Deep Learning for Pavement Distress Detection

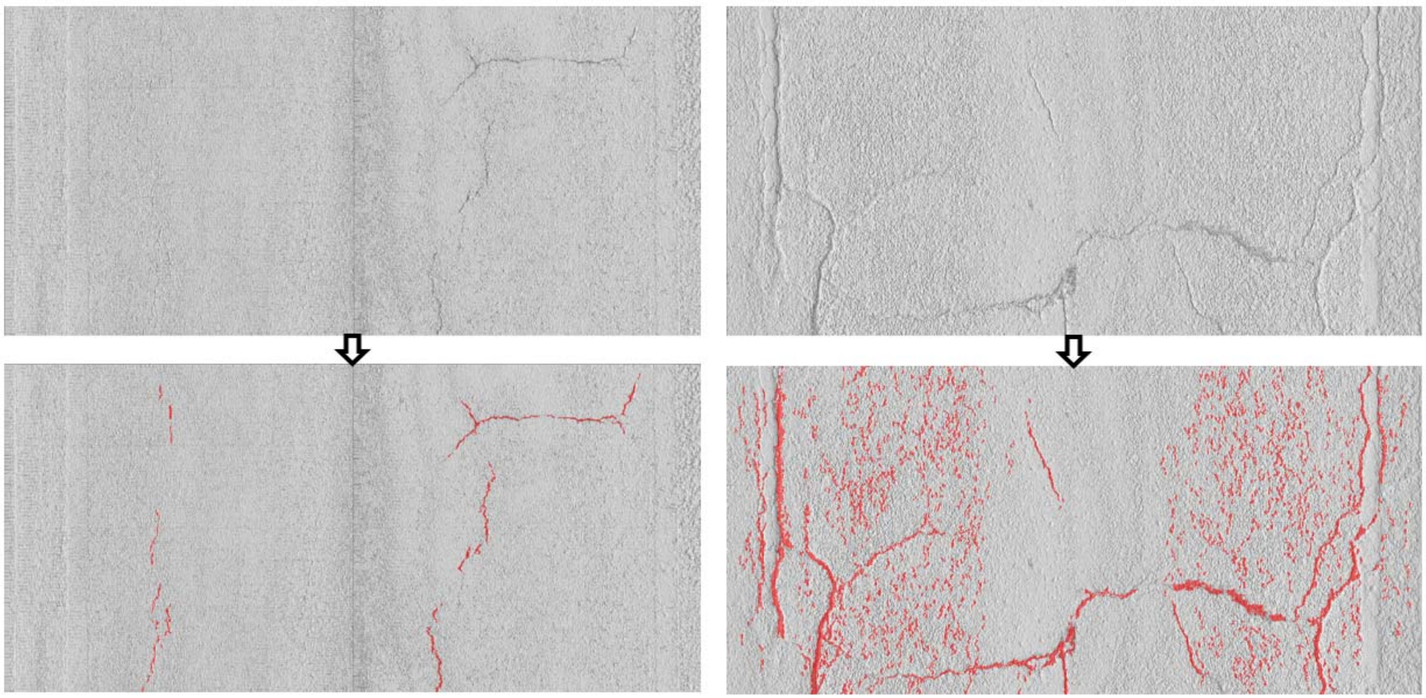
By
Kelvin C. P. Wang, Allen Zhang, Yue Fei, Josh Q. Li, and Cheng Chen
Oklahoma State University
Stillwater Oklahoma

Challenges of Cracking Automation

- Complexity
  - Pavement Surface: A Highly Complicated Environment with Extensive Uncertainties
  - Distress Identification: Challenging Even for Well-trained Human Operators
  - Diverse Pavement Surface Texture
  - Various Presences of Pavement Distresses

Common Failures

- Inconsistent Accuracies for Pavement with Various Texture

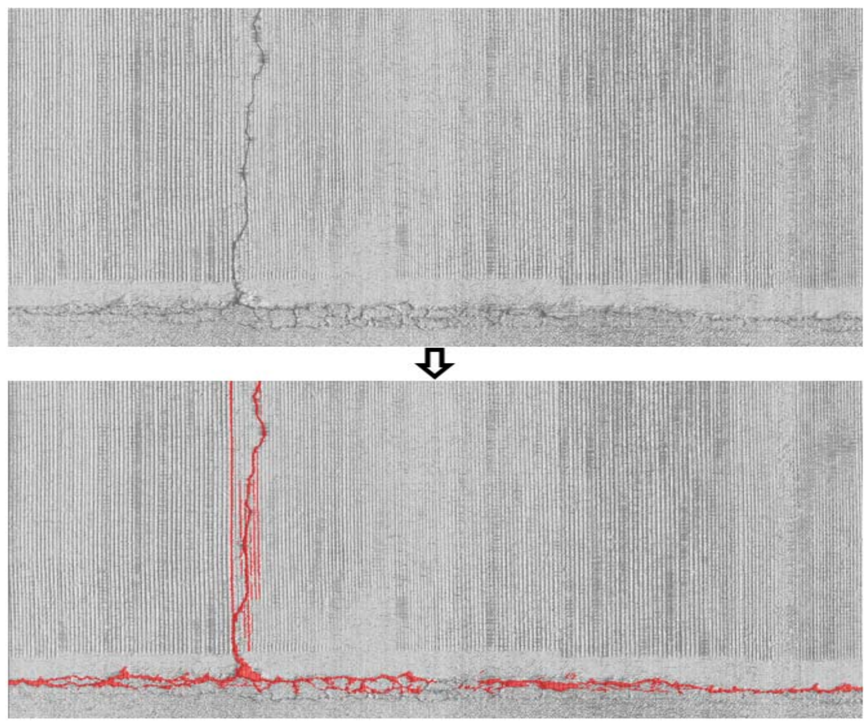


Smooth Pavement Surface

Highly Textured Pavement Surface

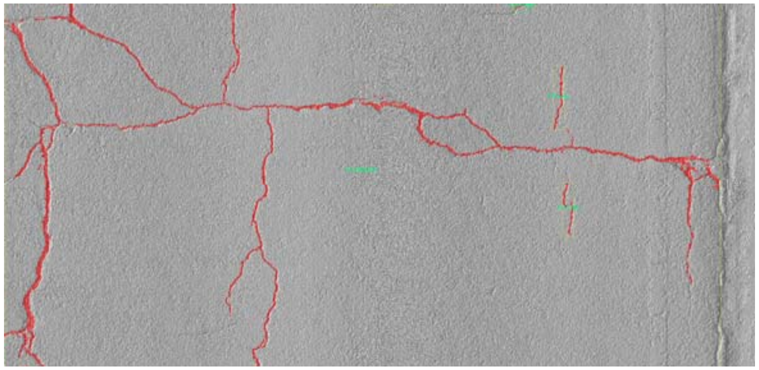
Common Failures

- Interference from Other Patterns



Objectives

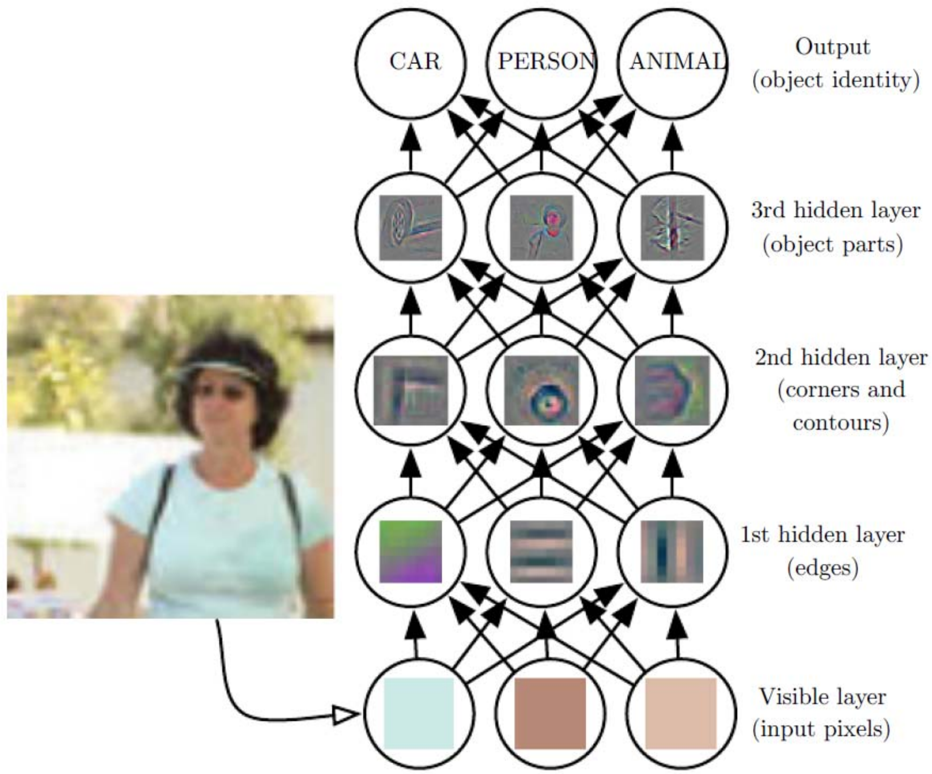
- Automated Crack Detection
  - Find the Actual Location of Distresses with Pixel-Perfect Accuracy
- Automated Crack Classification
  - Label Distress Types



Deep Learning

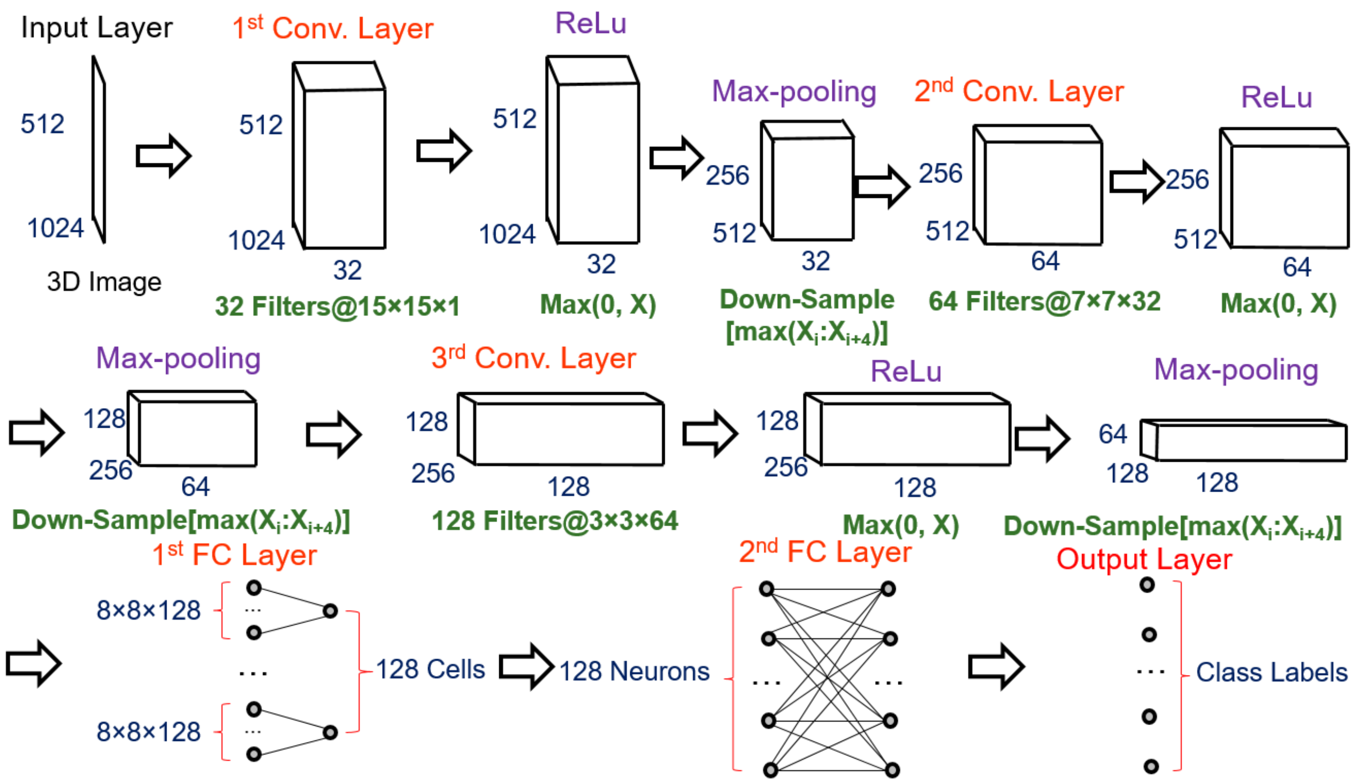
- Strong Learning Ability
  - Learning from Experiences
  - Exploiting Understanding on New and Unlabeled Examples
- Versatility
  - A Deep Learning Network Can Detect Multiple Types of Pavement Distresses
- Enhanced Reliability
  - Feed with Exhaustive Variations of Pavement Distresses

Compositional Model for Image Recognition



(Goodfellow et al., Deep Learning, 2016)

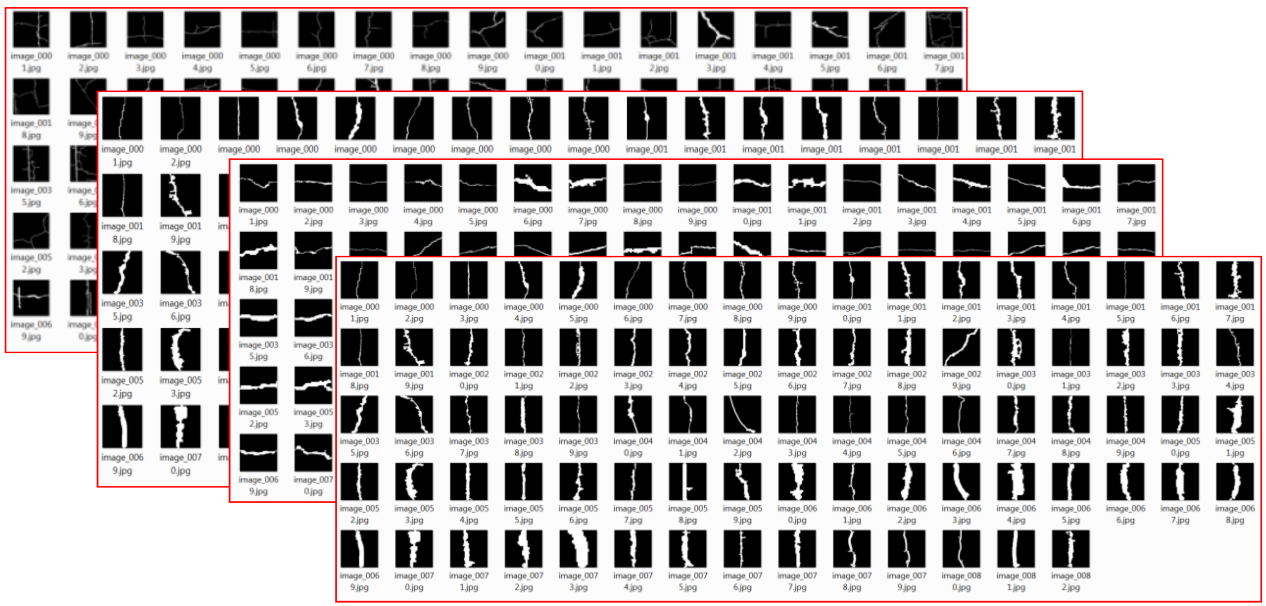
Convolution Neural Network for Distresses



- 11 Layers
- 1,246,496 Parameters

Convolution Neural Network for Distresses

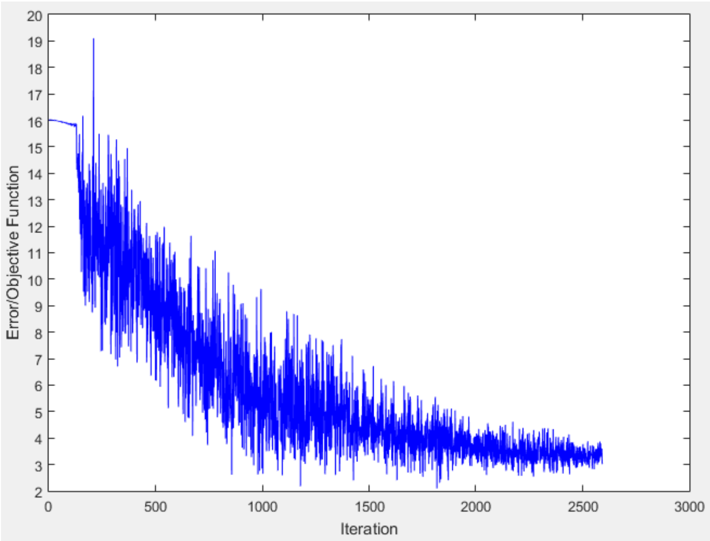
- Recognize Pavement Distresses in Small Cells



Preliminary Training Results

- Recognition Accuracy > 96%

# of Samples	# of Samples with False-positive Errors	# of Samples with False-negative Errors	False-positive Error	False-negative Error	Accuracy
23,296	163	684	0.7%	2.936%	96.364%

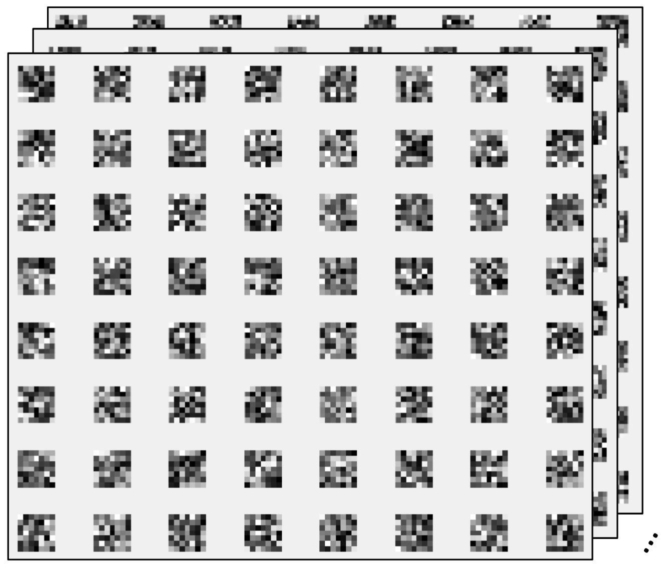


Error Curve

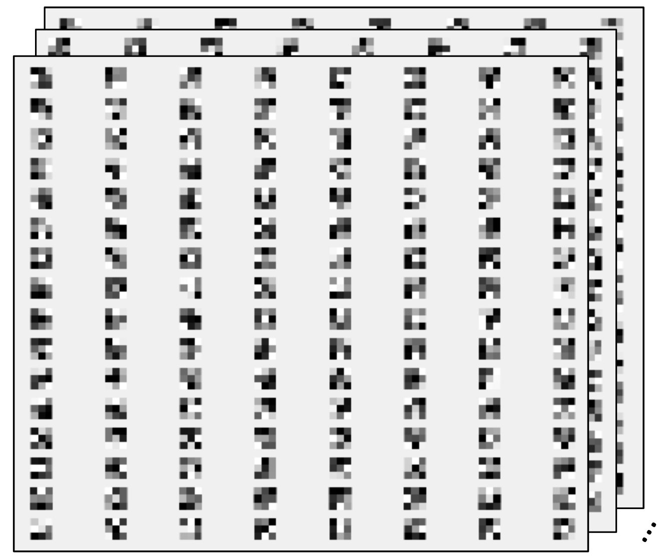
Preliminary Training Results

- Learned Filters

1st Convolution Layer
32@15×15×1



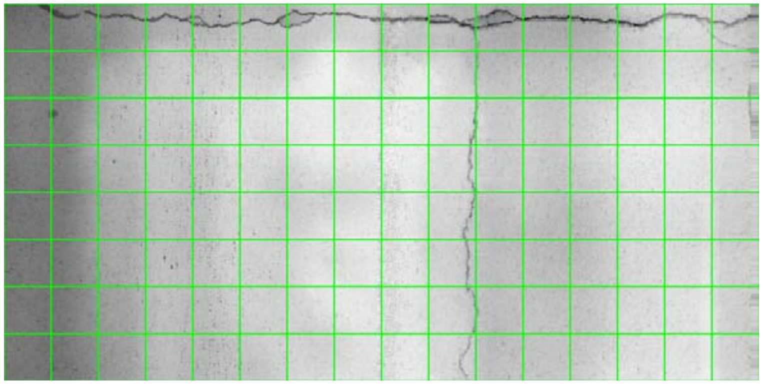
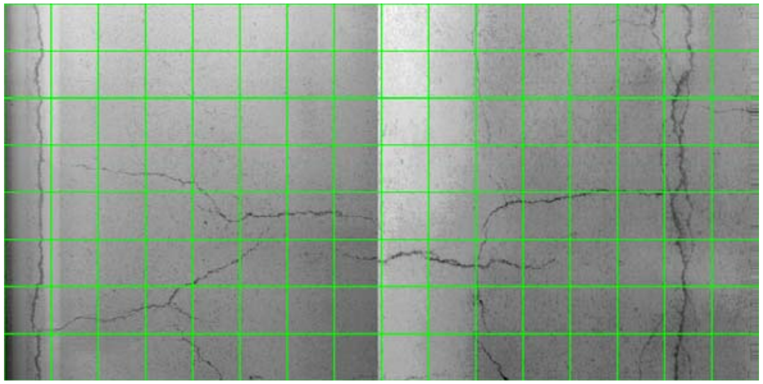
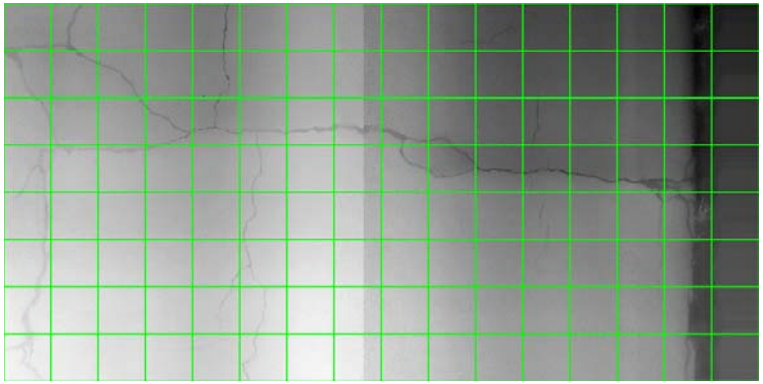
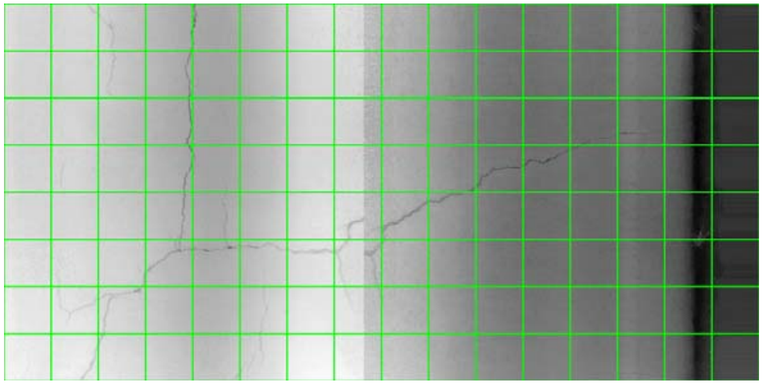
2nd Convolution Layer
64@7×7×32



3rd Convolution Layer
128@3×3×64

Preliminary Training Results

- Example Images with No Recognition Errors

Preliminary Training Results

- Example Images with False-positive or False-negative Errors

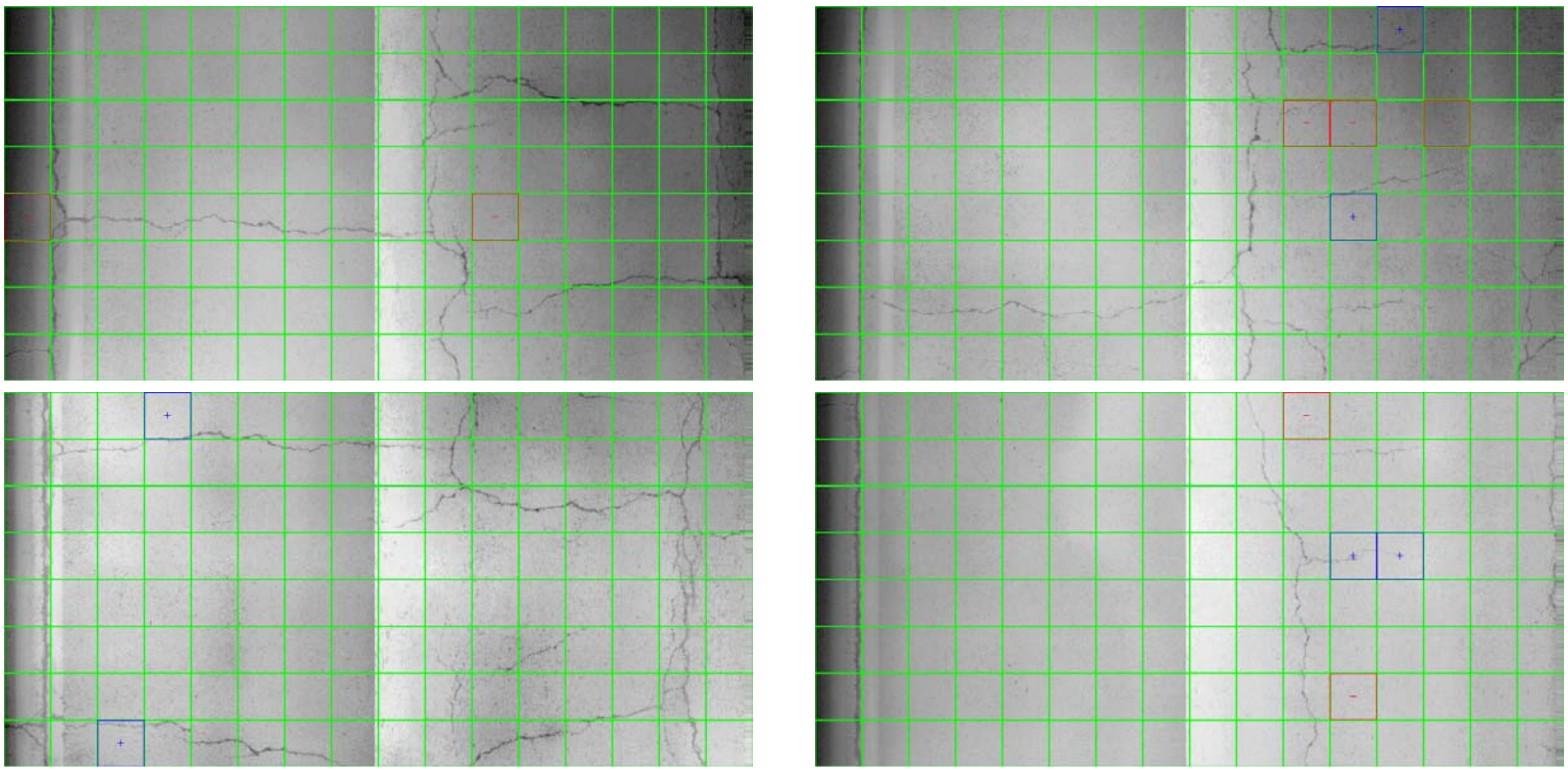
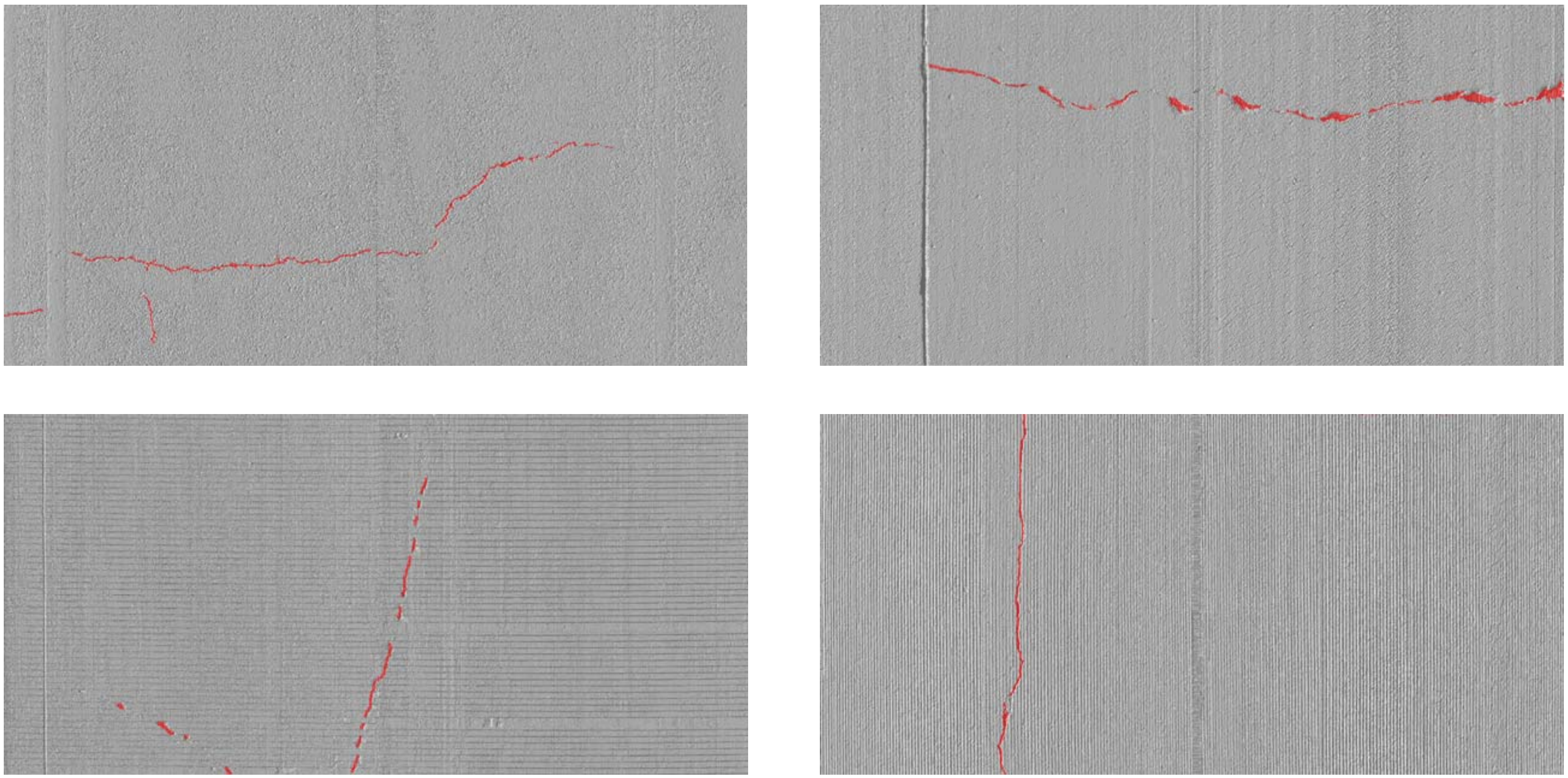


Image Library

- Data Type
  - 3D Data & 2D Images
- Image Library Size
  - 2016-2017: 150,000 3D Images + 150,000 2D Images
  - 2017-2020: 1,000,000 3D Images + 1,000,000 2D Images
- Ground Truth
  - Manually Marked
- Diversity
  - All Typical Variations of Pavement Distresses

Typical Samples in Image Library



Future Tasks

- Exhaustive Image Library
    - 3D Pavement Data & 2D Pavement Image
    - All Variations of Pavement Distresses
    - Manually Marked Ground-truth
- Long-term Training & Optimization
    - Training on Entire Network Using Gradient-based Algorithm
    - Sufficient Computational Horsepower
- Self-taught Learning
    - Unsupervised Learning from Unlabeled Data;
    - Progressive Improvements in Real-time Applications
- Real-time Application
    - Parallel Computing to Reduce Processing Time