AI & Its Potential Impact on Future Pavement Evaluations

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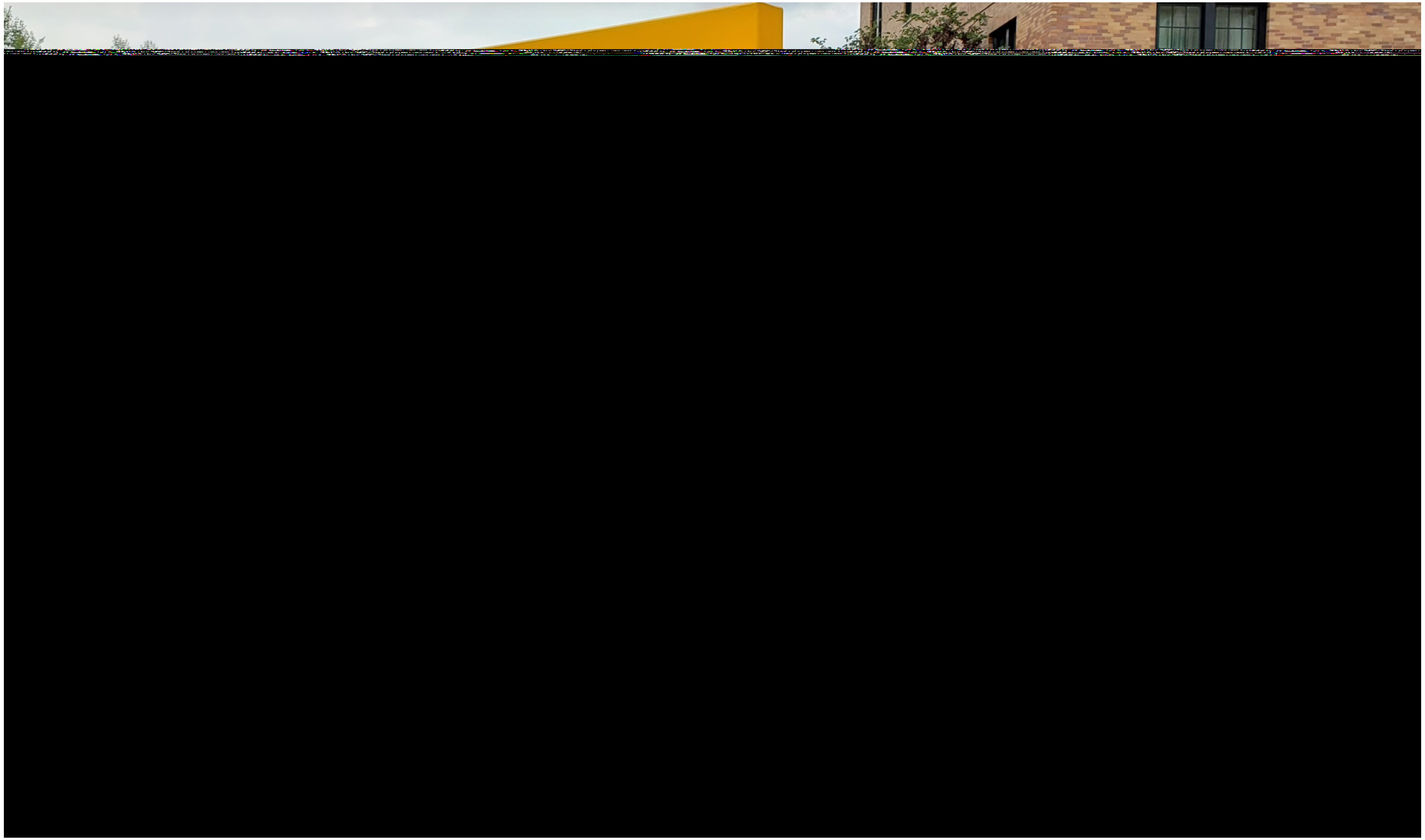
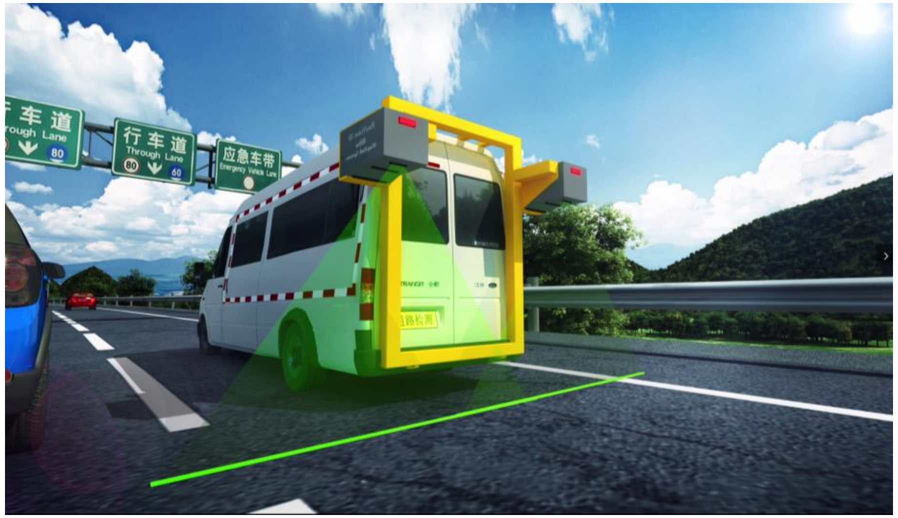
Introduction to Western Transportation Institute (WTI)

- Major Research Institute in Transportation in the US
- Known for Rural Transportation Research
- WTI in Bozeman, MT; Montana State University
  - $10million Annual Research Expenditure at its Peak with 50 Staff Members
  - Will Grow in Safety Research & Automated Evaluation

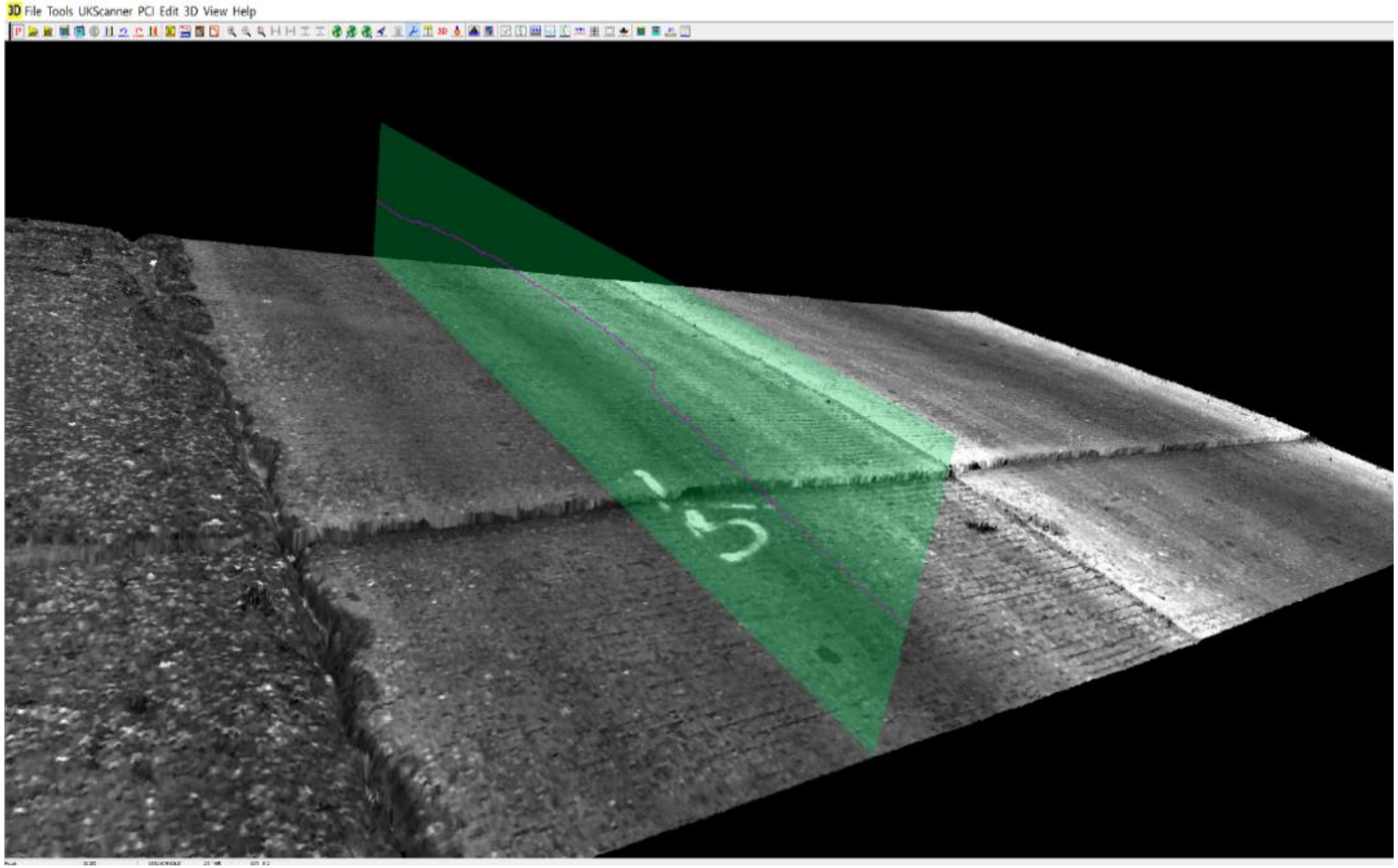
0.5-mm 3D, Pave3D 8K After 30 Years



30-Year Commitment

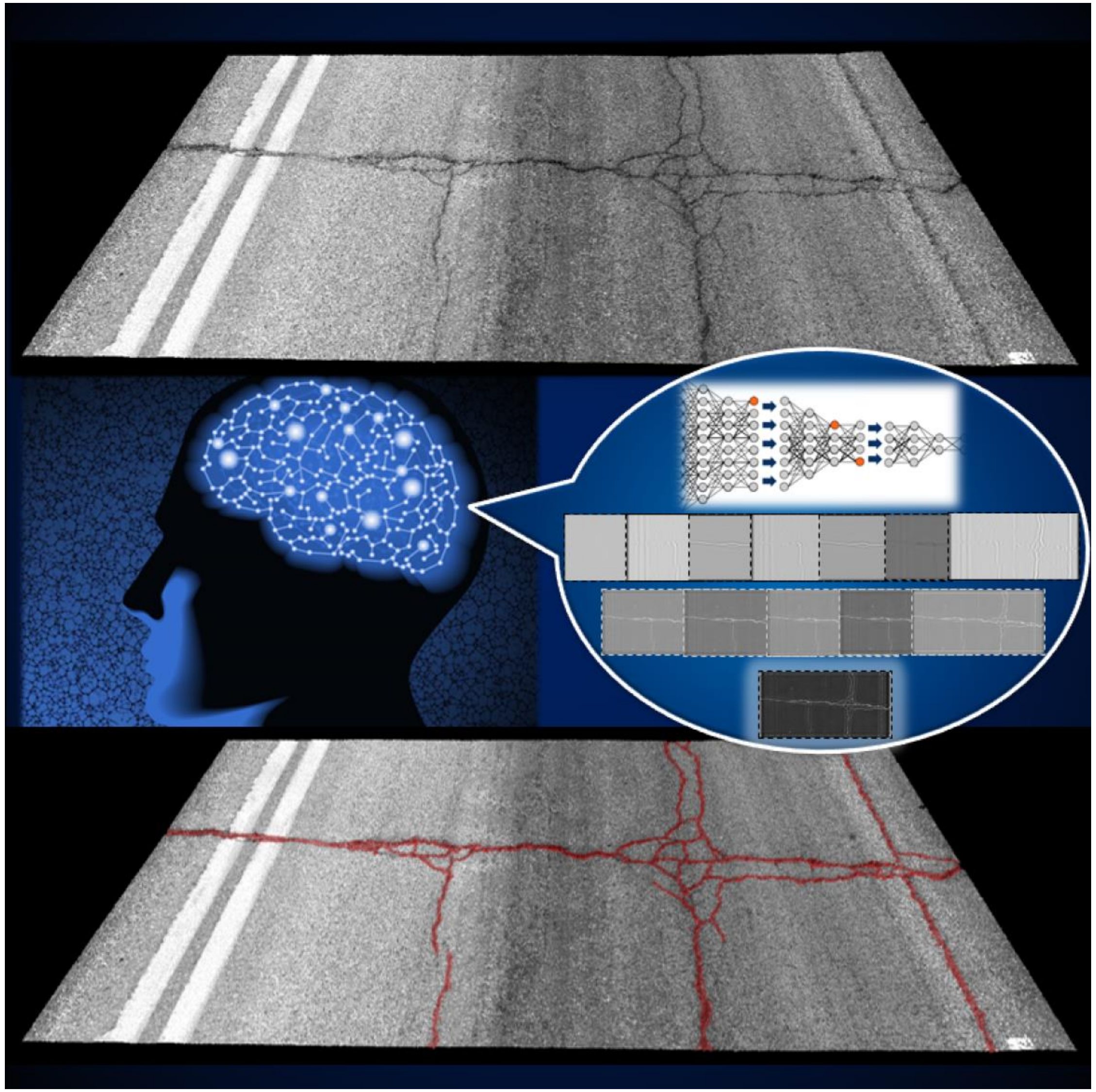


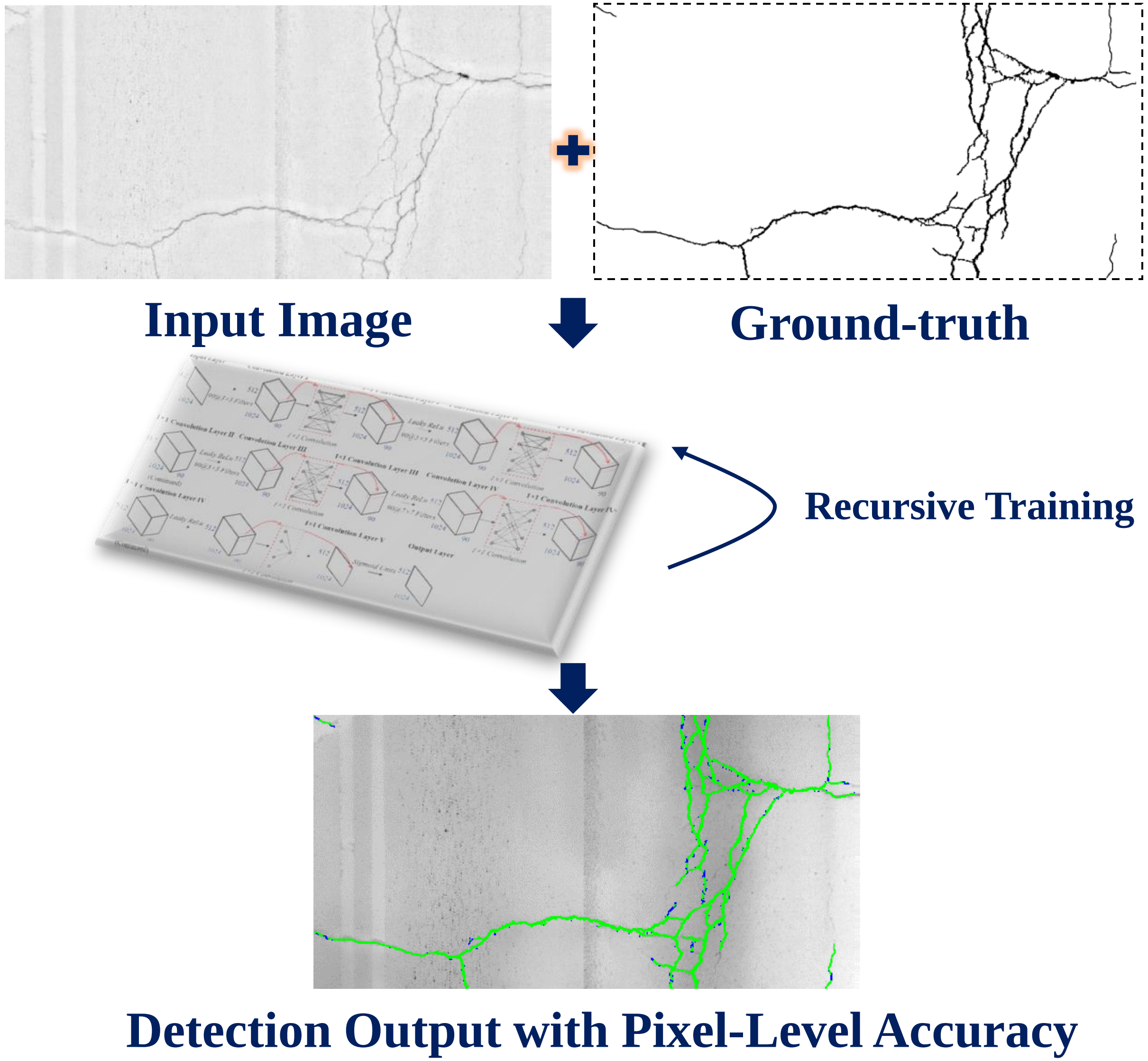
Speed: 100km/h



Resolution: 1mm

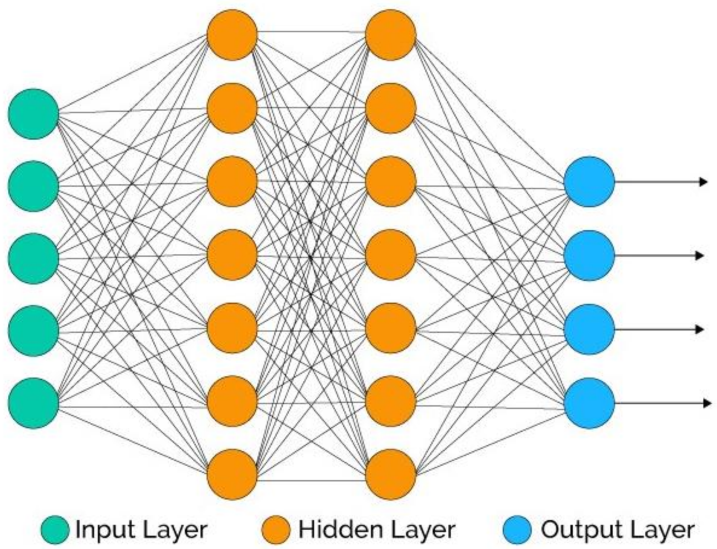
CrackNet



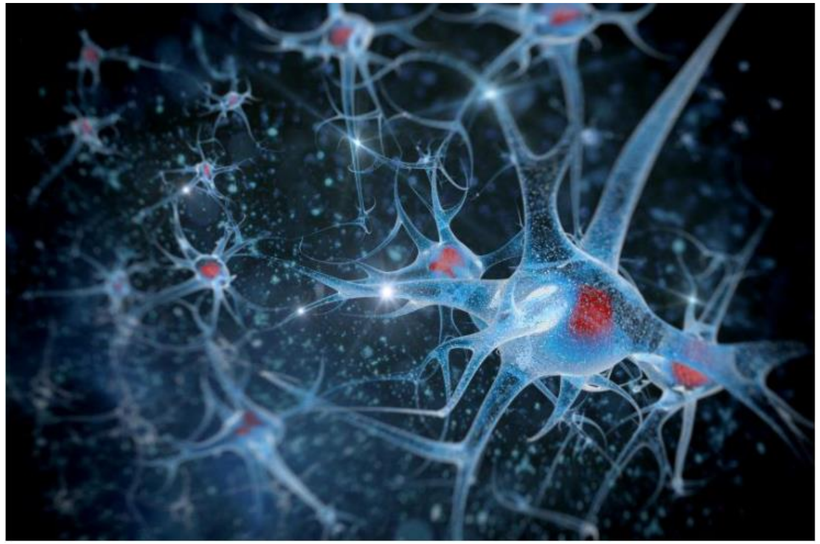


(Zhang at al. **2017**, in Computer-Aided Civil and Infrastructure Engineering)

Traditional Artificial Neuron Network (ANN)



# of Neurons<10^4

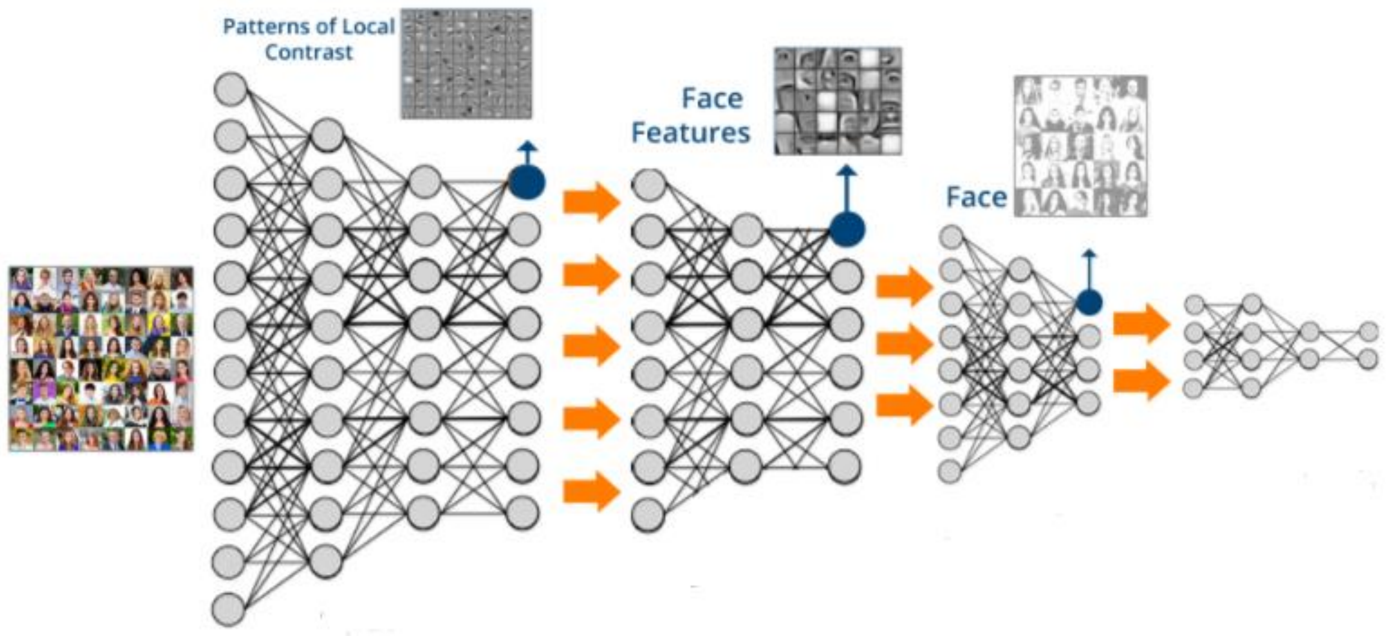


# of Neurons=10^{11} (Human Brain)

- Shallow Abstraction
  - Limited Number of Layers & Neurons
  - Cannot Fully Reflect the Complexity of Problems
- Limited Amount of Data

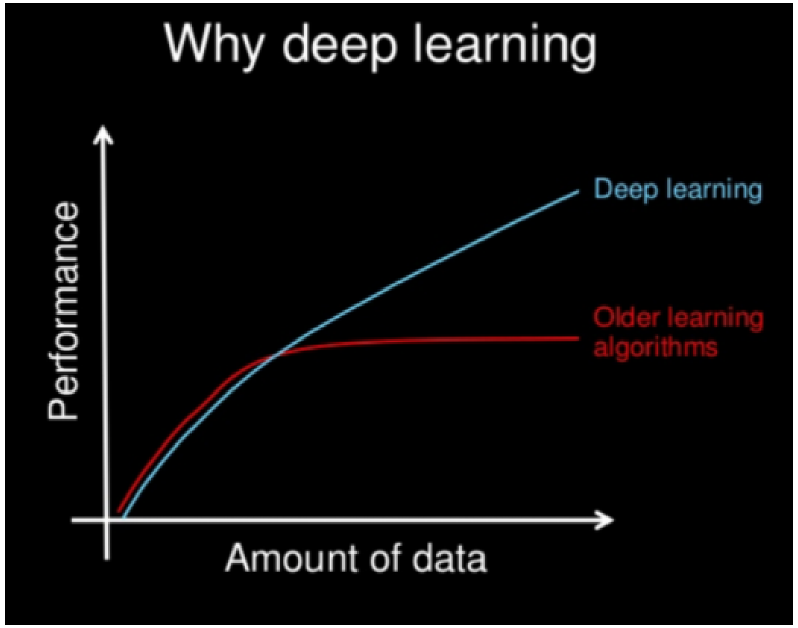
Deep Learning: New Generation of ANN

- ❑Deep Abstraction: # of Layers: 10^1-10^3, for Complex Problems
- ❑Complex Connections Among Neurons: 10^2-10^4 per Neuron
- ❑Enhanced Reliability: Exhaustive Variations of Example Data
- ❑High-Performance Processing: **Critical**



Why Deep Learning?

- ❑Strong Learning Ability and Versatility
  - ➢ A DL Network: Multiple Types of Objects (Pavement Distresses)
- ❑Enhanced Reliability
  - ➢ Feed with Exhaustive Variations of Examples
- ❑Learning/Knowledge Accumulation
  - ➢Similar to Human Learning Process



Some Insights in Deep Learning

- Artificial Neurons: Simulating Humane Neurons
- Large # of Neurons & Layers
- Key: Connecting Weights between Layers of Neurons
  - Low Resolution of Weights: around 8-bit or less simulating range of signal variations of humane neurons
  - GPUs: perfect for massive parallel processing at low resolution
  - Very Sparce & Huge Matrix Operations: new hardware
- Many New Methods on Deep-Learning by Large Firms
  - Innovations to determine weights for higher performance
- Learning/Training and Inferencing: two separate processes

Applications of Deep Learning

- Cognition based Classification
  - Perfect for Cracking Identification, like CrackNet
  - Can be very fast depending on GPU & Platform
- Other Problems in Pavement Evaluation
  - Non-Cracking Visual Distresses
  - Pavement Safety
- "Long-Shot" Pavement Problems
  - Relating Surface Deflections to Layers' Moduli?
  - Pavement Materials Properties
  - Specific Challenges in ME based Pavement Design

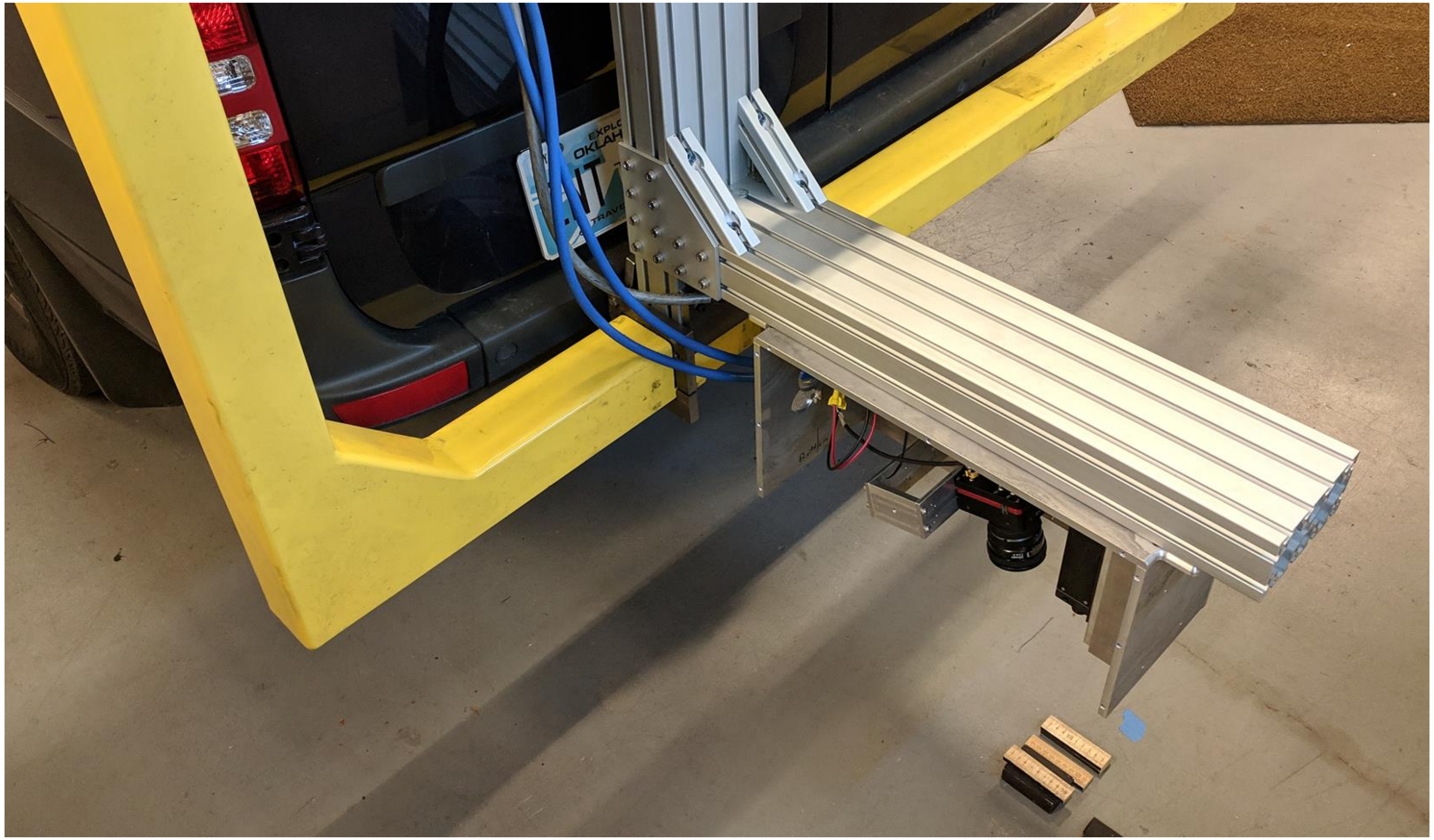
Introduction to Non-Contact Safety Sensor

- Pavement texture, friction, and hydroplaning: three main aspects in performing pavement safety evaluations
- Not possible: microtexture at highway speeds
- Current friction testing devices: expensive, hard to maintain, unable to perform network friction evaluation, & data accuracy-repeatability in question
- Need a new approach to collecting pavement safety information in a true non-contact and continuous manner for network survey

Factors in Pavement Safety Evaluation

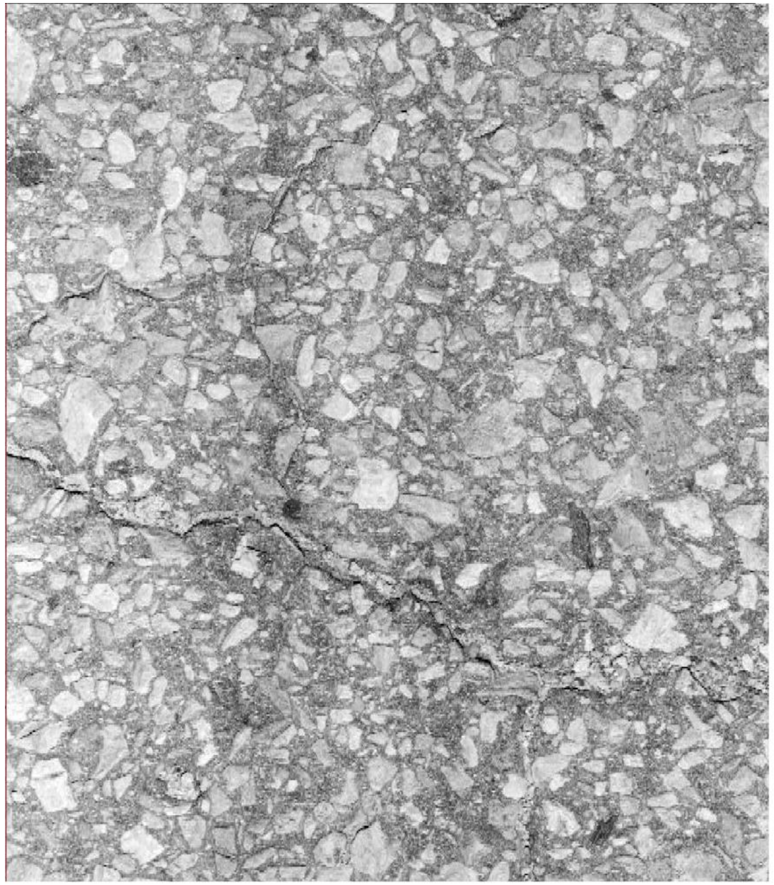
- Pavement texture, friction, and hydroplaning: three main aspects in performing pavement safety evaluations
- The number and severity of traffic crash: increase when roadway sections have low friction numbers or texture depth
- Highway locations with a propensity for hydroplaning: identified and corrected with proper remedies to minimize the potential safety risks

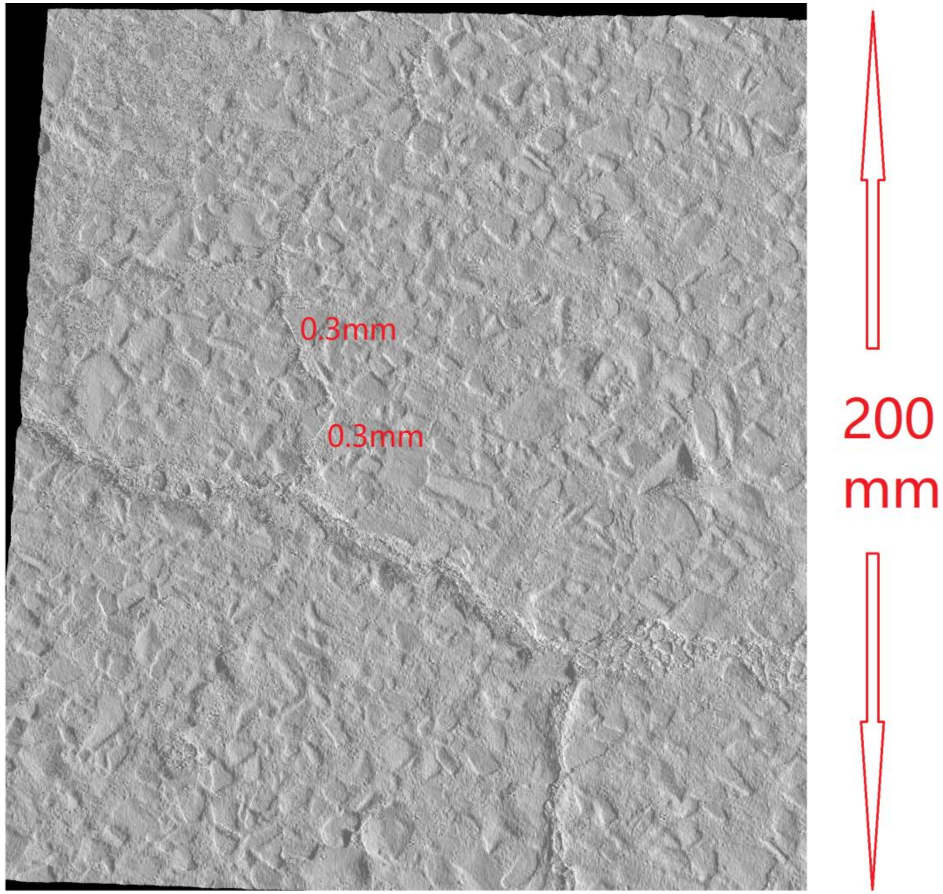
Prototyping 0.1-mm 3D Laser Imaging



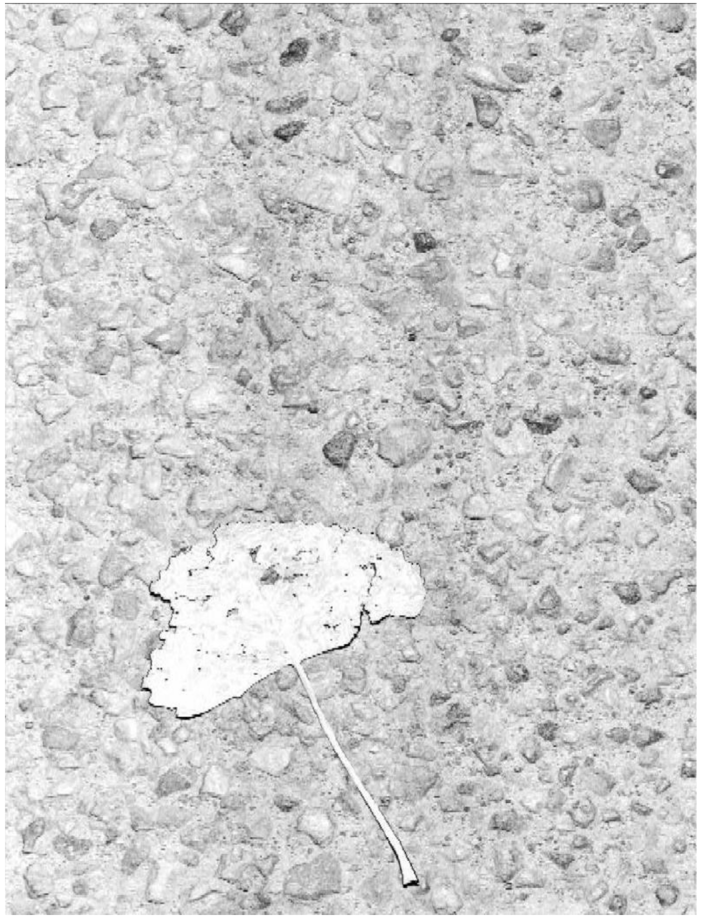
Current 0.1-mm 3D Safety Sensor

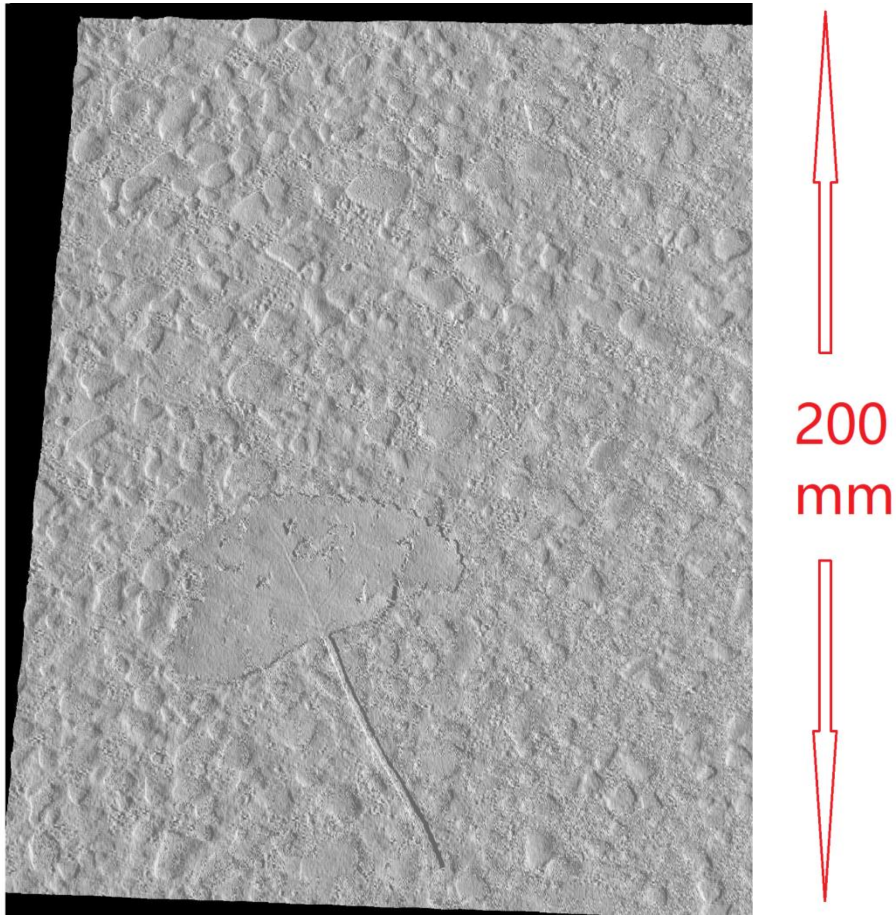
Samples of 0.1mm 3D Pavement Surface





Samples of 0.1mm 3D Pavement Surface





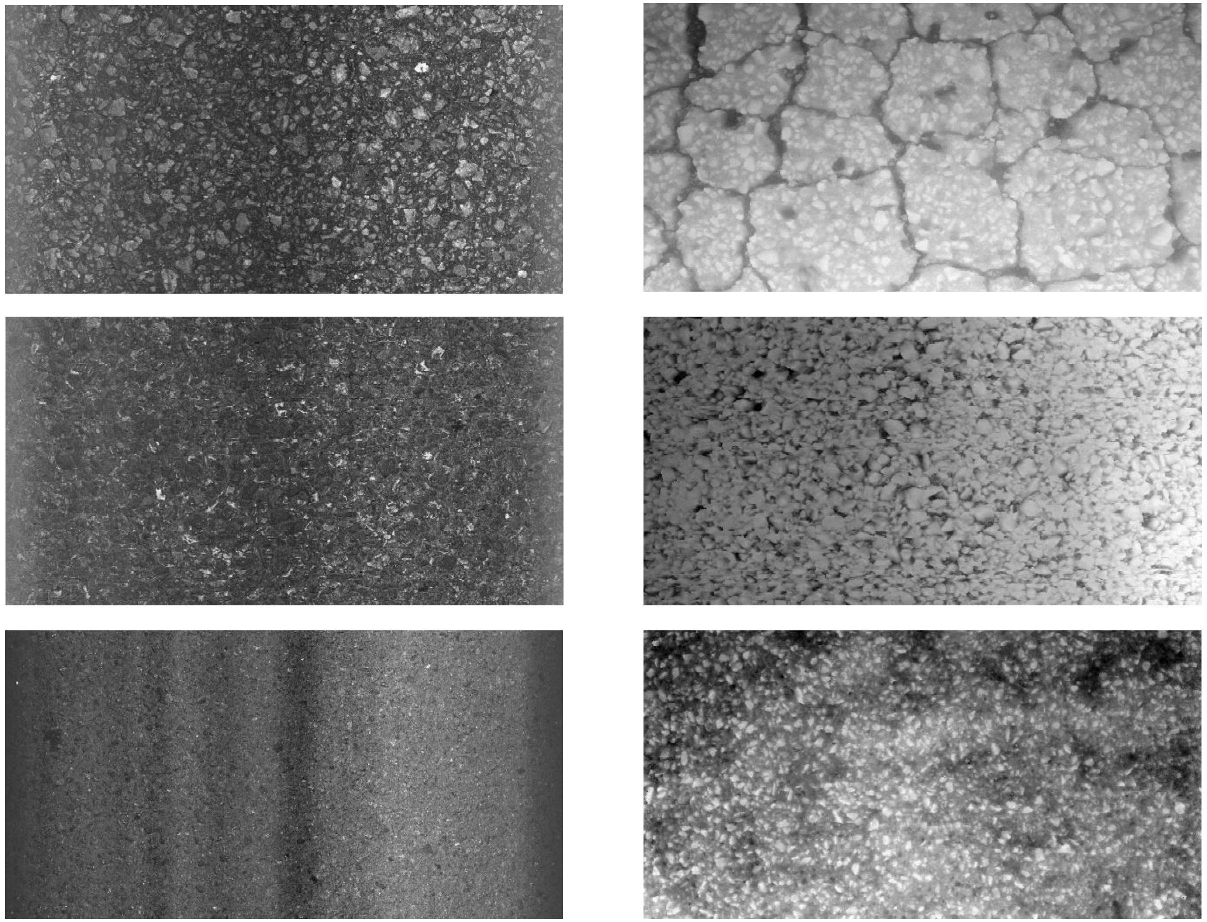
Example Images of 0.1 mm Safety Sensor

2D Images | **3D Images**

Very old AC

SMA

Micro surfacing



Asphalt Pavements

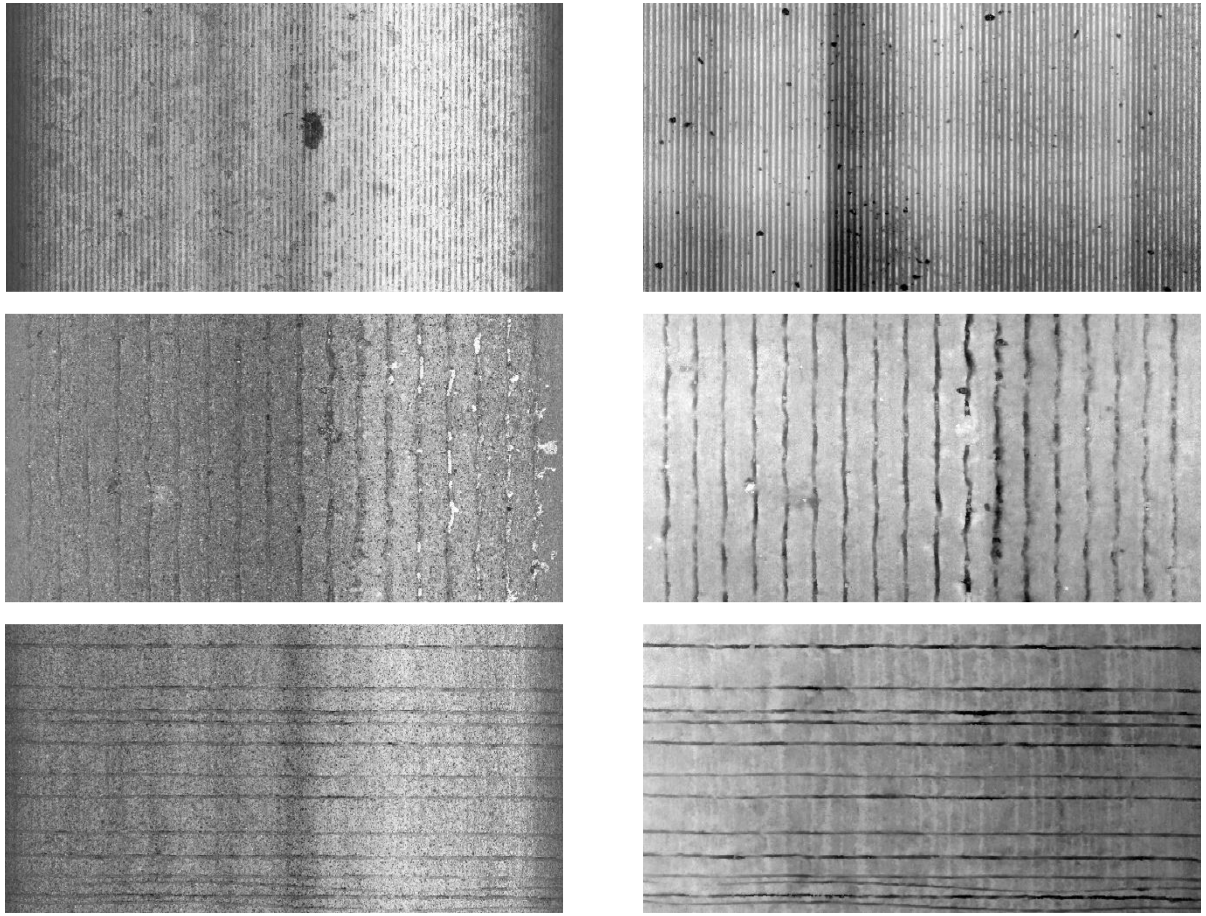
Example Images of 0.1 mm Safety Sensor

2D Images **3D Images**

Diamond Grinding

Groove

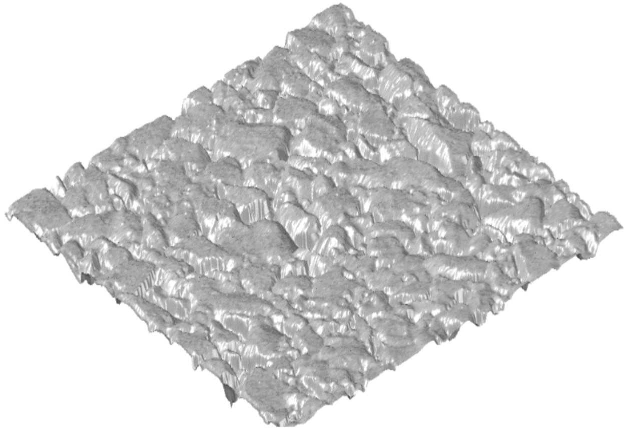
Transverse Tining



Concrete Pavements

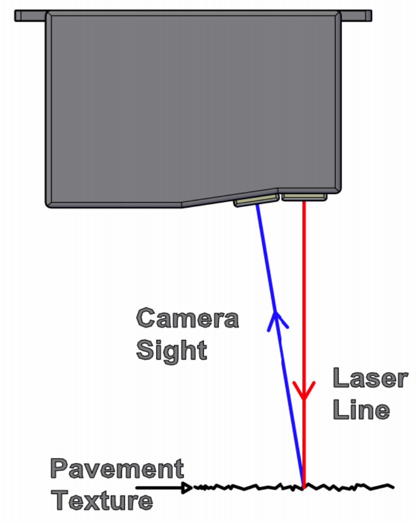
Need of Ultra-High Resolution for Safety Sensor

- Using three-dimensional (3D) imaging technology for pavement texture evaluation
- Stationary devices for 3D texture evaluation
  - Collect high resolution 3D texture images statically
  - Unable to conduct network texture evaluation



Objective

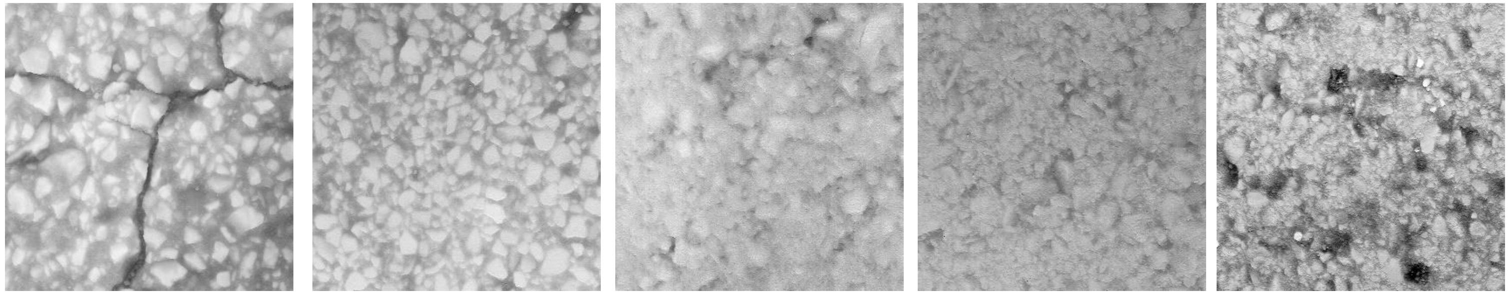
- Reconstruct 0.1 mm 3D texture data using PT-SRGAN at highway speed
    - 0.1 mm 3D data along transverse direction
    - Resolution along longitudinal/travel direction
    - Need to increase the longitudinal/travel resolution
    - Super Resolution (SR) Techniques



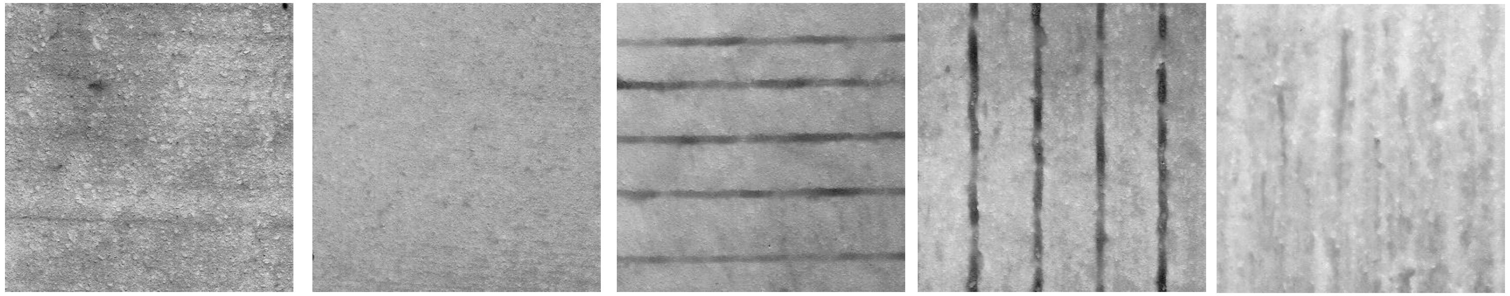
Data Collection

- Collect true 0.1 mm texture data at a speed < 1 mph via 0.1 mm 3D Safety Sensor
  - 10 road surface types (5 AC and 5 PCC)
  - 1468 images for model training, validation, and testing

5 AC

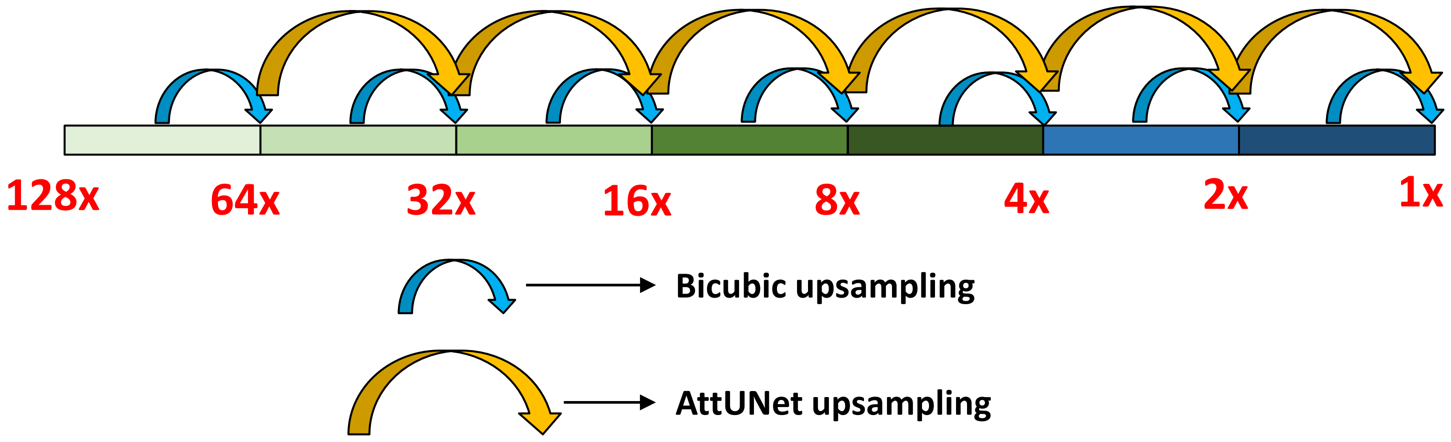


5 PCC



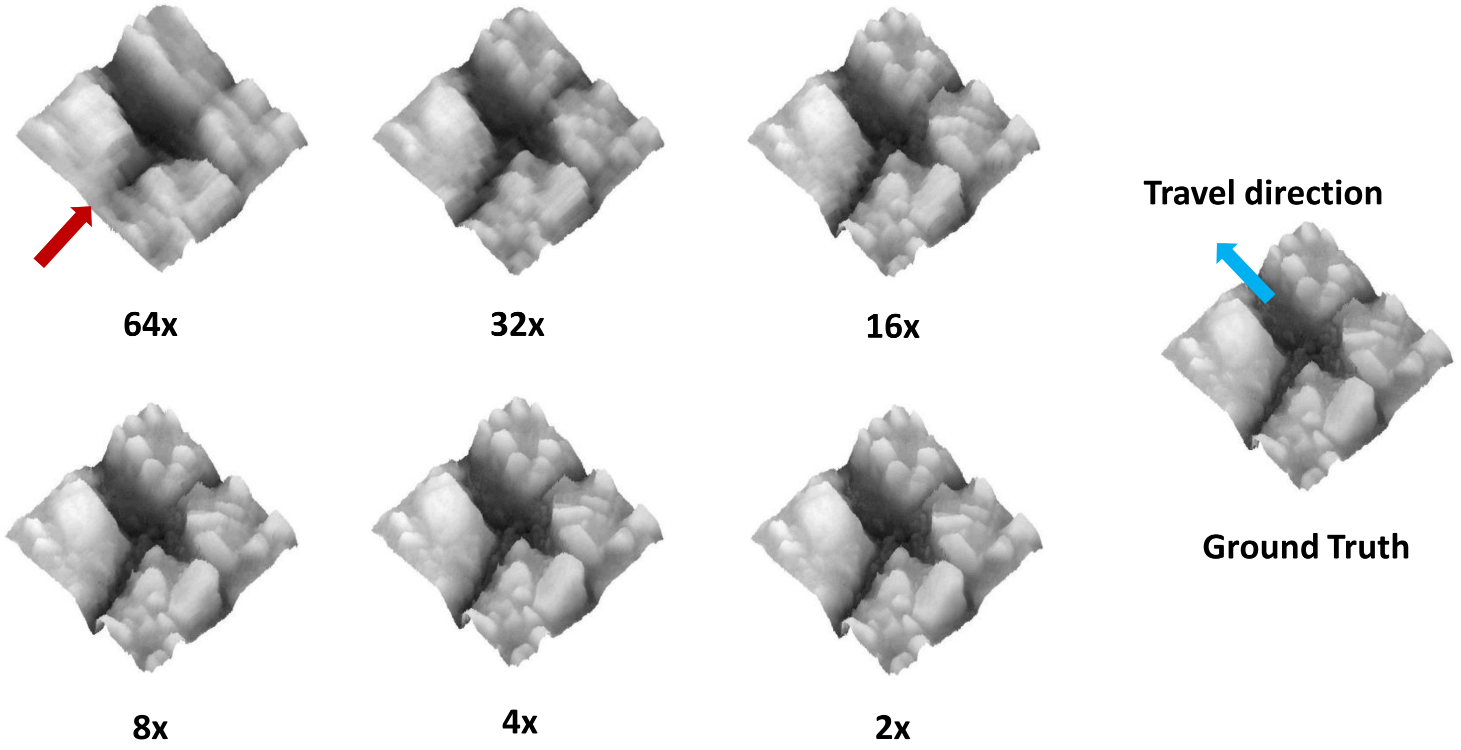
Recursive GAN on Akin-Laplacian Pyramid

- Advantages
  - High upscaling factors: up to 64x
  - Any upscaling factor in combination with bicubic upscaling at each scale



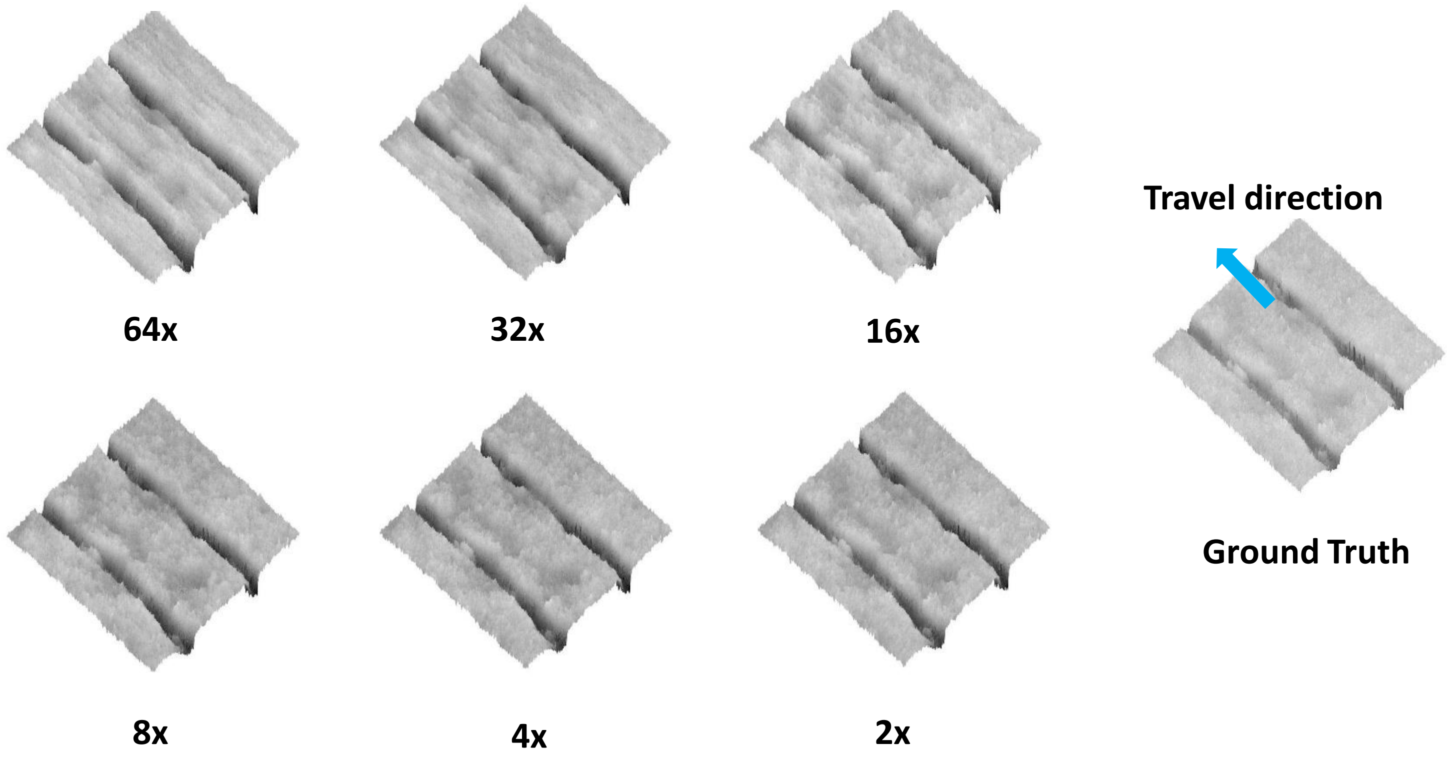
Example Results (1)

- Asphalt pavement

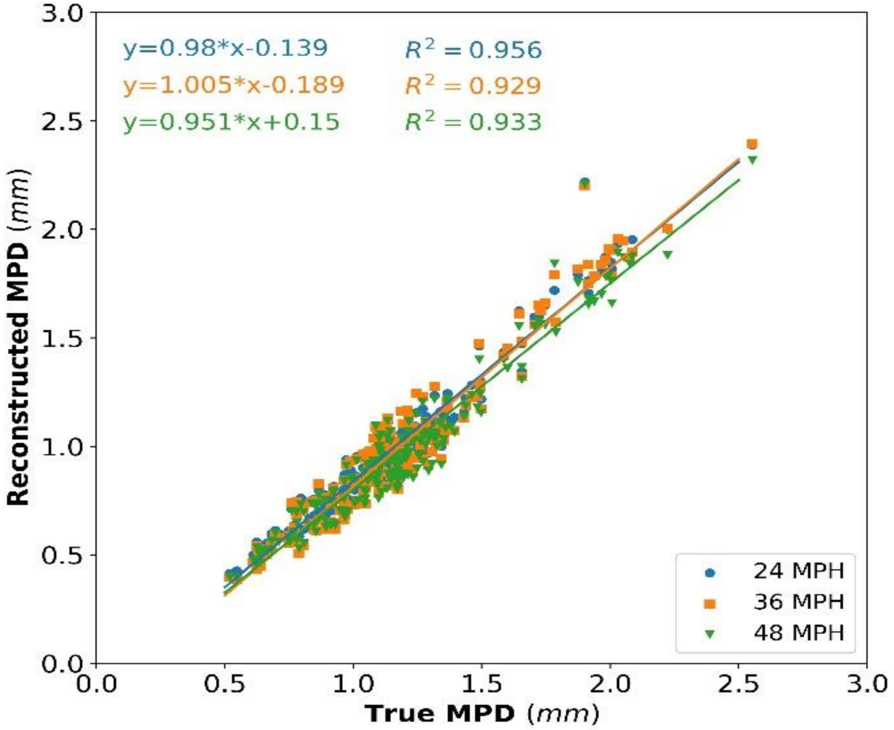


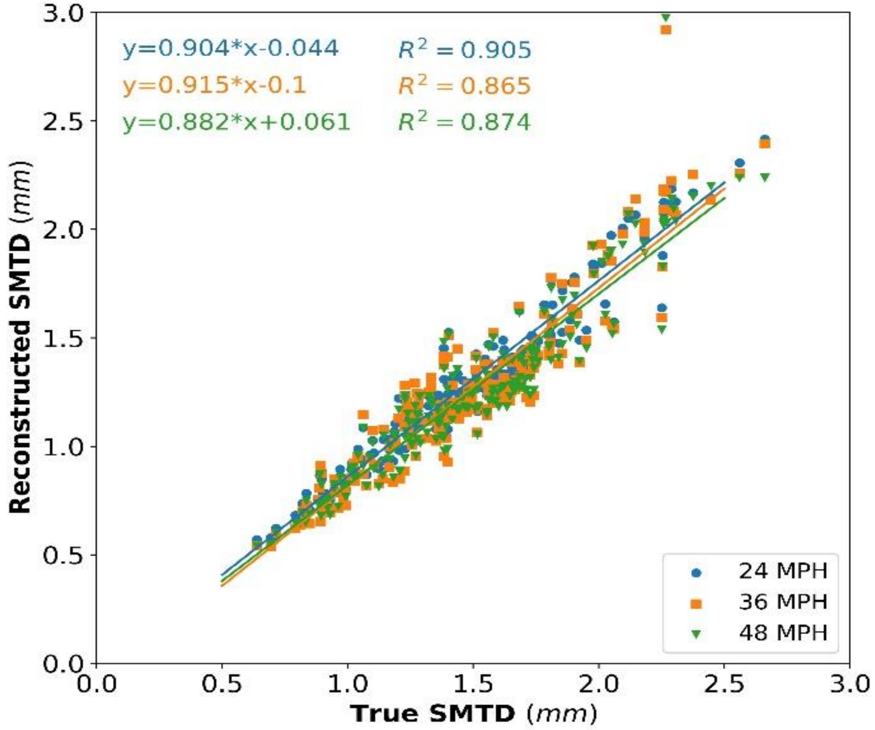
Example Results (2)

- Longitudinally grooved concrete

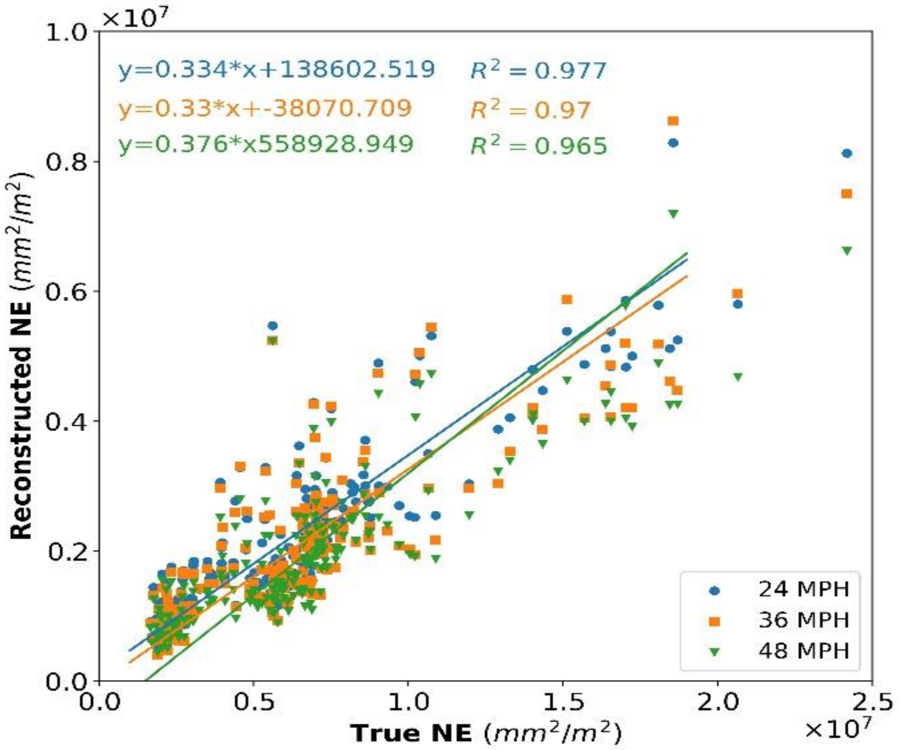


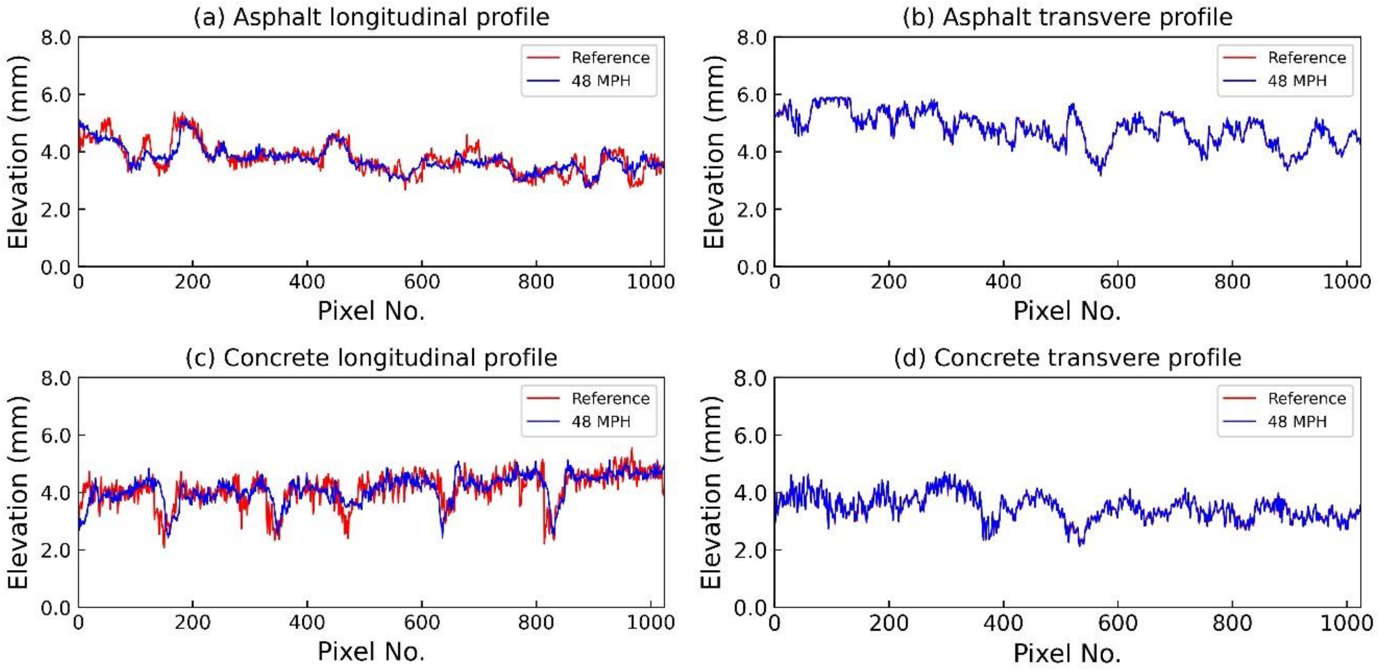
MPD and MTD for Macro-texture



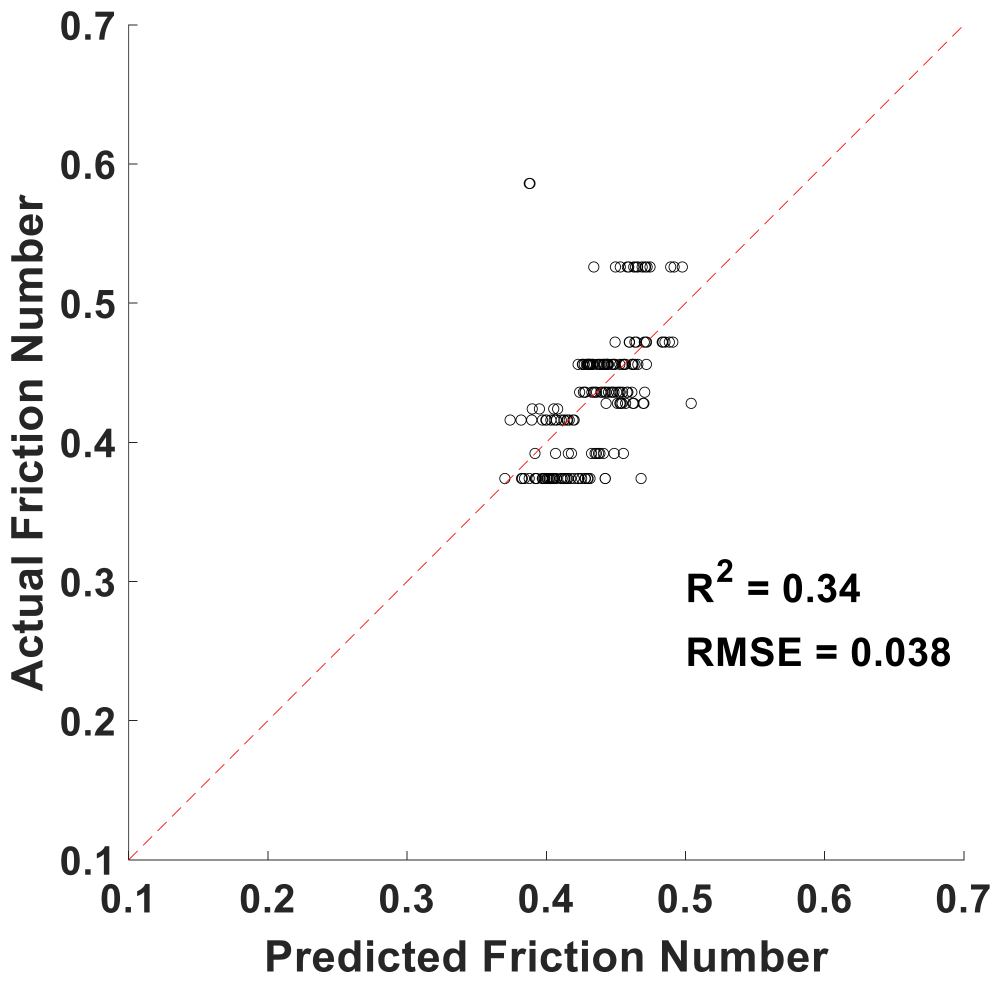


Wavelet Energy for Micro-Texture

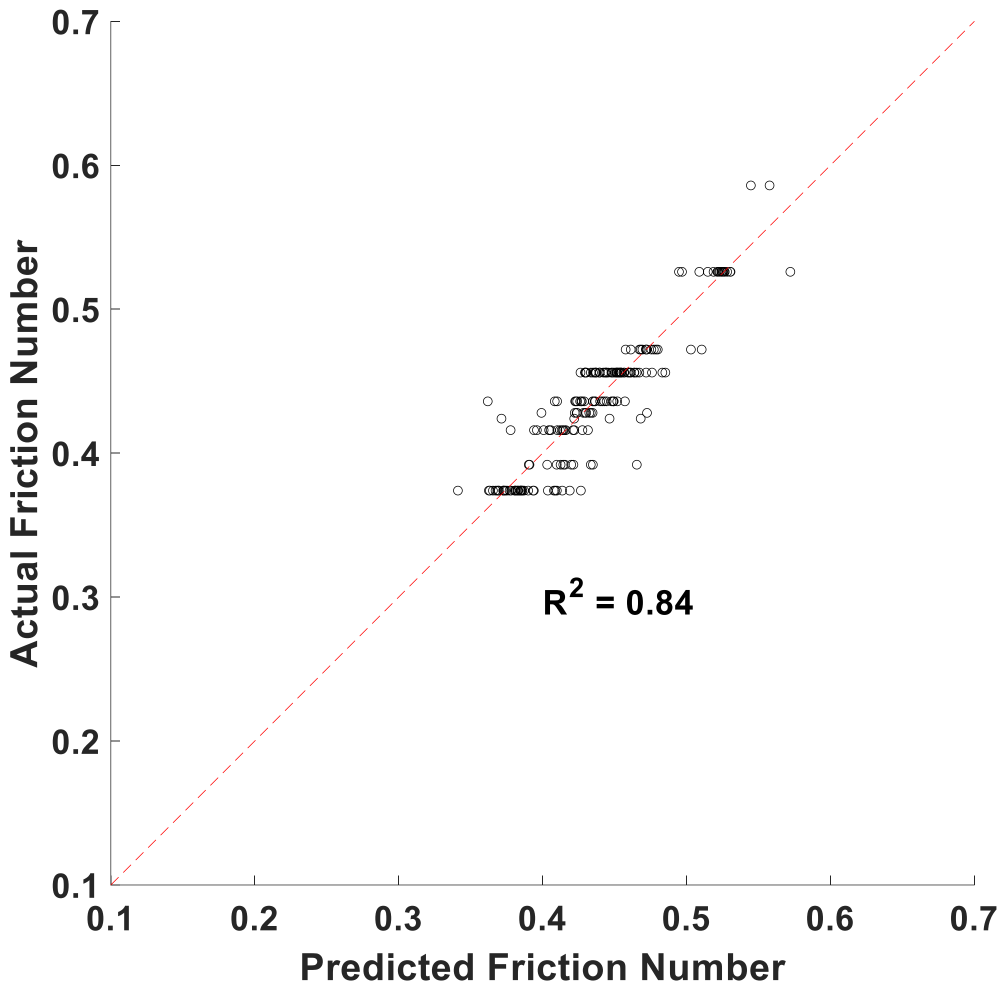




Pavement Friction Prediction - DFT



Multivariate Linear Regression Model



Neural Network Model

Conclusions

ERPUG

Present

- **Deep Learning Outperforms Traditional Approaches**
- **Deep Learning Fulfills Pavement Distress Detection**
- **GPU Parallel Computing Supports Real-time & Faster Detection**

Future

- **Reduced Dependence on Manually-Labeled Data**
- **Fully-Intelligent Multiple Distress Detection**
- **ME-Design to PMS: Many AI Based Solutions**
- **Bright Future: Non-Contact 3D Safety Sensor**