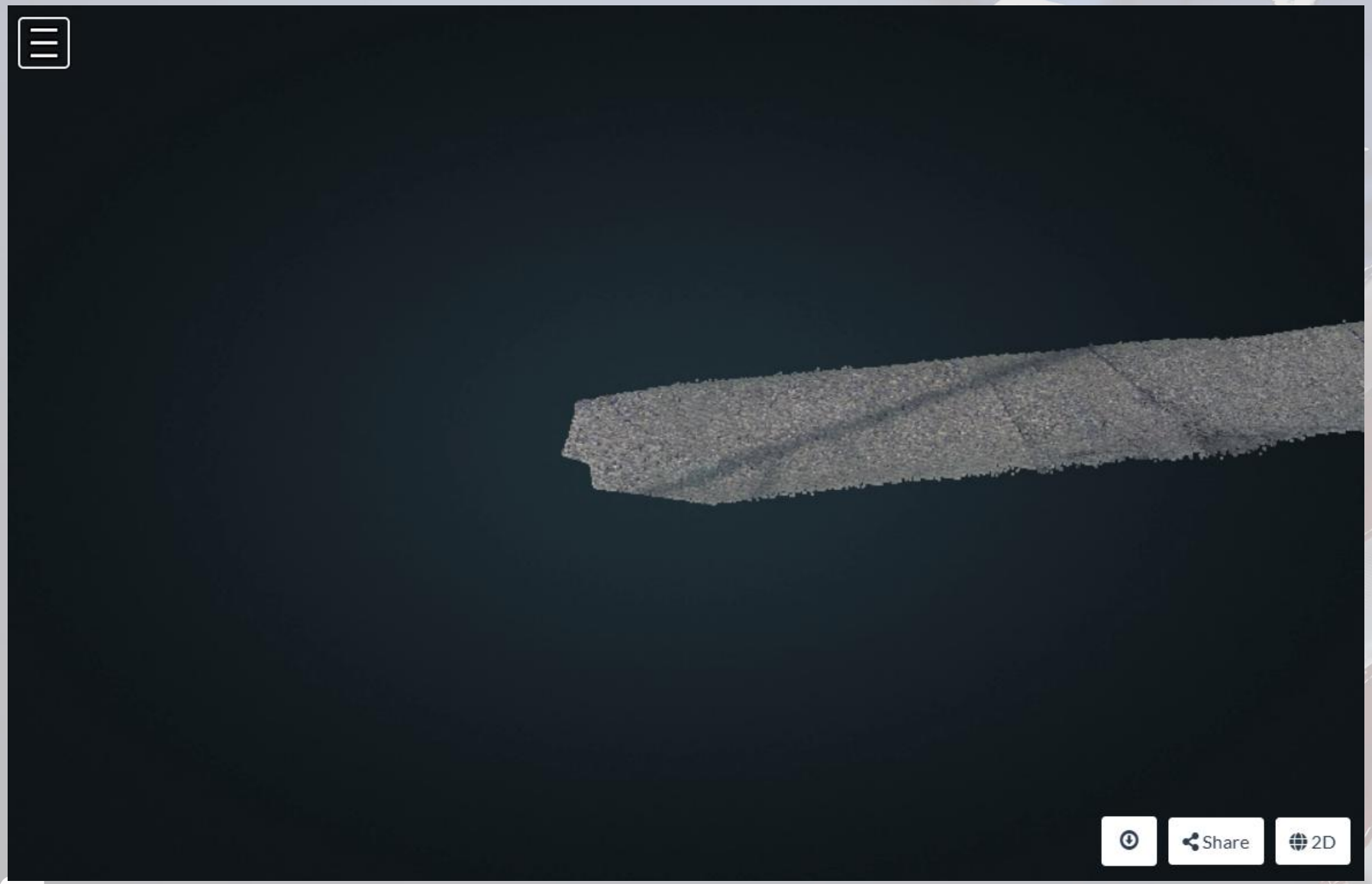
Prototype Setup

GPS antennas

Dual cameras shooting high-resolution images at high rates.

The prototype allows for inexpensive measurement of pavement surface characteristics, not just texture, and can also be used as a general mapping tool.

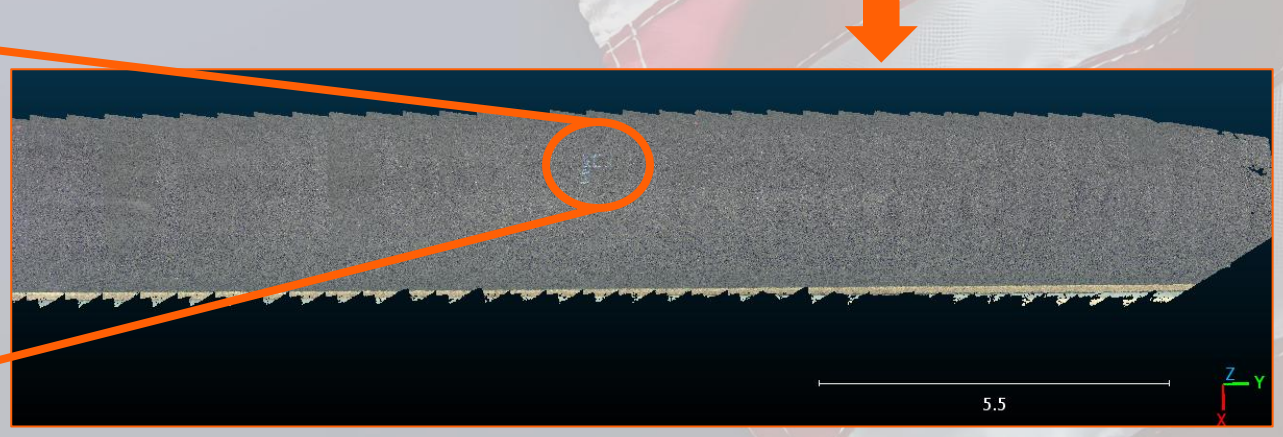
Demo



CART Validation

DATA COLLECTION - Laser

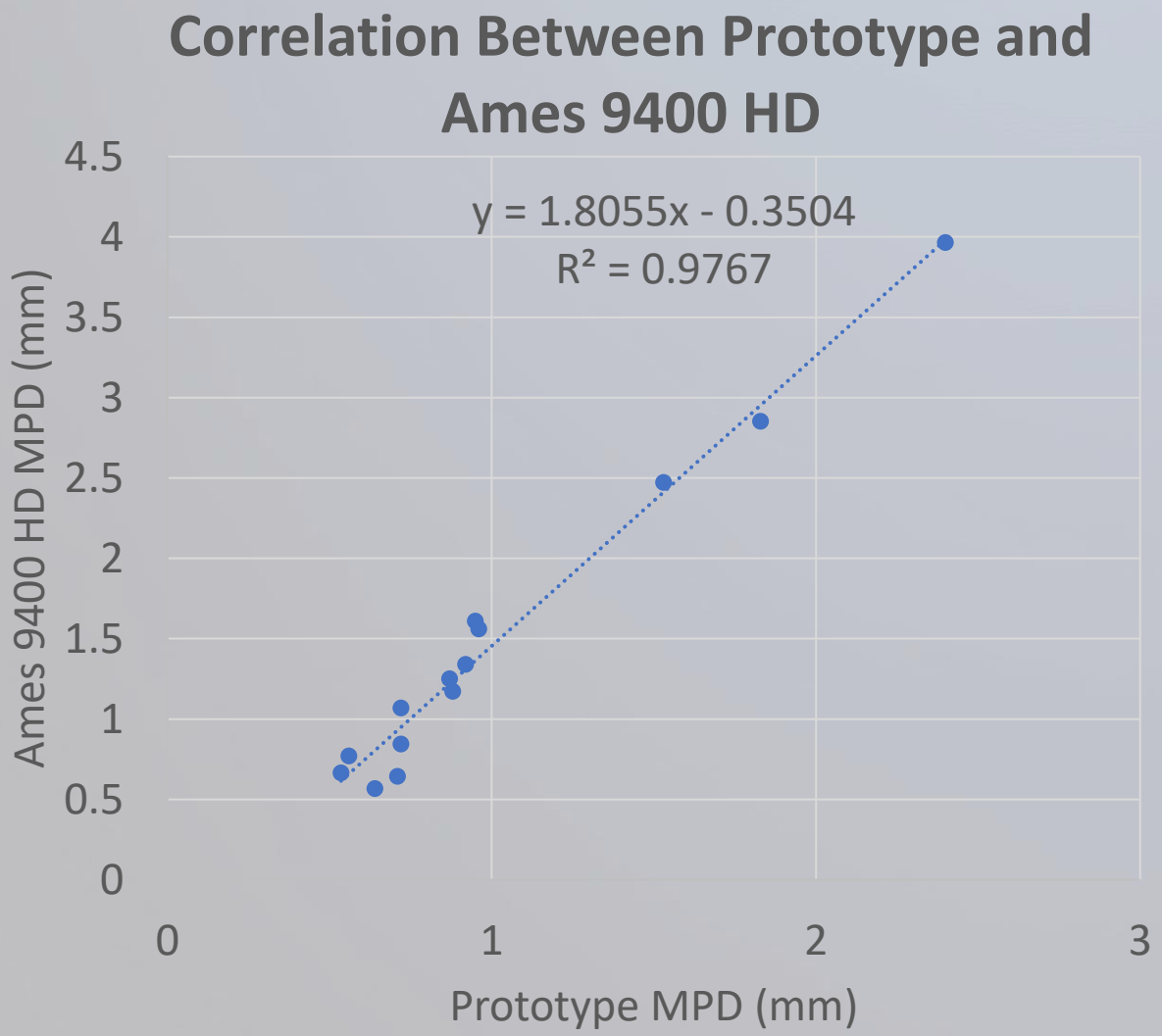
DATA COLLECTION - Prototype



Surface 3D Reconstruction

Measurement comparison

Measurement Comparison



- Correlation coefficient between AMES 9400 HD and prototype is 98%.
- An equivalent measurement to the laser device:

$$MPD_L = 1.805MPD_P - 0.35$$
$$for\ 0.5mm < MPD_P < 2.5mm$$

- where MPD_L is measurement from AMES device and MPD_P is prototype measurement.

System Highlights

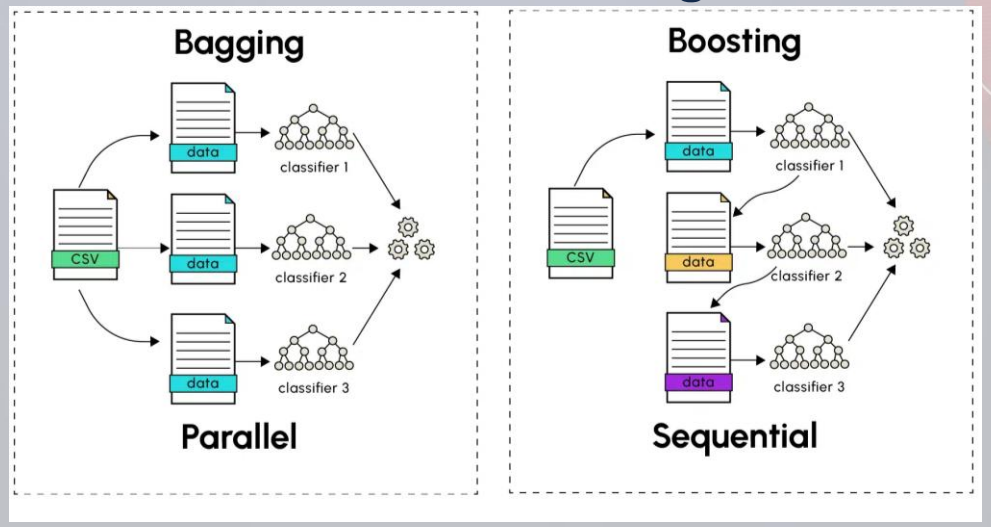
- ~ 0.5 mm point cloud resolution
- Processing scales horizontally with multiple compute nodes
- Measurements correlate well with laser system
- Currently operates up to 35 mi/hr, and up to 45 mi/hr with software refinements

Predicting Friction

To predict friction, a model that uses the measured texture as an input was developed.

Texture data → **?** → **Friction**

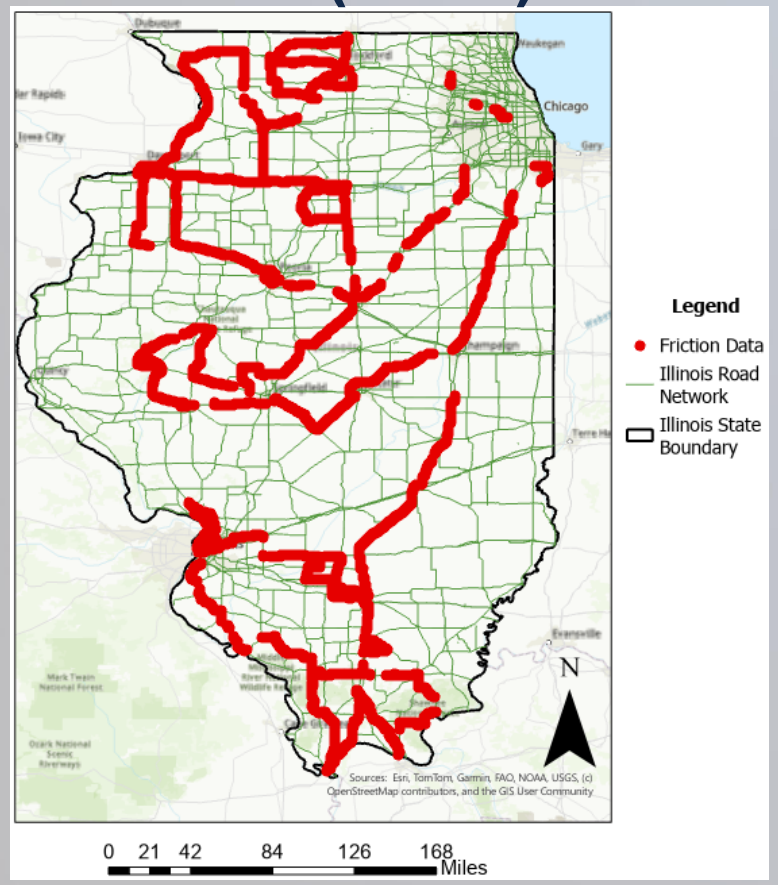
Ensemble Learning



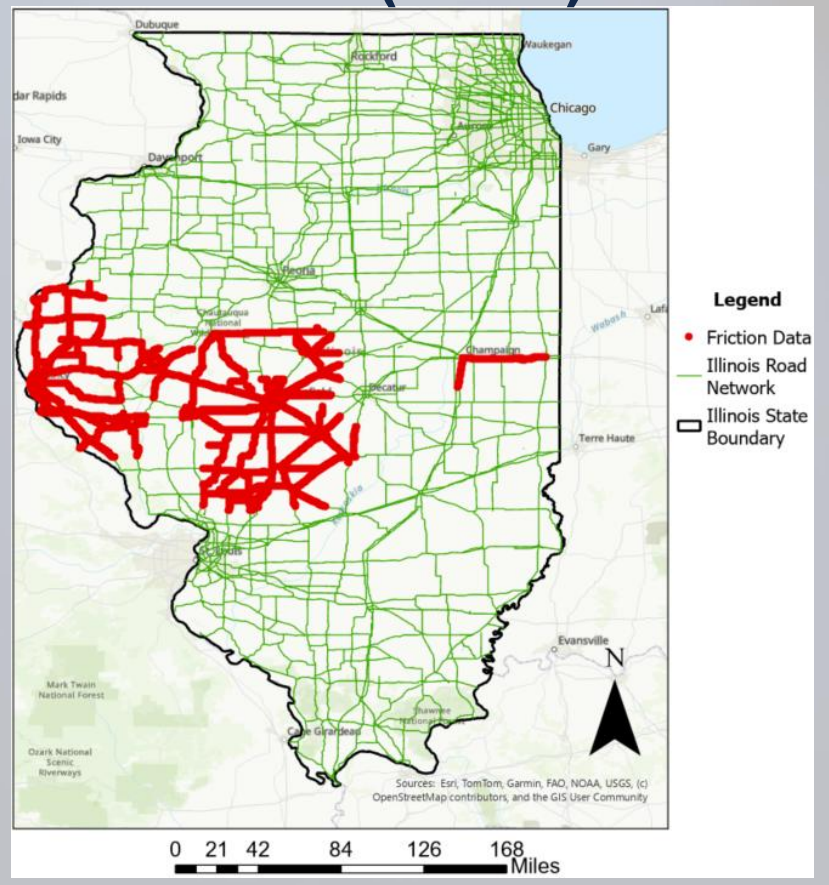
- **Random Forest**
- **Extra Trees**
- **Gradient Boosting**
- **XGBoost**

Data Source

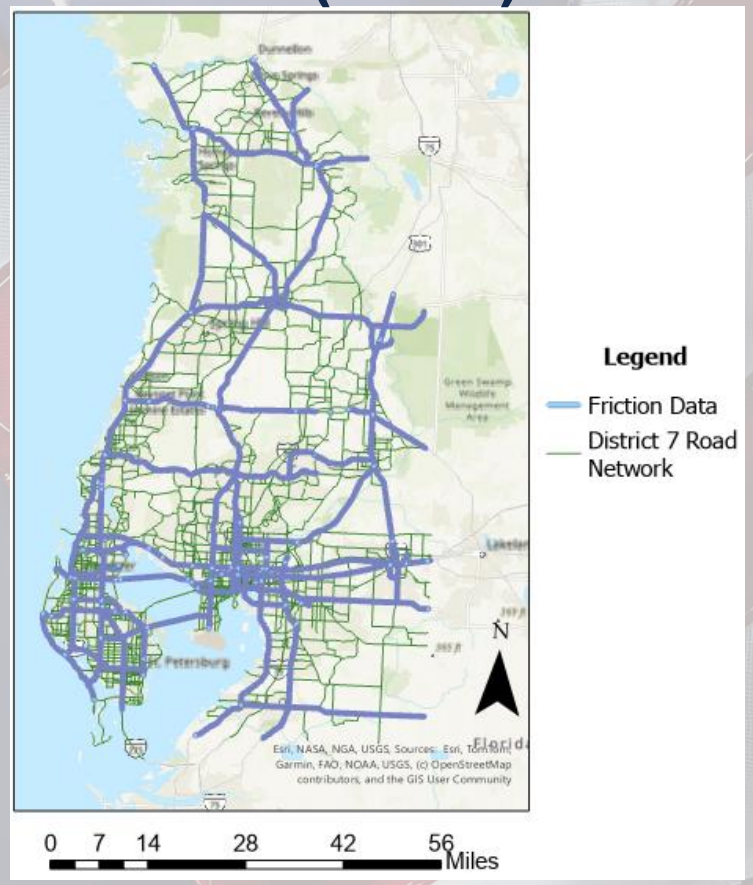
Illinois (2023)



Illinois (2025)



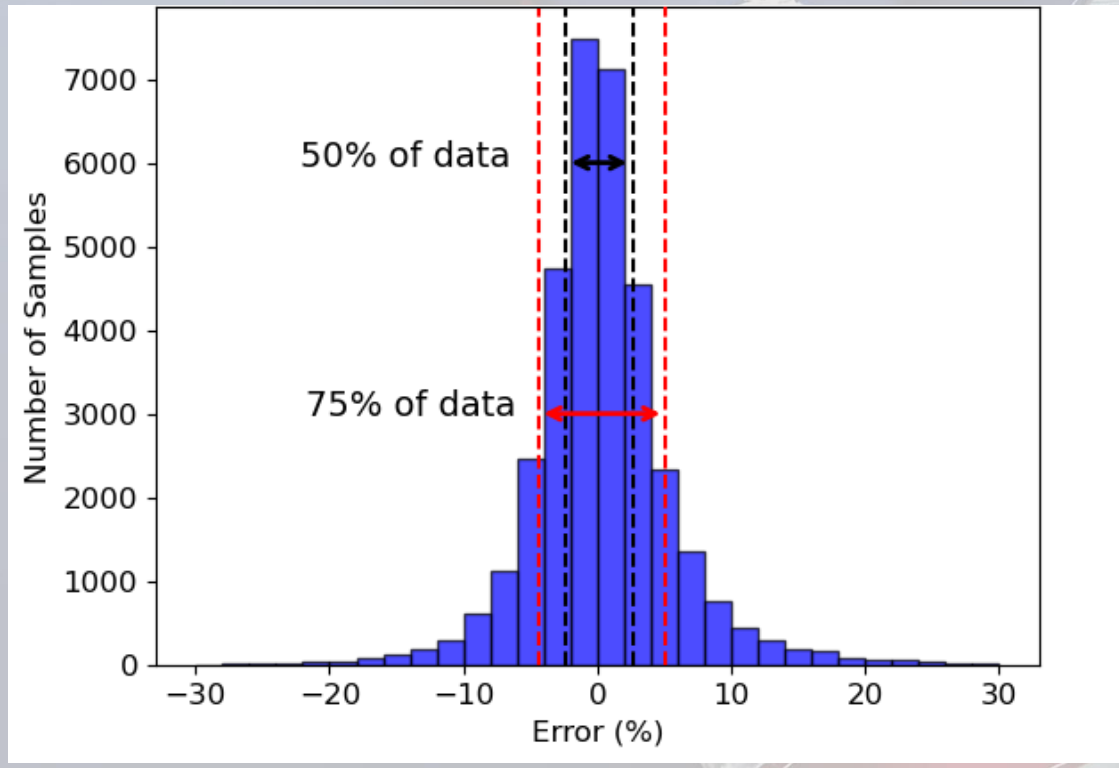
Florida (2024)



Results

Extra Trees achieved the best performance and was also the fastest to train.

MODEL	R^2	MAE	RMSE
RANDOM FOREST	82%	1.96	2.96
EXTRA TREES	83.16%	1.89	2.85
GRADIENT BOOSTING	81.66%	1.99	2.99
XGBOOST	82%	2.02	2.95



The results show that with sufficient training data in diverse scenarios, data-driven models can predict surface friction with high accuracy.

Impact for Agencies and Vendors

- **New option for pavement surface data collection.**
- **Lower cost compared to current state of practice.**
- **Expanded testing in rural areas.**
- **Technology is transferable to normal vehicles (including autonomous vehicles), which can provide wide coverage of road networks.**

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Thank you! Any Questions?