# Continuous and Contactless Friction Measurement

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# Acknowledgements

- **Professor Imad L. Al-Qadi and Professor Mani Golparvar Fard**
- **Illinois Department of Transportation, Federal Highway Administration**
- **Technical review panel, special thanks to John Senger**
- **ICT research engineers**
- **ICT students and staff**

# Introduction

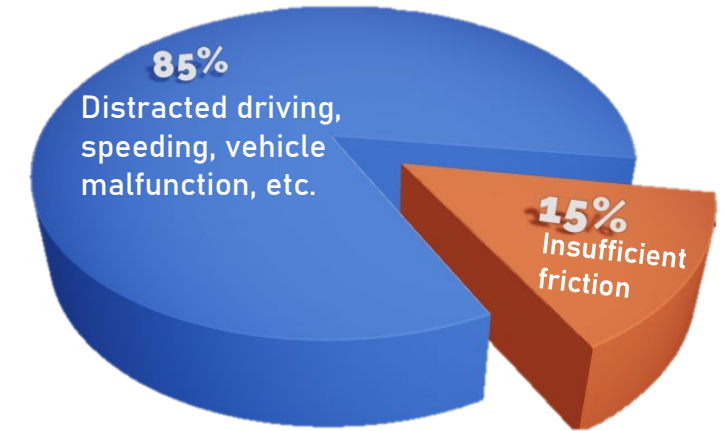## United States

**6 Million crashes annually**

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

## Illinois

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

## Crash Causes

**85%**
Distracted driving, speeding, vehicle malfunction, etc.

**15%**
Insufficient friction

**Maintaining adequate friction on roads is critical for traffic safety.**

# Current State of Practice


Source: TxDOT
**Locked Wheel Skid Trailer**


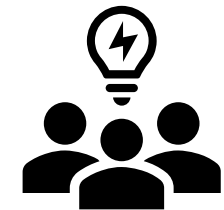Source: The Transtec Group
**GripTester**


Source: VTTI
**Sideway Force Coefficient Routine Investigation Machine (SCRIM)**
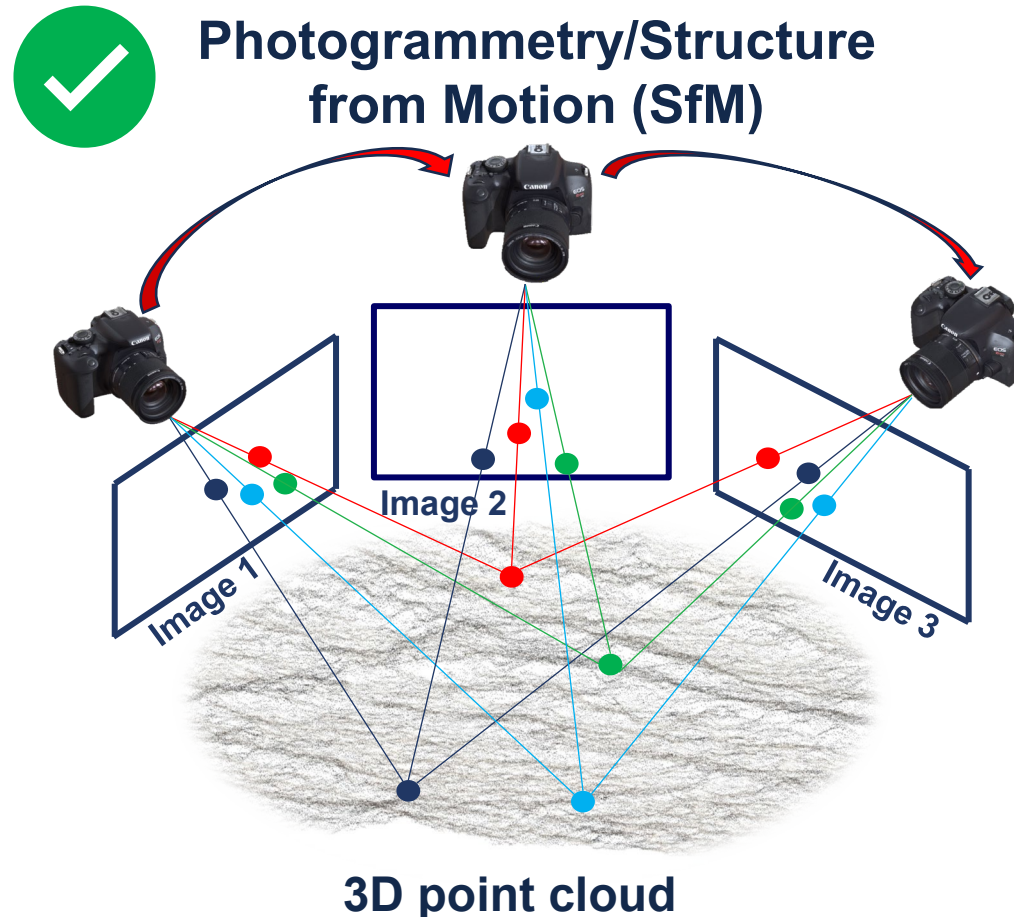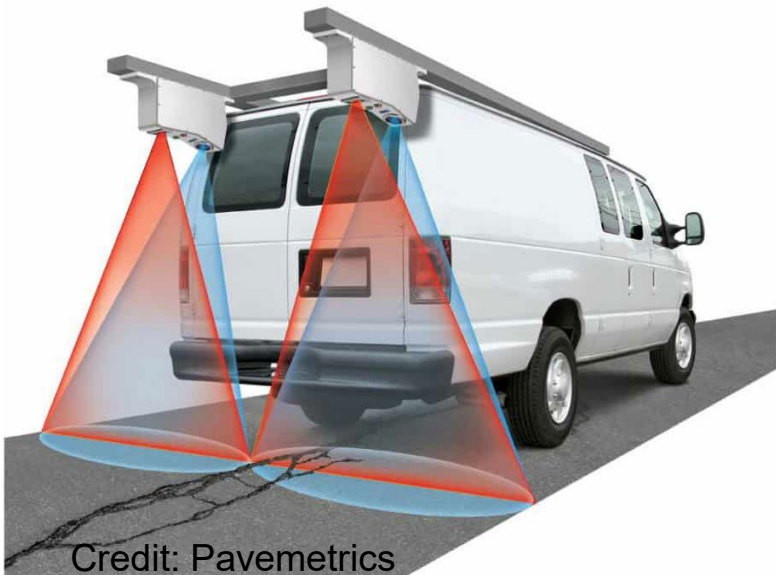
## Limitations:

- **Relatively expensive to own and operate**
- **Variable measurements**
- **Require extensive training**
- **Spot/sporadic measurements**

**Alternative methods are needed.**

# Contactless Friction – Texture Measurement

**To reduce the cost and complexity of routine friction testing, a contactless technique is being developed for pavement surface friction testing.**



**Photogrammetry/Structure from Motion (SfM)**

**High-speed laser scanning**

Credit: Pavemetrics

Image 1

Image 2

Image 3

**3D point cloud**

**Advantages:**

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

# Network-Level Measurement Challenges Using SfM

## Requirements for SfM to be viable for data collection at network level:

1. **Resolving the scale ambiguity**
2. **Imaging setup**
   a) Number of cameras, camera specifications
   b) Camera orientation, height, and spacing
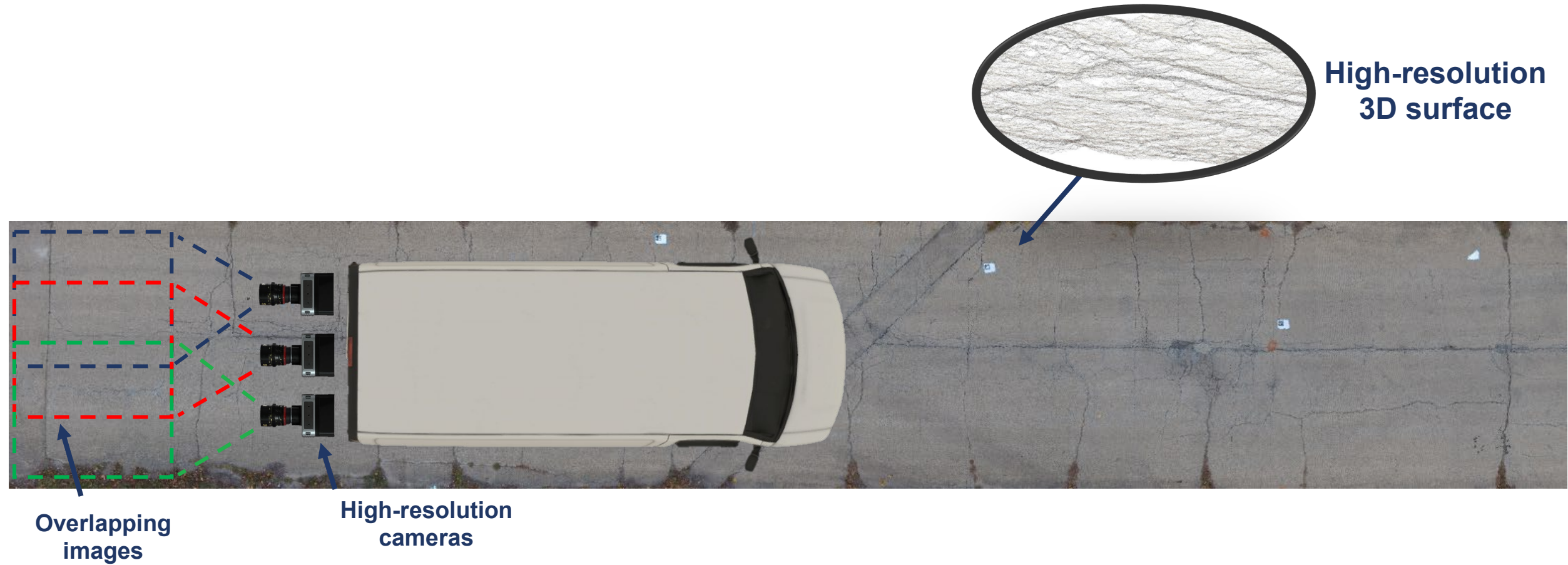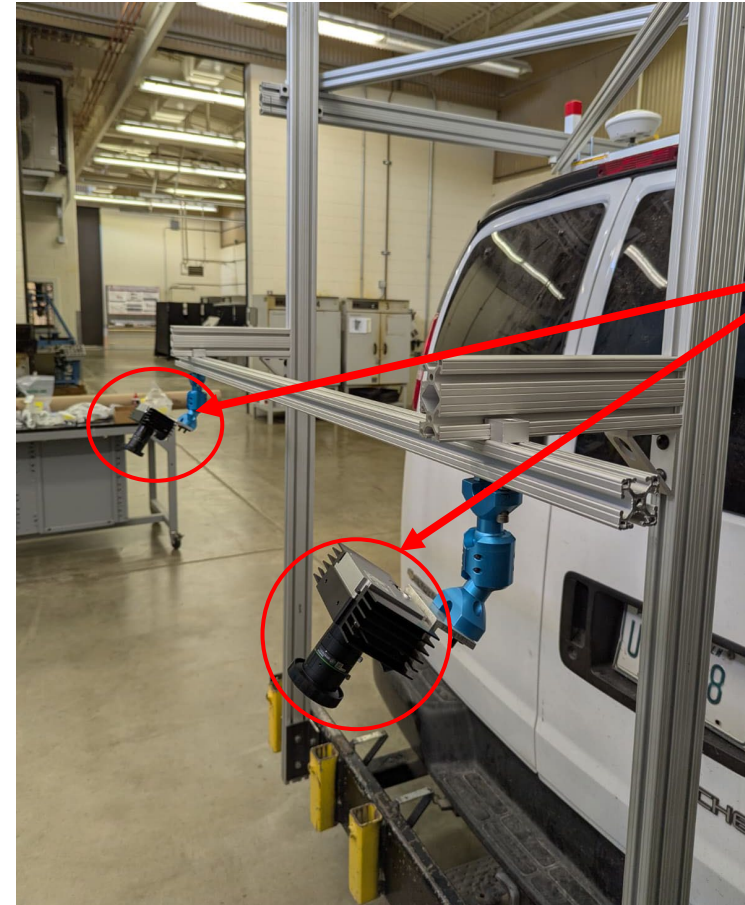3. **Efficient data acquisition system**



**Ruler for reference**

**Ground control point for reference**

# SfM Vehicle-Mounted System



High-resolution
3D surface

Overlapping
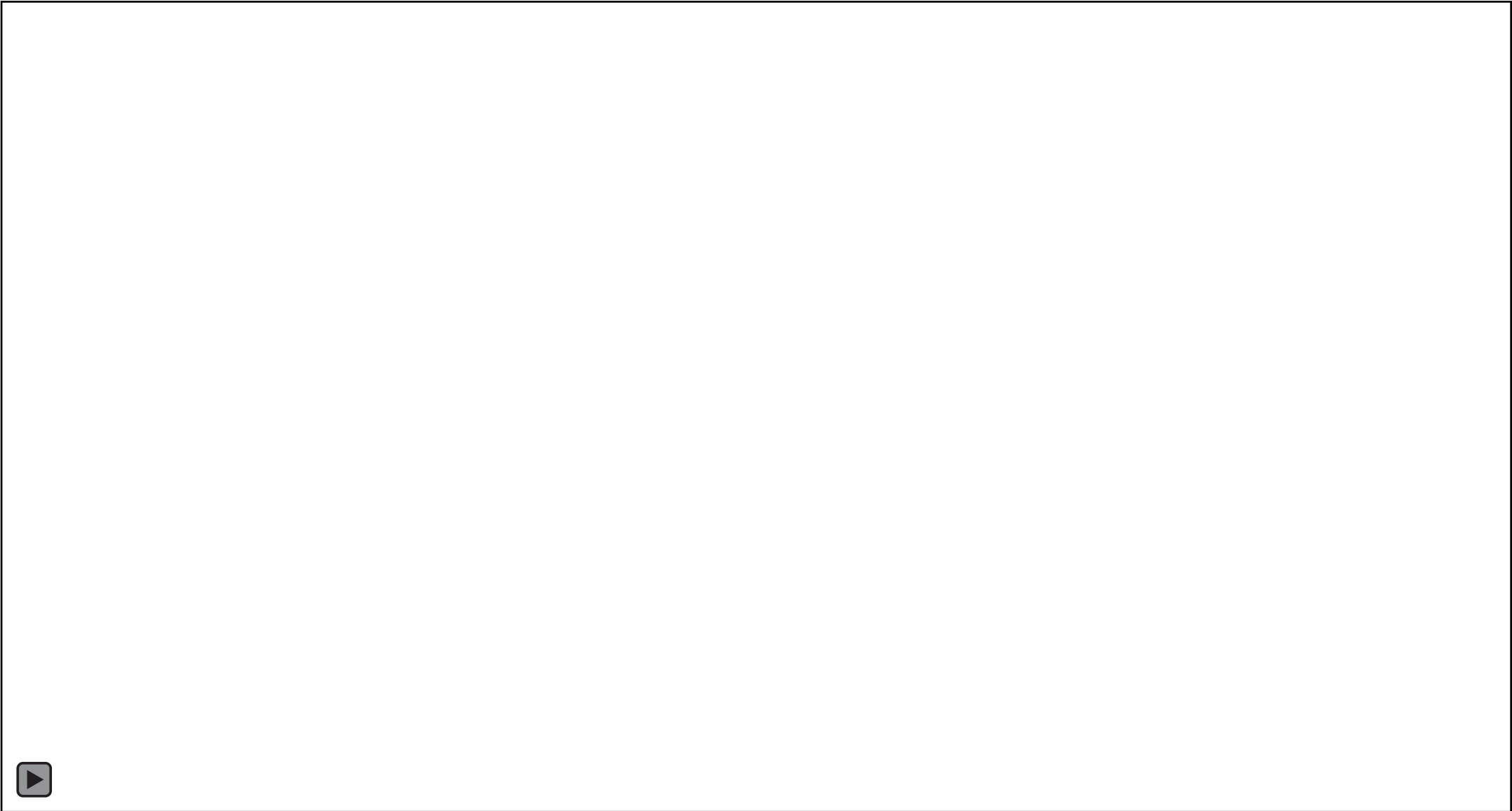images

High-resolution
cameras

# Prototype Setup



**Antennas for RTK GNSS receiver**

**Dual cameras shooting 24 MP images up to 100 fps.**

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

# Demo

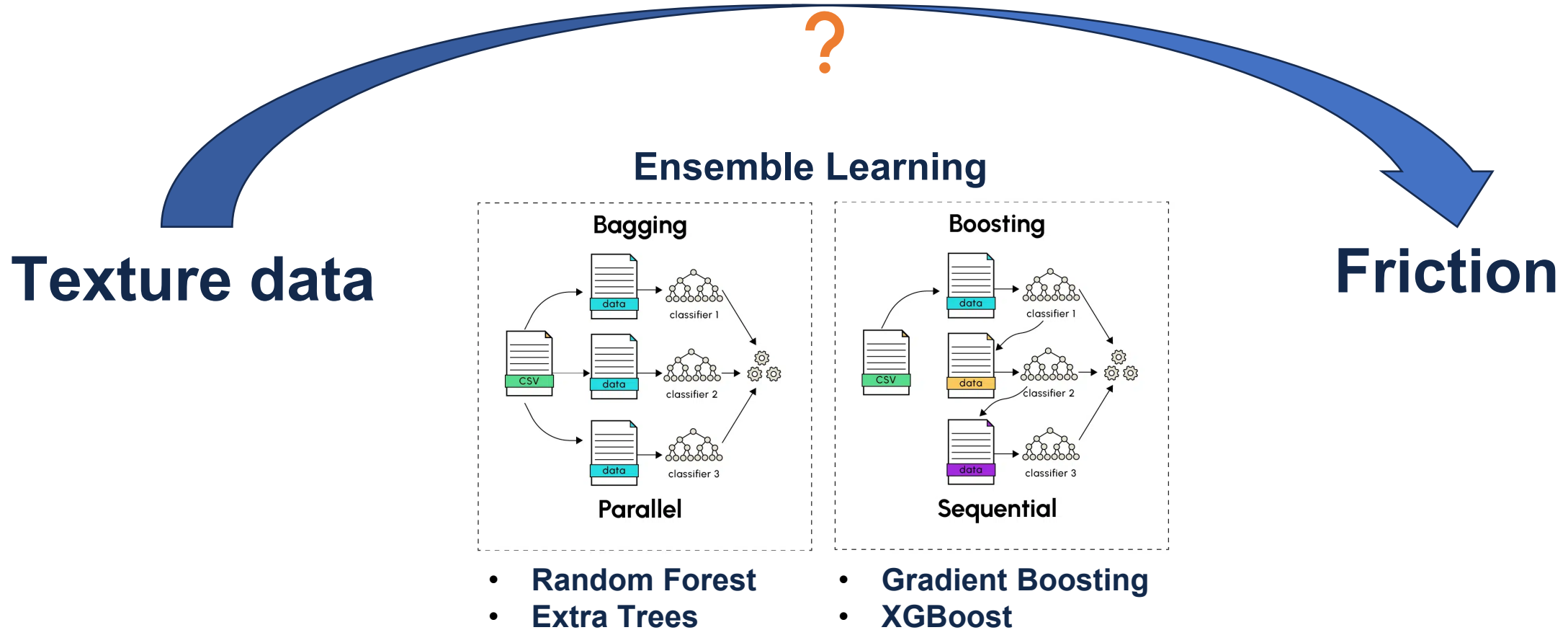# Results Highlights

- **0.5 – 1 mm point cloud resolution**
- **Fast processing: can be done on several computers simultaneously**
- **Automated texture extraction**
- **Correlates well with measurements from laser system**
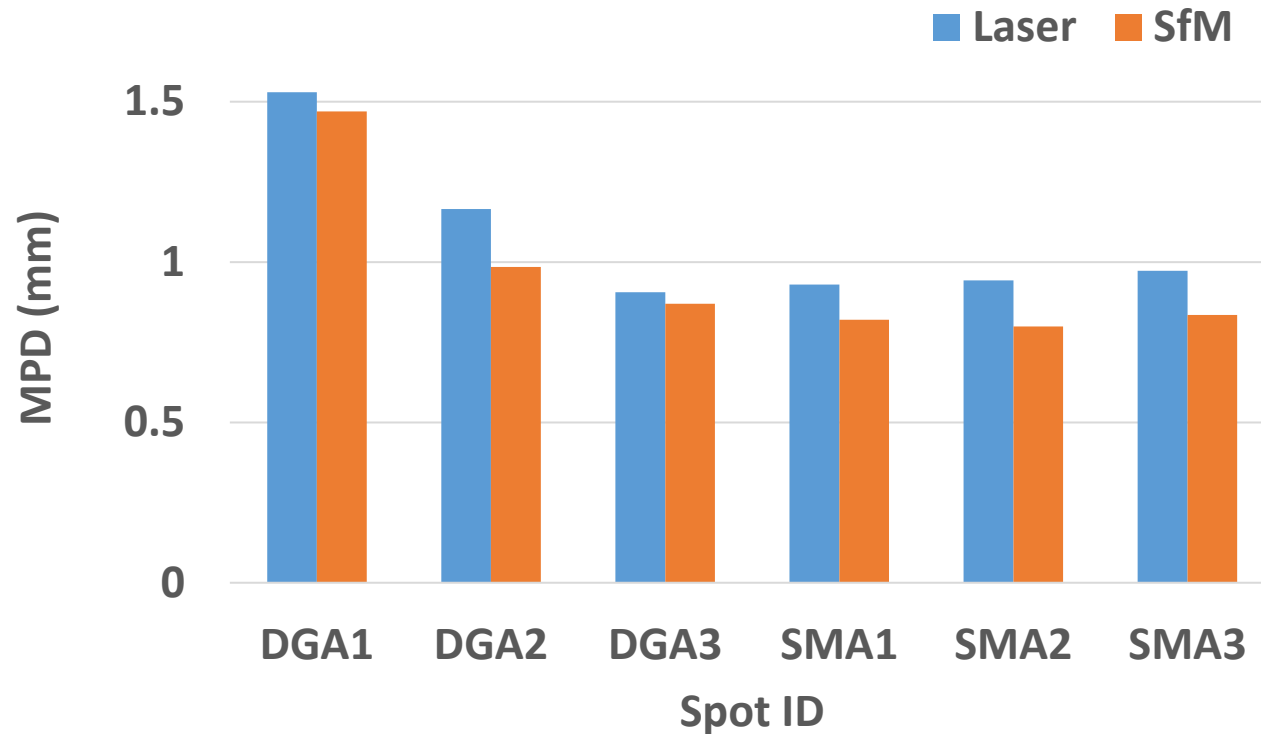


**94% Correlation!**

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



**Texture data**

**?**

**Friction**

**Ensemble Learning**

Bagging — Parallel
Boosting — Sequential

- **Random Forest**
- **Extra Trees**

- **Gradient Boosting**
- **XGBoost**

# Data Source

## Friction Equipment




Test tire
Water hose

## Illinois Data



Legend
• Friction Data
— Illinois Road Network
▢ Illinois State Boundary

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community

0  21  42        84        126        168
Miles

## Florida Data



Legend
— Friction Data
— District 7 Road Network

Esri, NASA, NGA, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community

0  7  14        28        42        56
Miles

**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 |
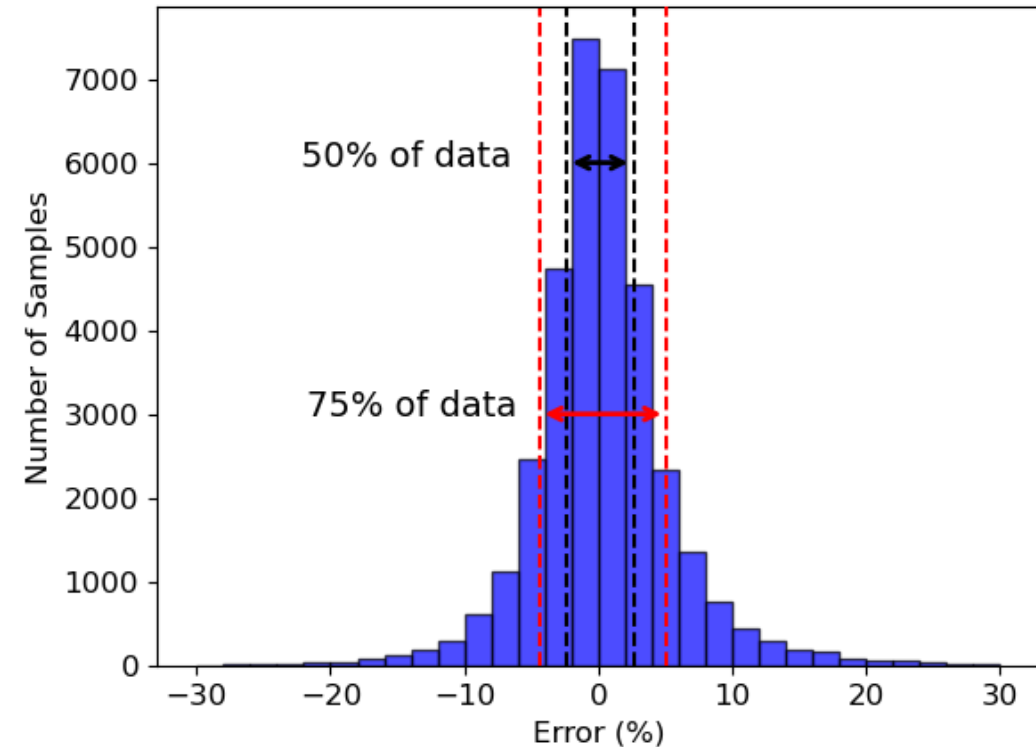


**The results show that with sufficient training data in diverse scenarios, data-driven models can predict surface friction with high accuracy.**

- **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.**

# Thank You
# Questions?

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