Multi-Object and Real-Time Processing of Pavement Surface Distresses with Sub-mm 3D Data in the AI Environment

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Road Profile User's Group (RPUG) Annual Meeting

Oct 14 2020

Pavement Data Collection

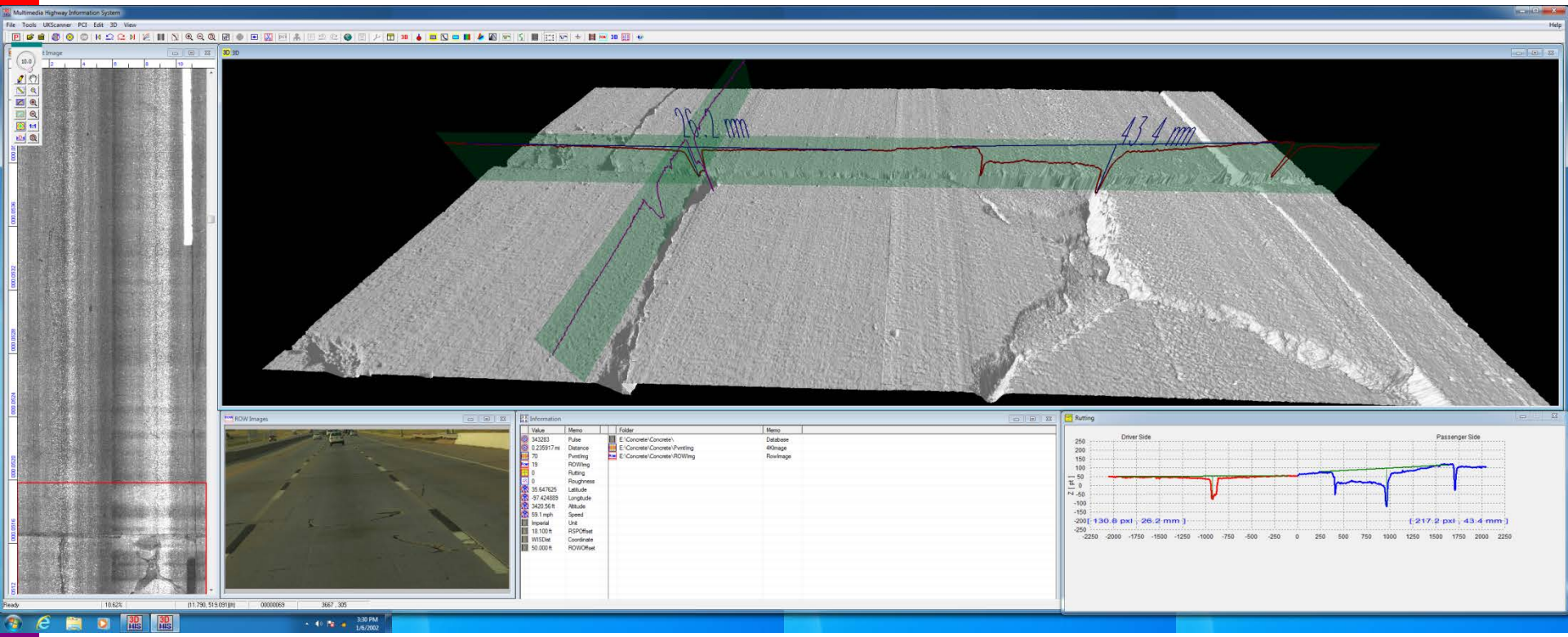
- Roughness: Functional
- Distress: Surface Condition, Mostly Cracking & Rutting Surveys
- Deflection: Structural Evaluation
- Friction: Safety
- Challenges of Cacking Survey
  - Cognition Based; Automation?
  - Repeatability, Consistency, Accuracy

Pave3D 8K in Truck Mount


三维智能路面检测系统
3D Intelligent Pavement Inspection System


94-75

Sample 3D Data at 1mm (60MPH)



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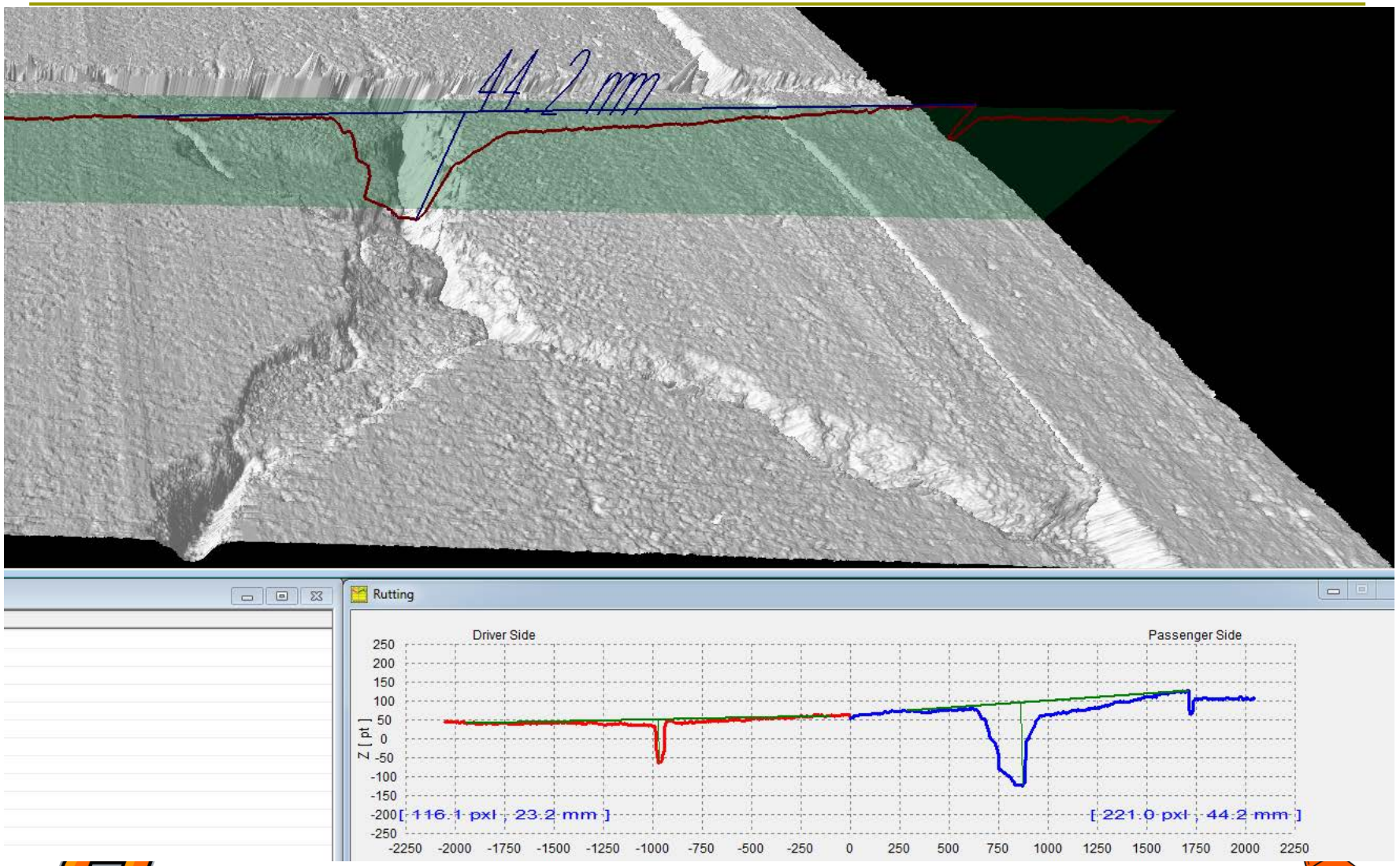

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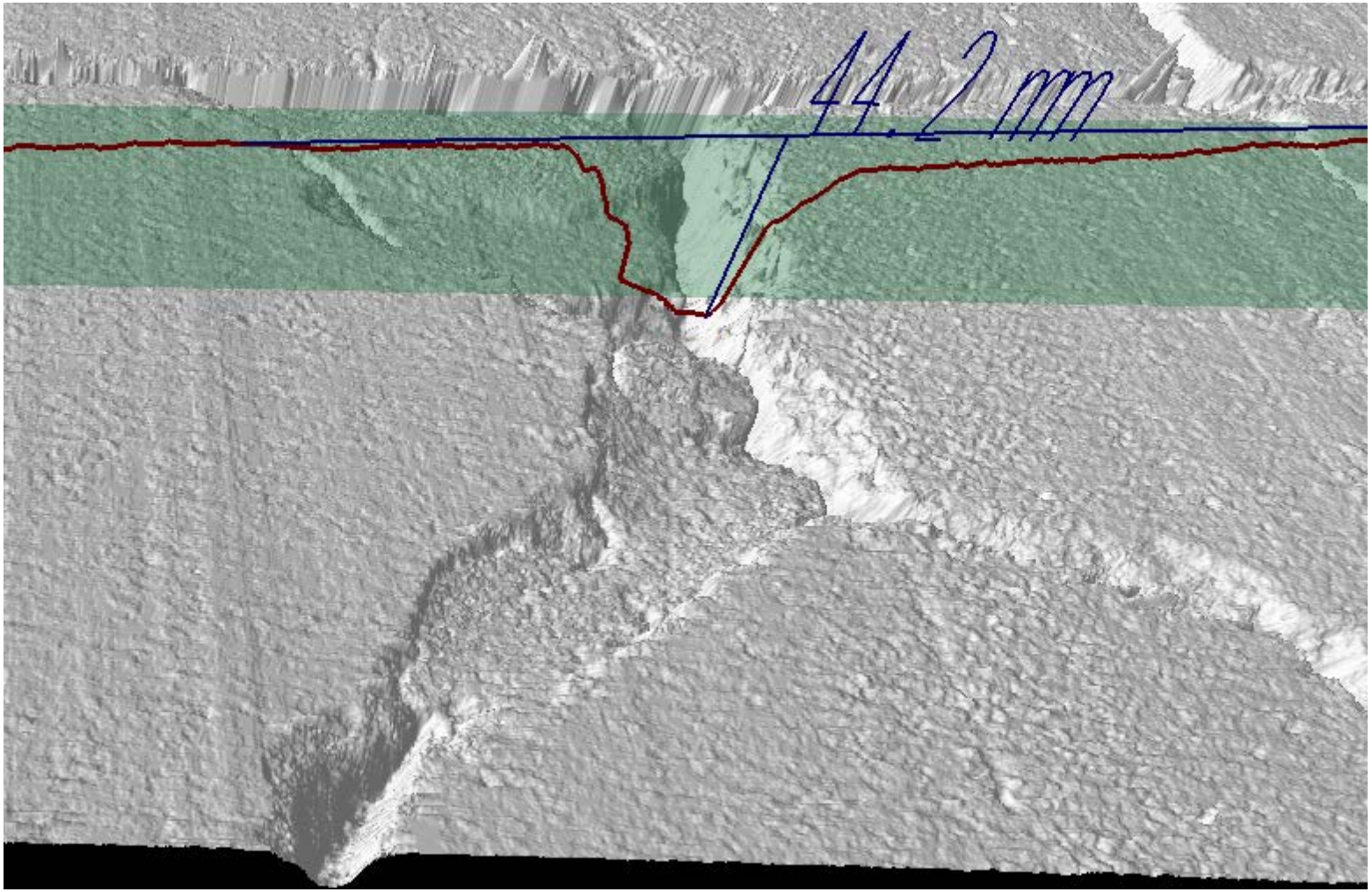
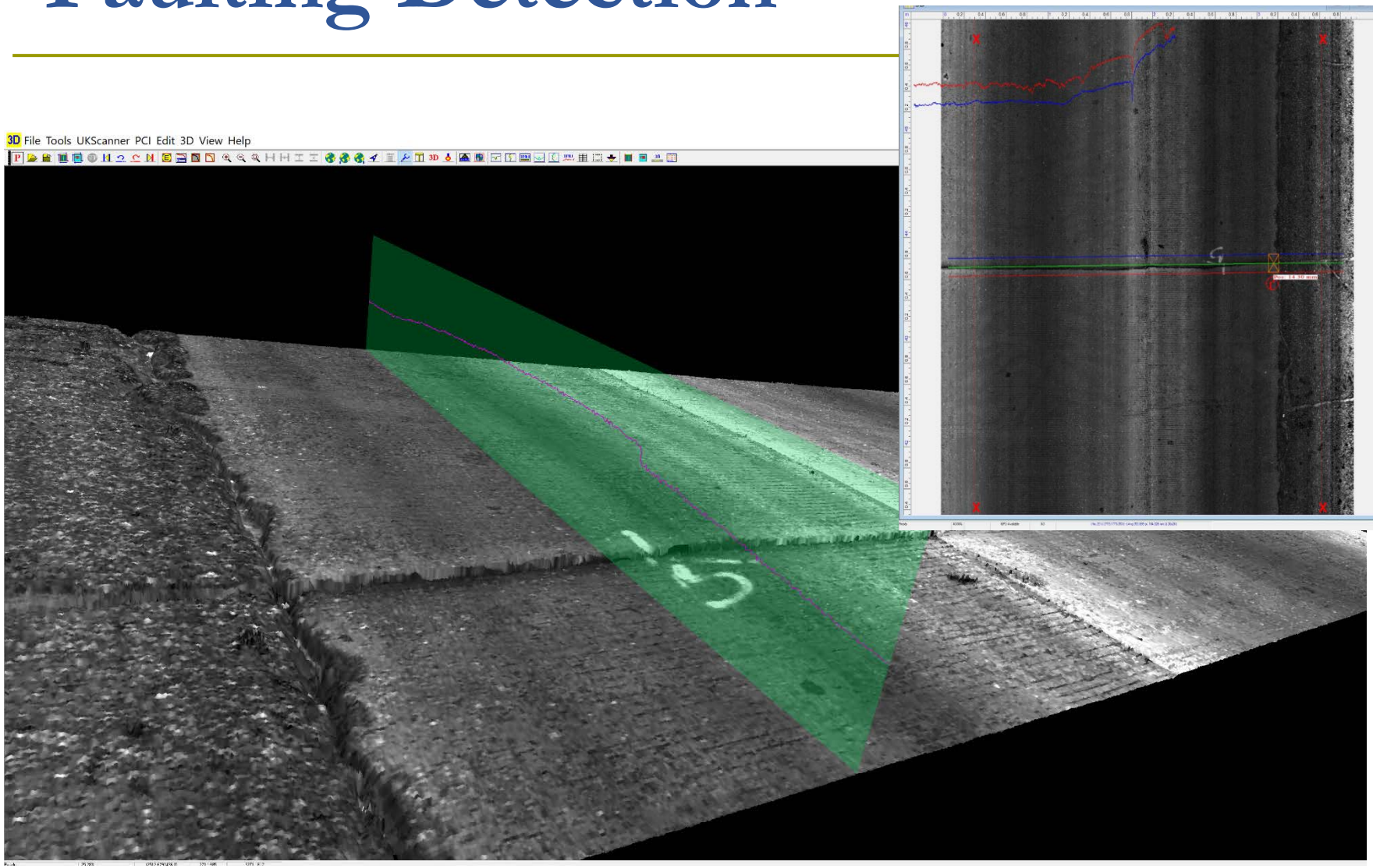
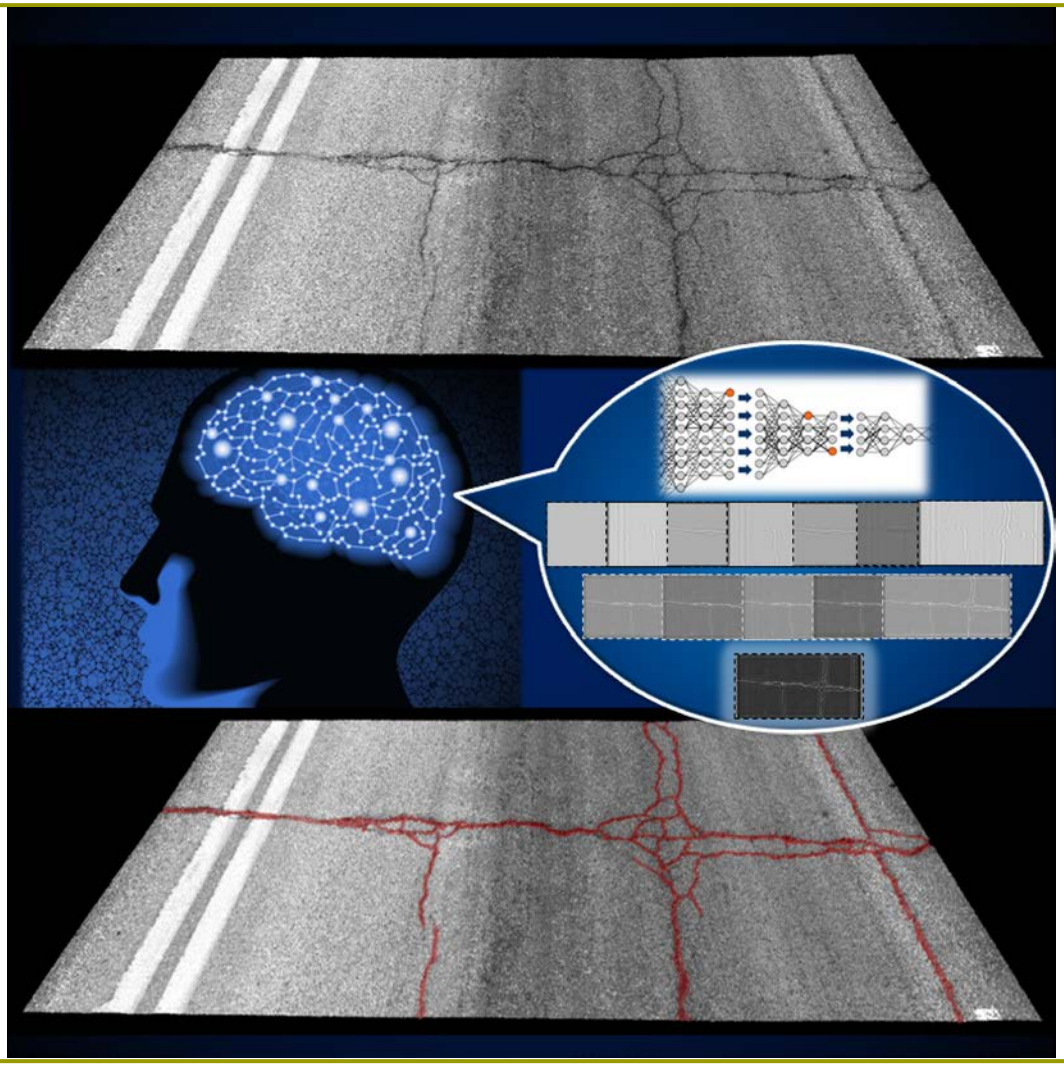


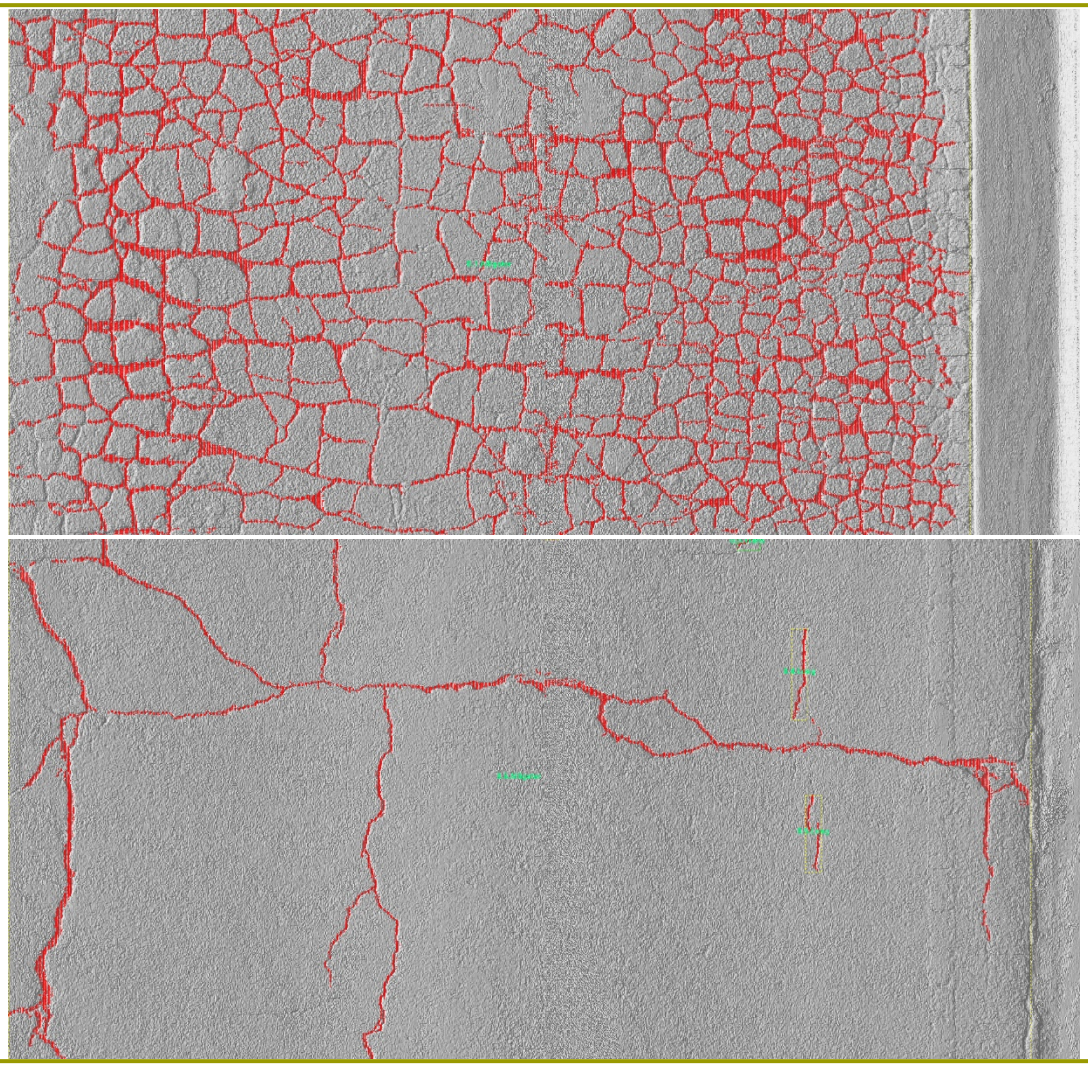
Faulting Detection



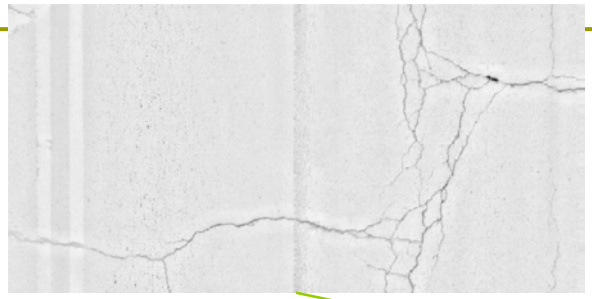
Deep-Learning for Cognition Capability



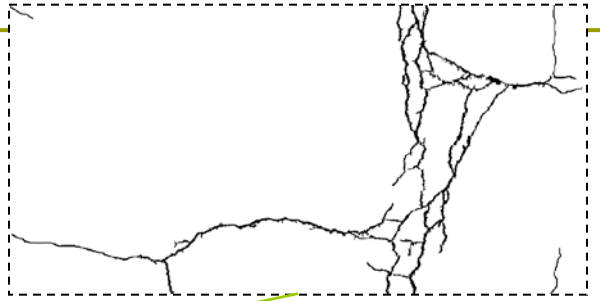
Learning Database: Critical for Learning



CrackNet: from Training to Operation

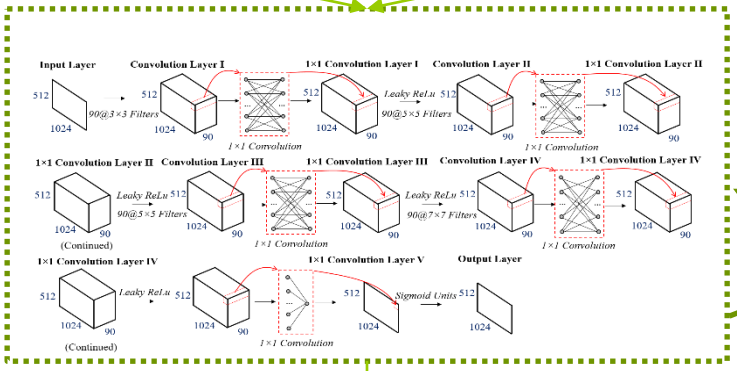


Input Image

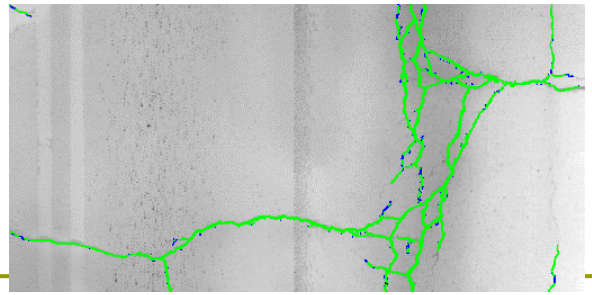


Ground Truth with Pixel-Perfect Accuracy

DL Network

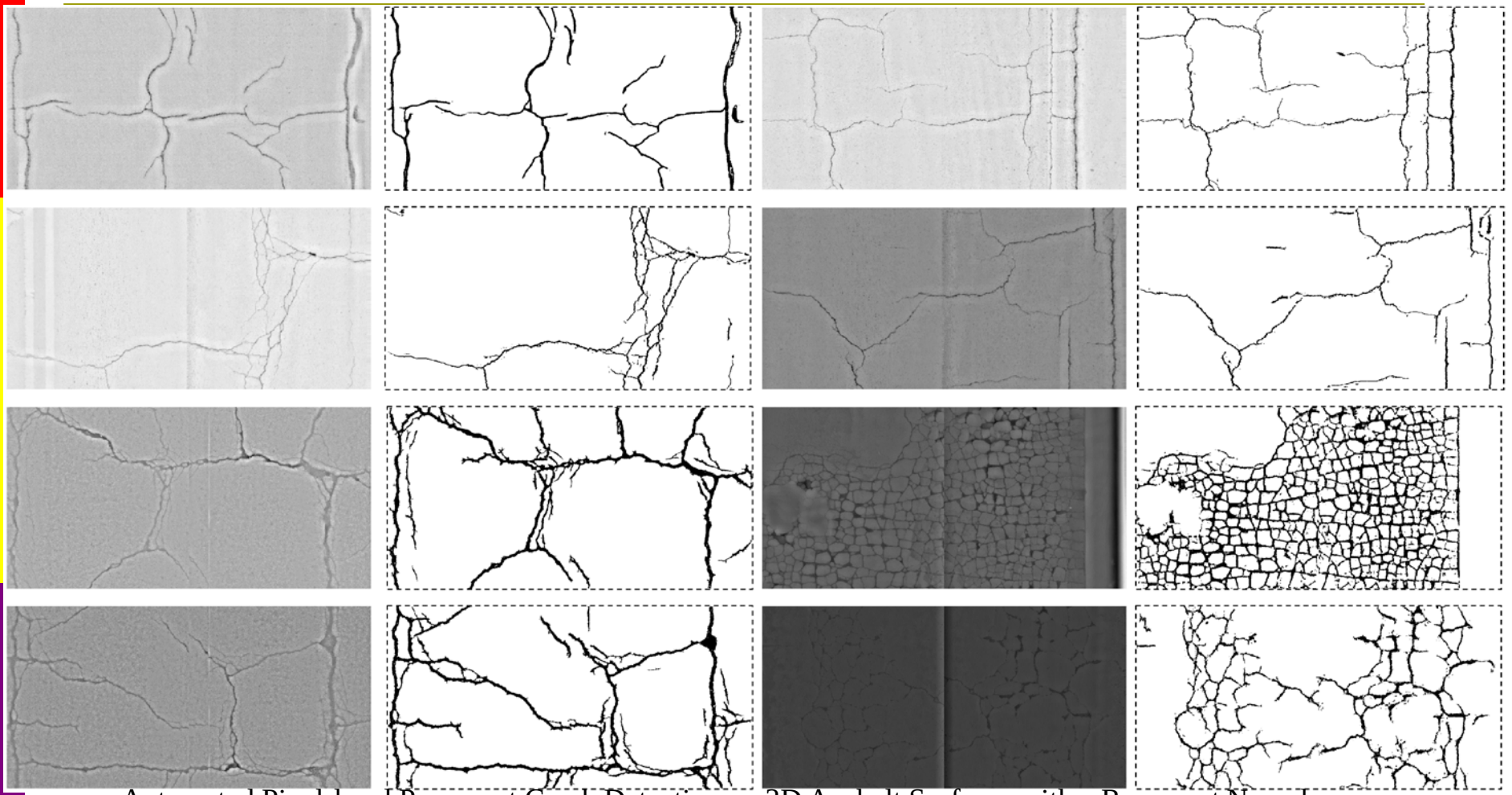


Recursive Training



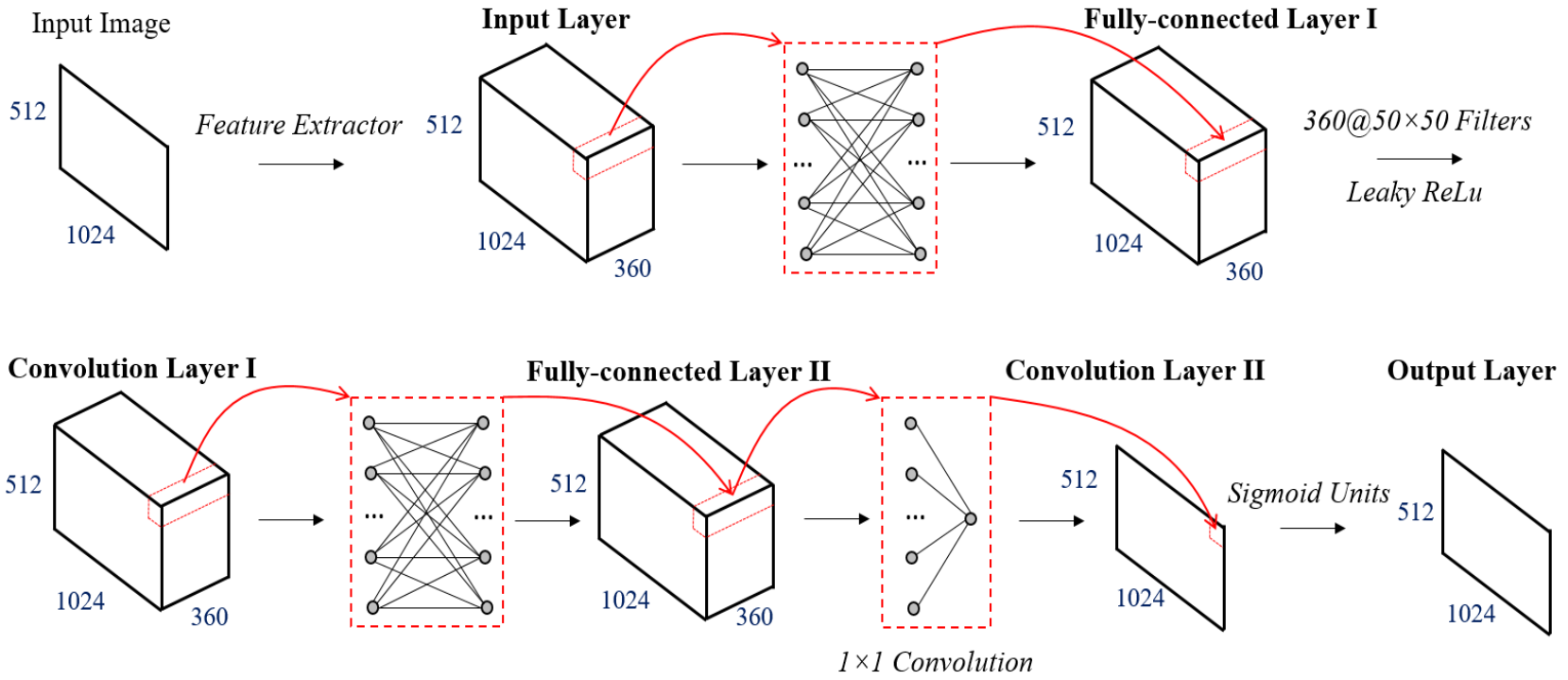
Detection Output with Pixel-Level Accuracy

Pixel Level Intelligence



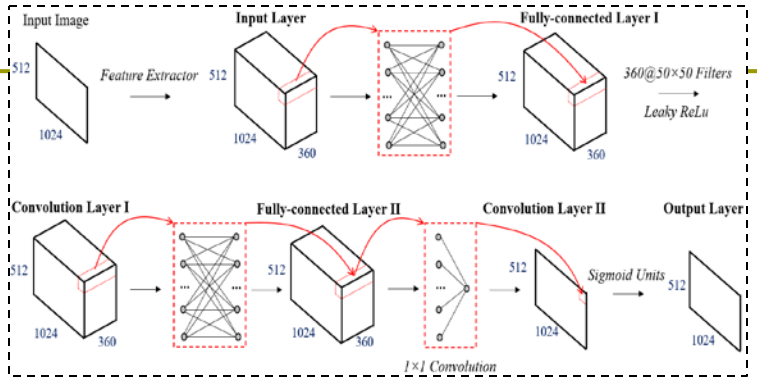
Automated Pixel-level Pavement Crack Detection on 3D Asphalt Surfaces with a Recurrent Neural Network [J], *Computer-Aided Civil and Infrastructure Engineering*, https://doi.org/10.1111/mice.12409.

First-Gen CrackNet (2016)



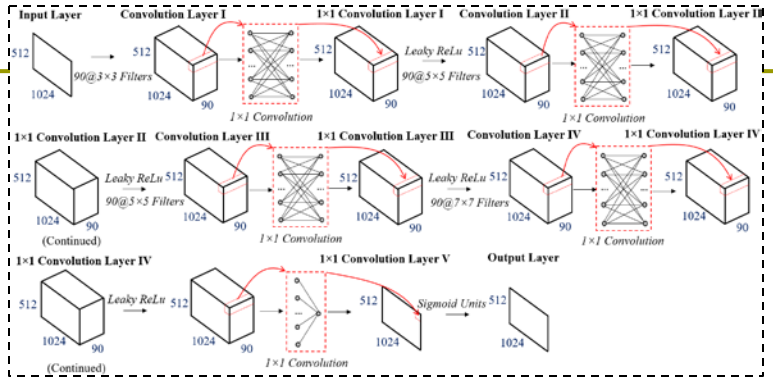
- 7 Layers
- 1,159,561 Parameters

Developments of CrackNet (2015 to 2019)



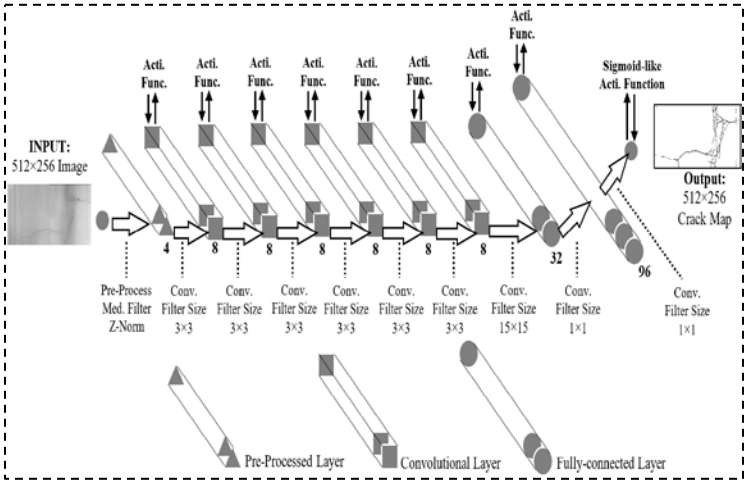
CrackNet

Automated Pixel-level Pavement Crack Detection on 3D Asphalt Surfaces Using a Deep-Learning Network, *Computer-Aided Civil and Infrastructure Engineering*, 32(10), 805-819



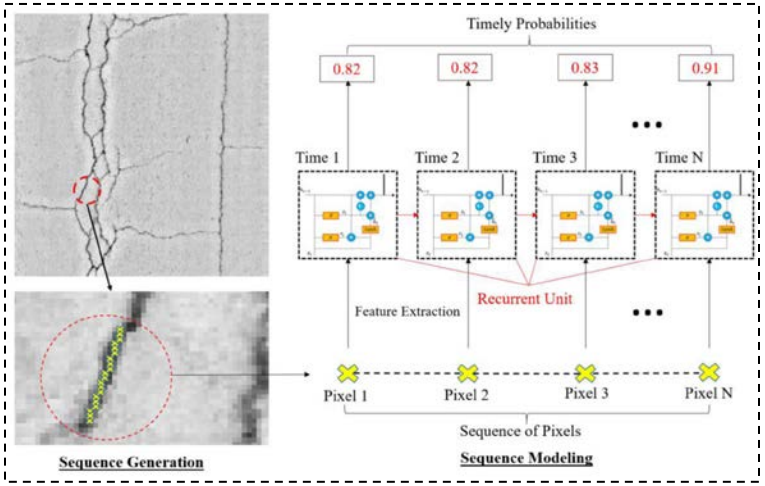
CrackNet II

Deep-Learning based Fully Automated Pavement Crack Detection on 3D Asphalt Surfaces with an Improved CrackNet, *Journal of Computing in Civil Engineering*, 32(5), 04018041.1-14.



CrackNet-V

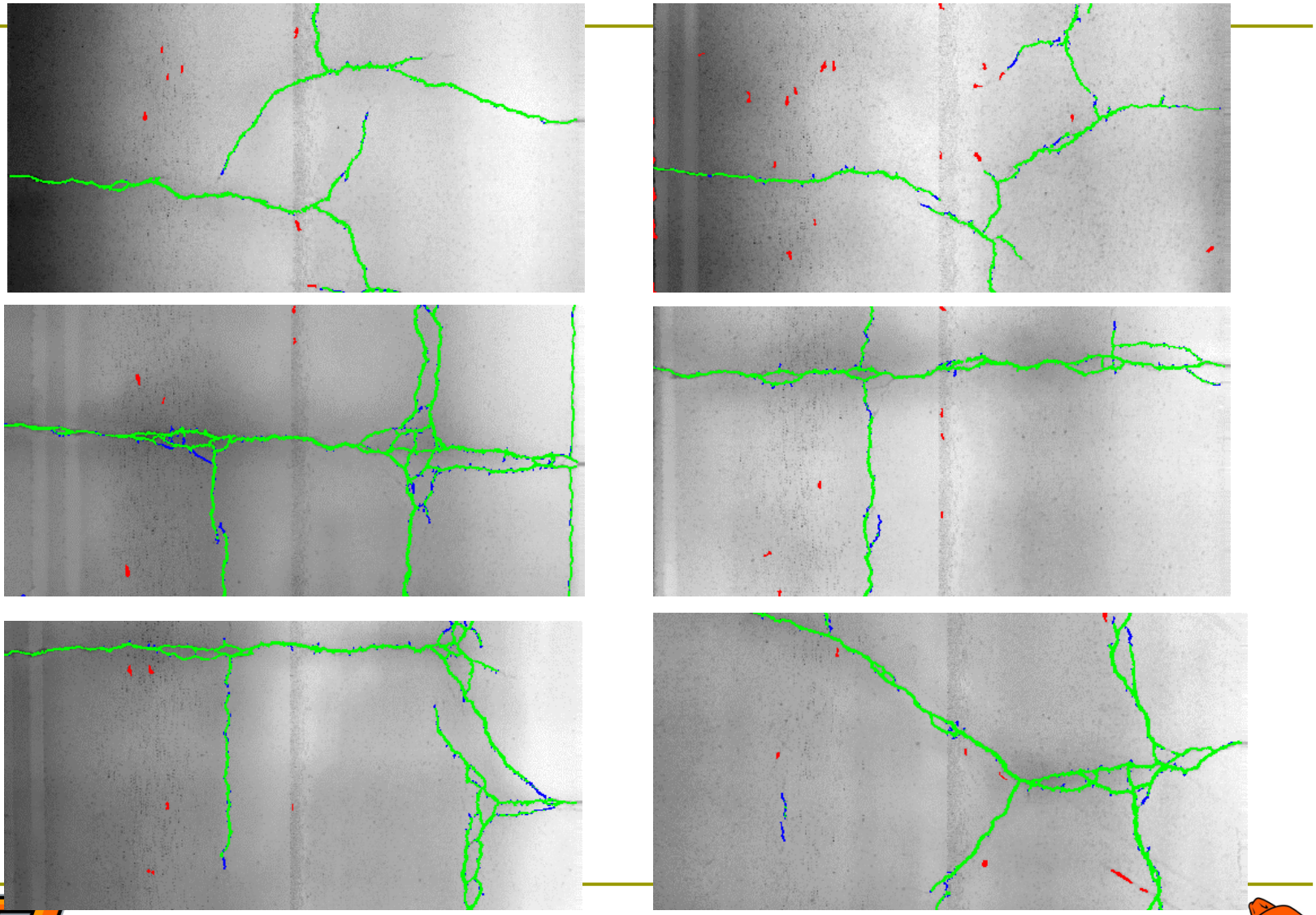
Pixel-Level Cracking Detection on 3D Asphalt Pavement Images through Deep-Learning based CrackNet-V, *IEEE Transactions on Intelligent Transportation Systems*, In Press.



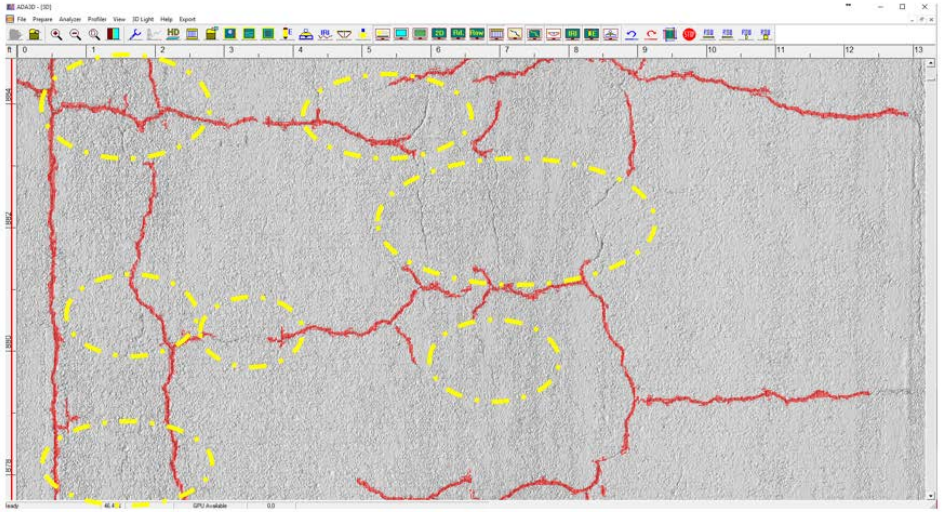
CrackNet-R

Automated Pixel-level Pavement Crack Detection on 3D Asphalt Surfaces with a Recurrent Neural Network, *Computer-Aided Civil and Infrastructure Engineering*, https://doi.org/10.1111/mice.12409.

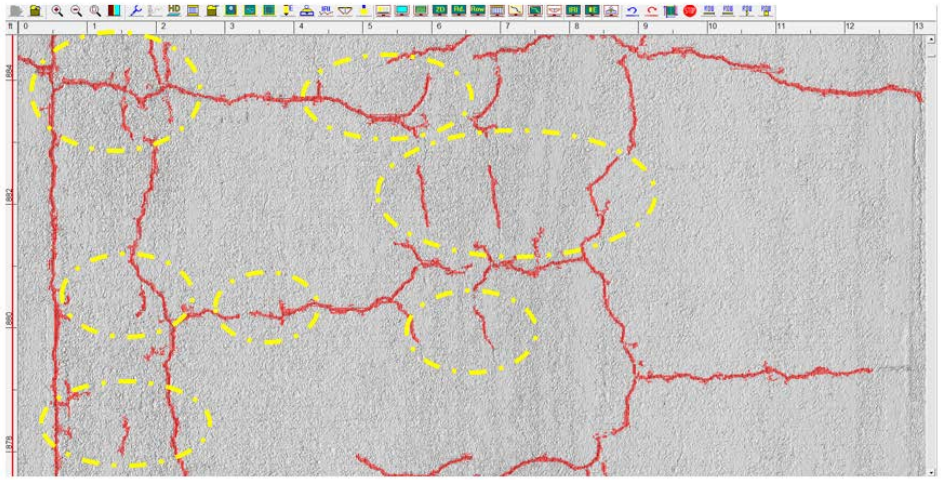
Sample Results of 1st Gen CrackNet



Samples of 2nd Gen CrackNet

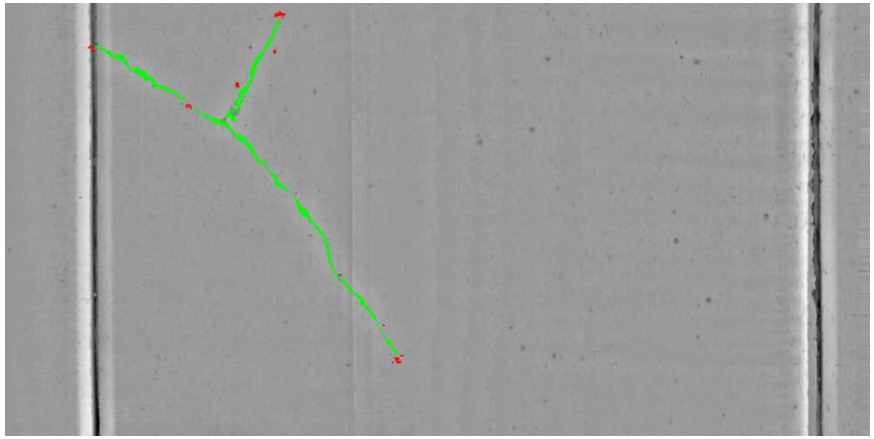


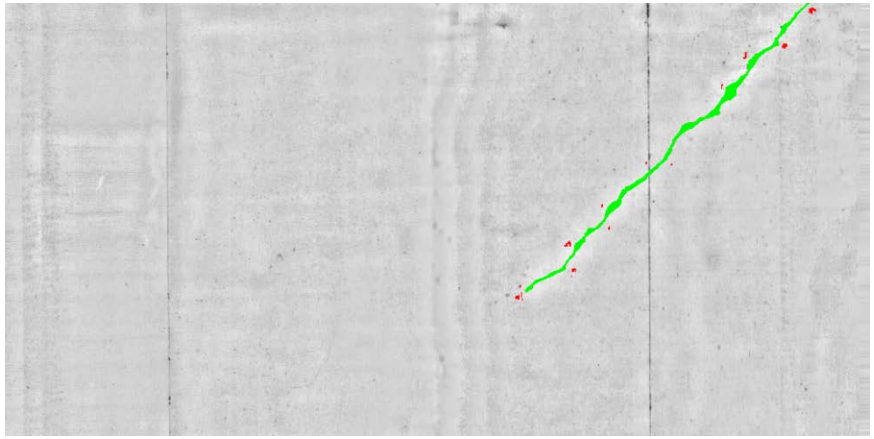
Best CrackNet



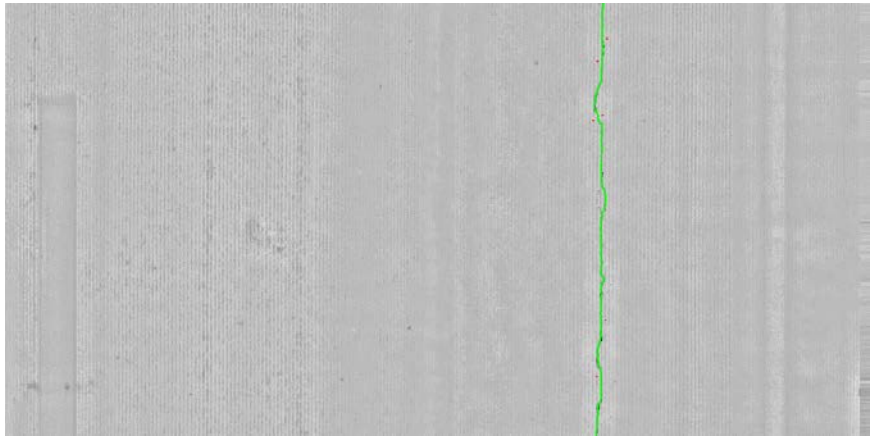
Best CrackNet + RNN

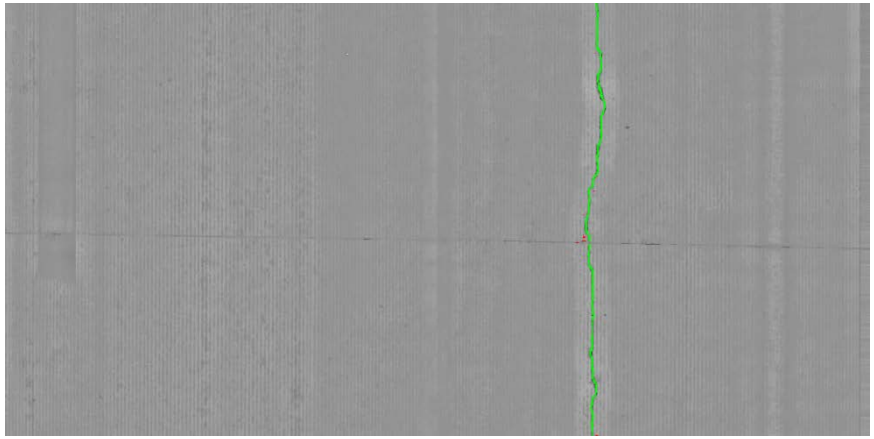
CrackNet on Concrete Pavements





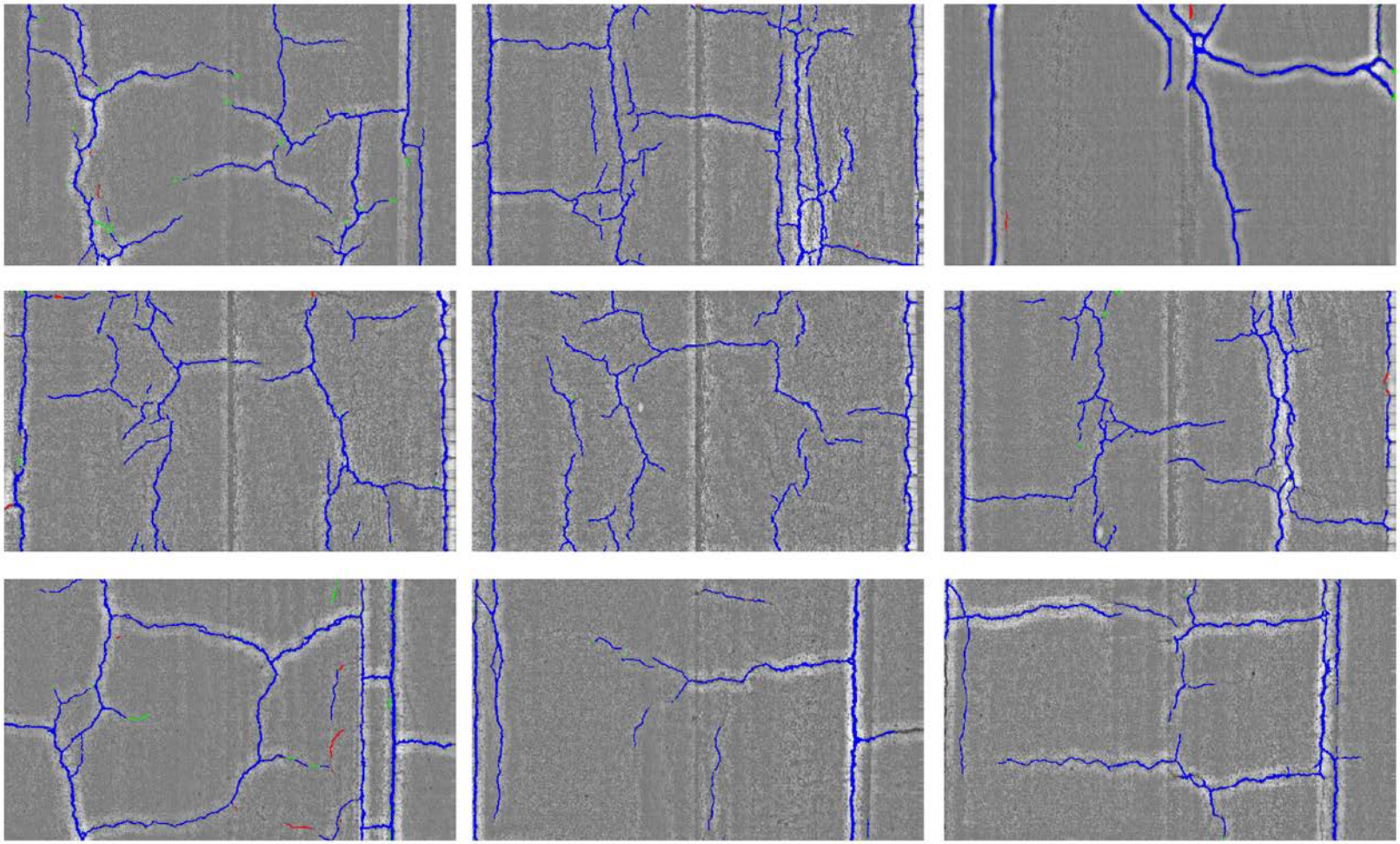
Non-Grooved Jointed Surface



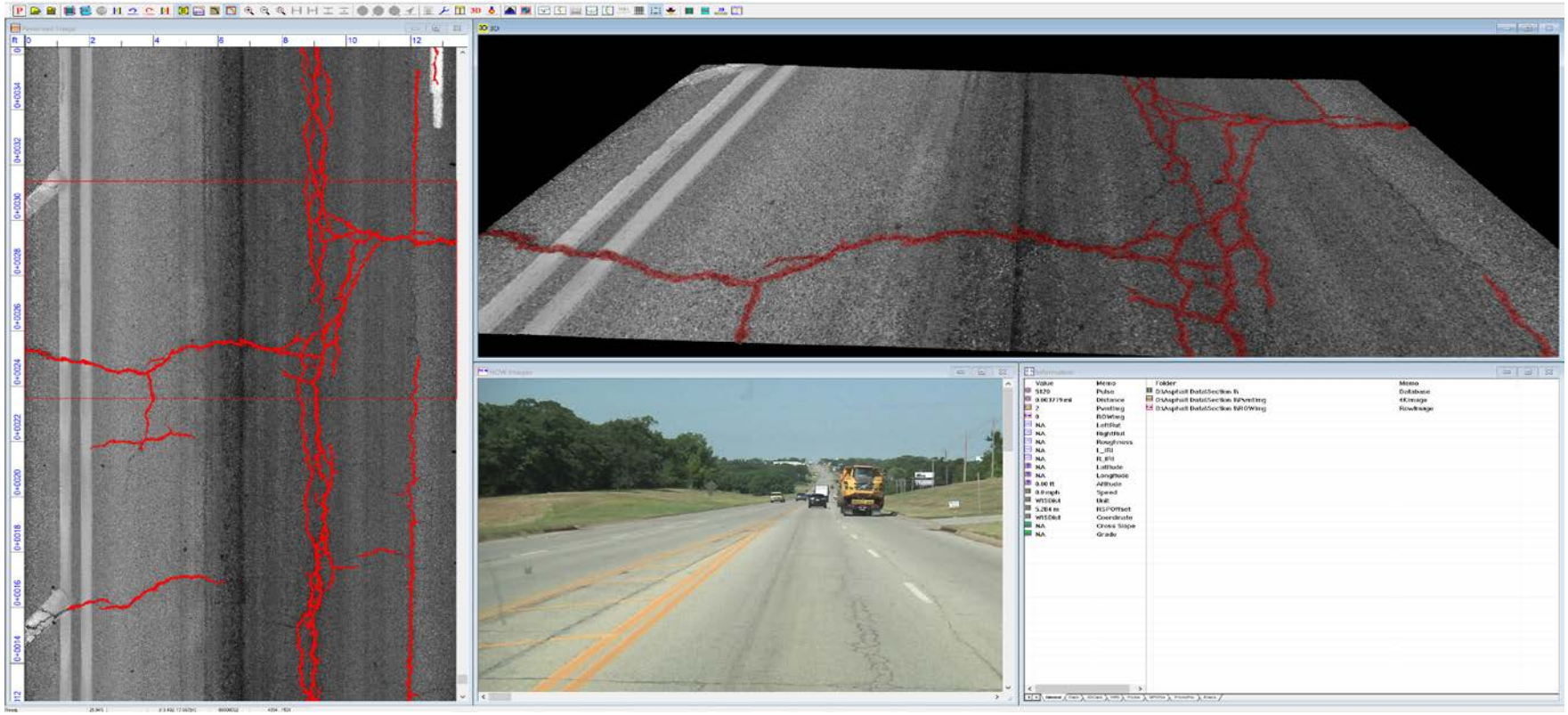


Grooved Jointed Surface

Recent Developments of CrackNet

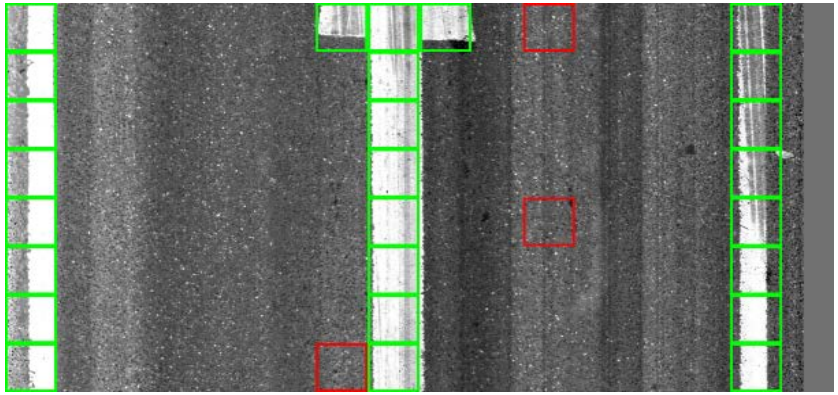


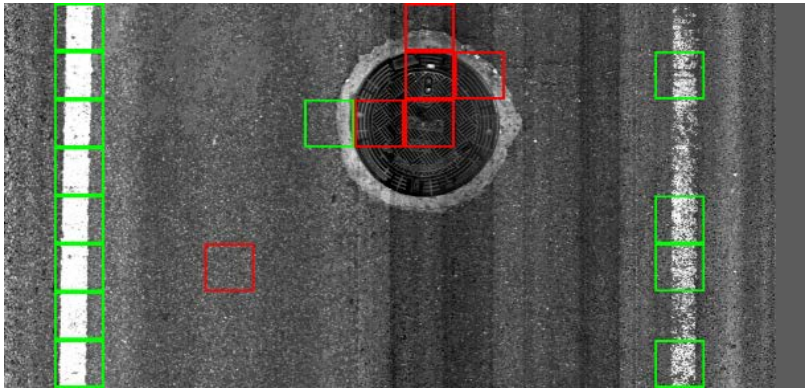
Recent Developments of CrackNet

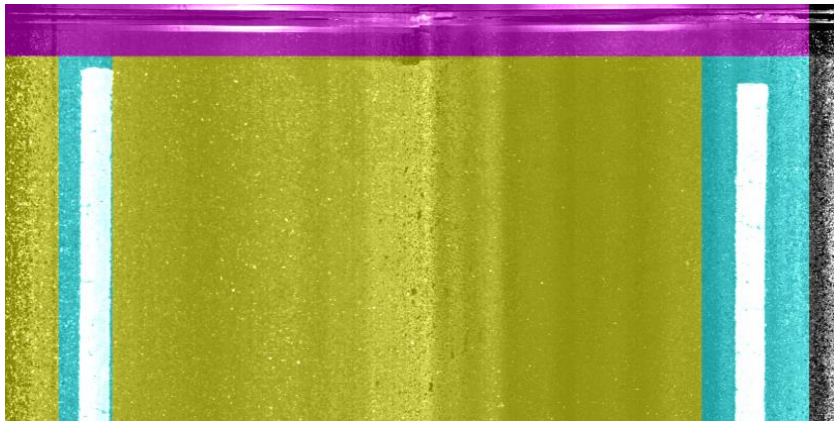


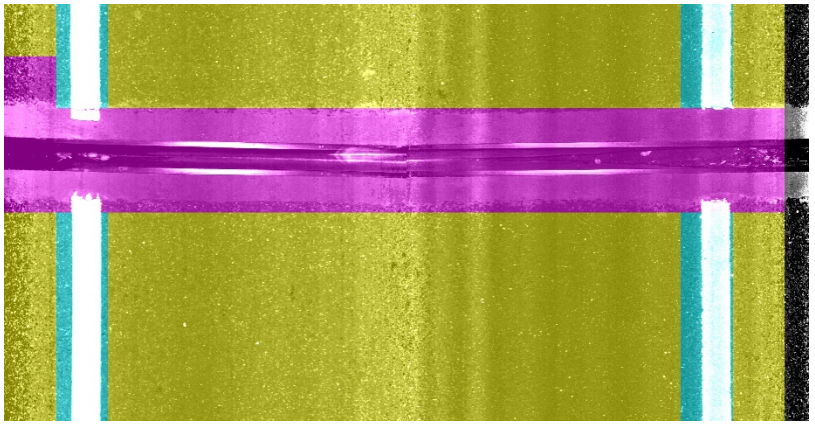
- Real-time Collection & Detection
- Processing Speed: 90 MPH

Other Non-Cracking Features: Markings, Man-Hole, Bridge Expansion Joint

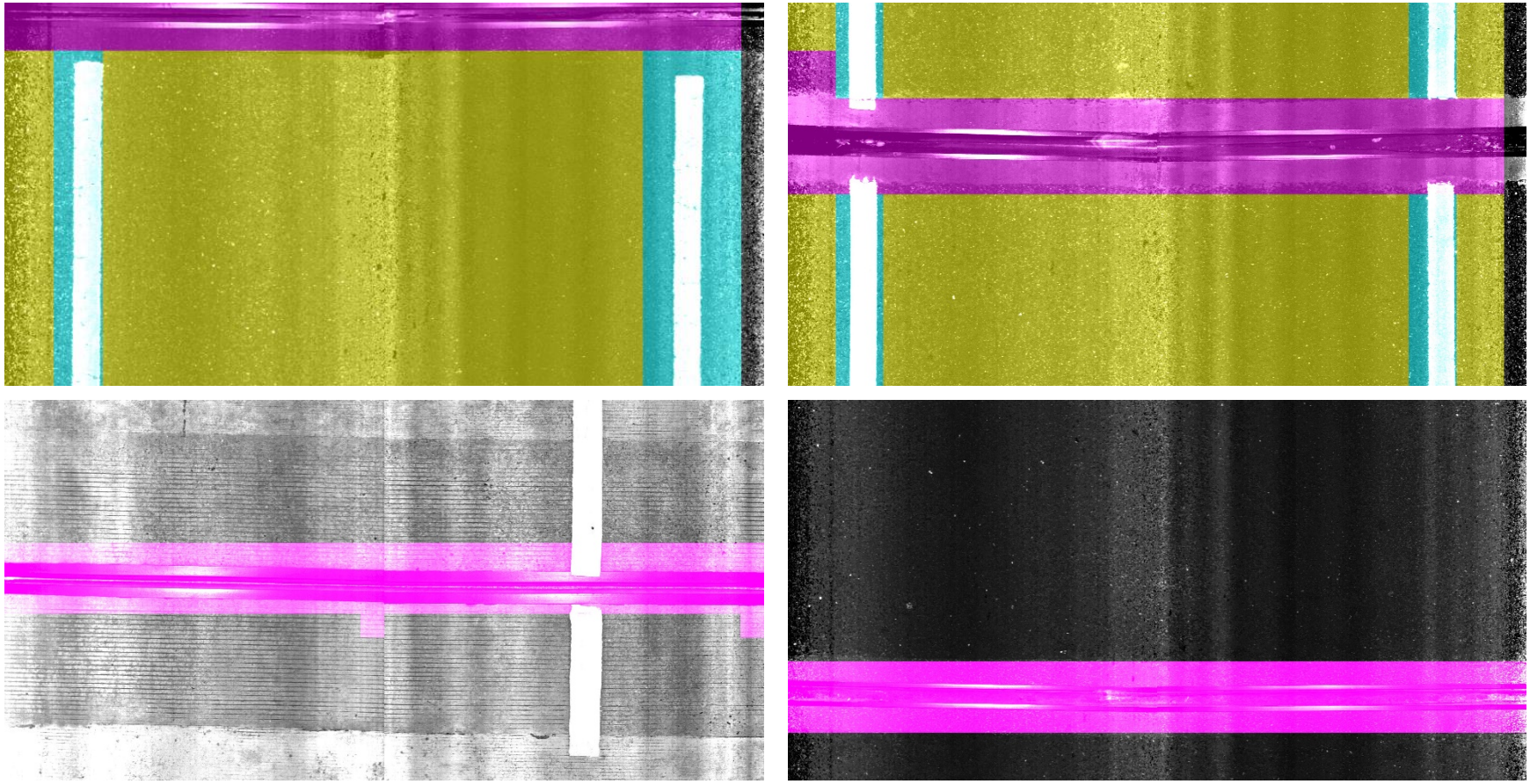






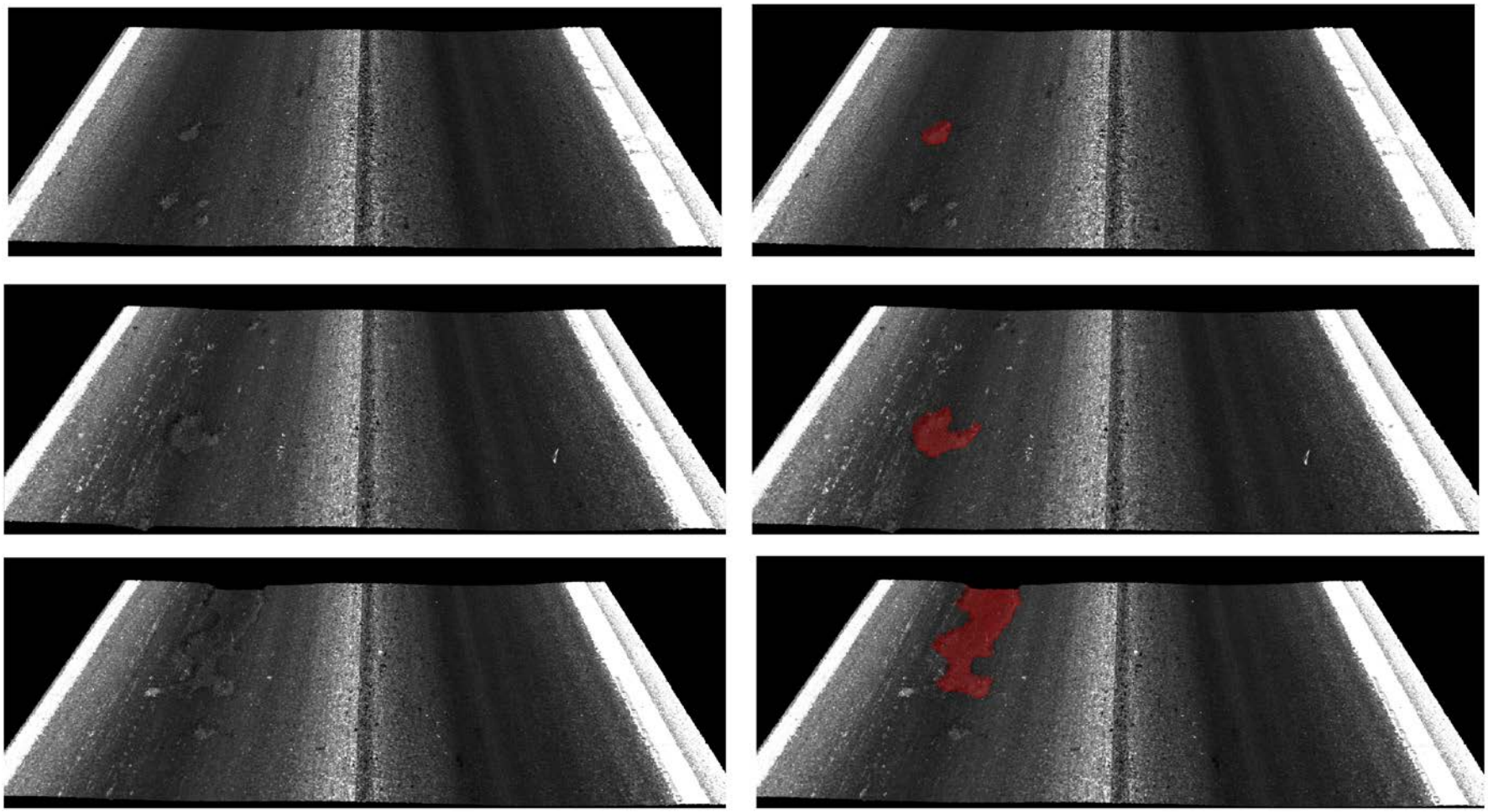


Expansion Joint Detection

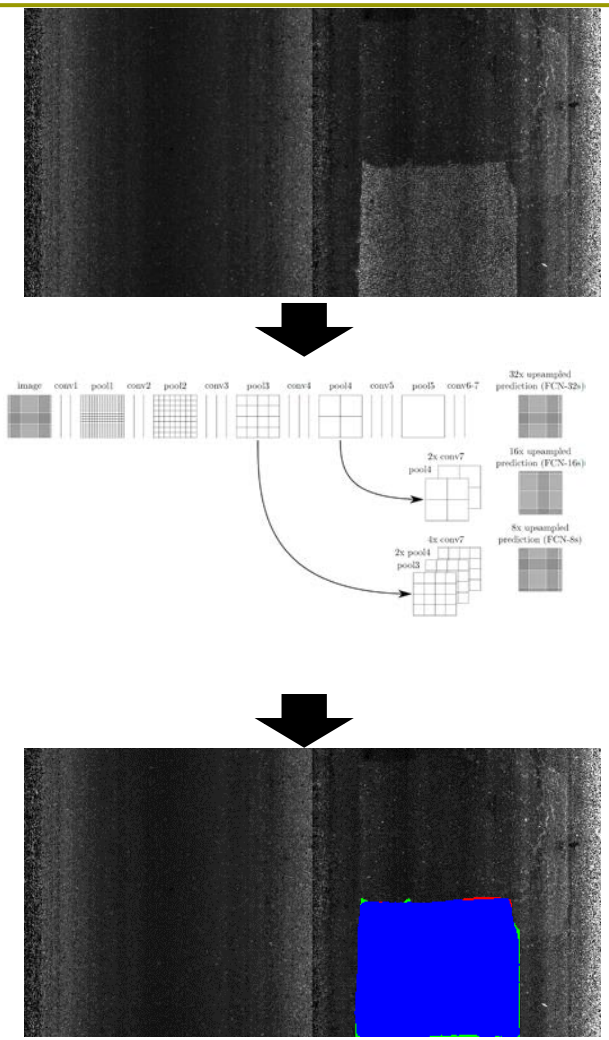


Accuracy: 93% **Processing Speed: 50 MPH**

Pothole Identification

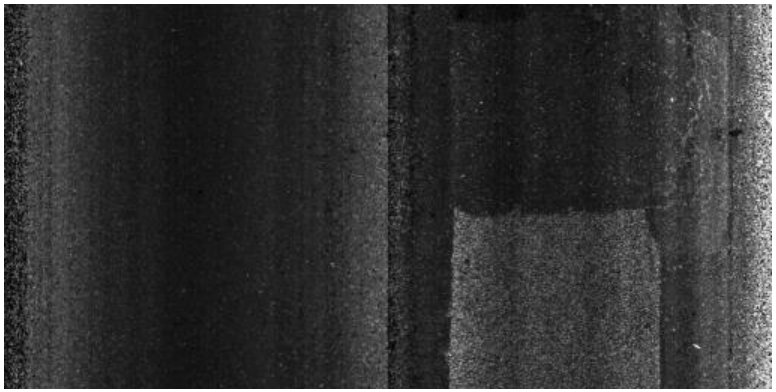


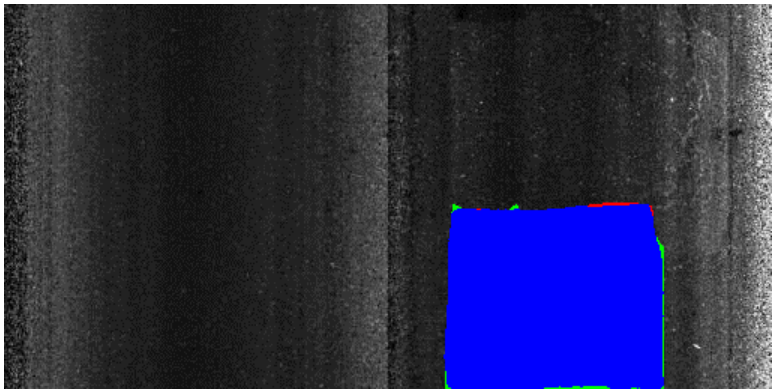
Pavement Patch Detection

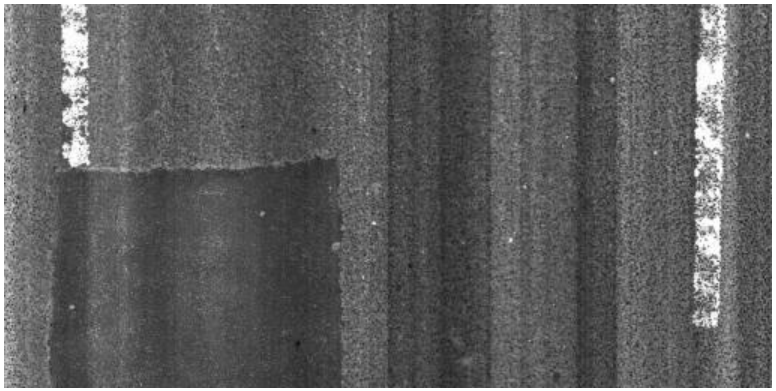


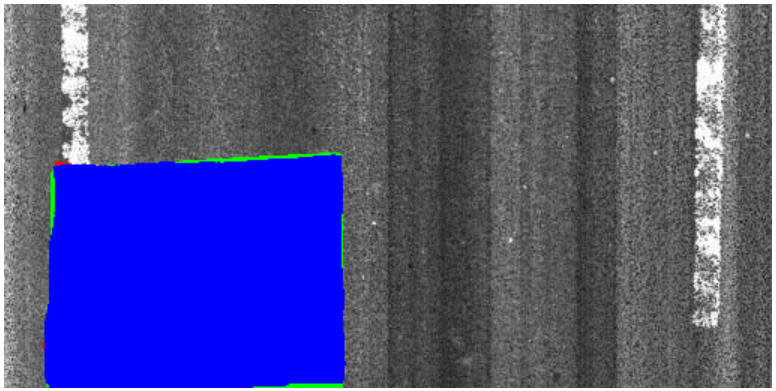
- Training & Testing Images Library
  - 22,000 manually annotated sample images
- Deep Learning for Semantic Segmentation
  - Pixel-level accuracy
- Accuracy
  - **84.58%**
- Processing Speed
  - **>100 MPH**

Pavement Patch Detection

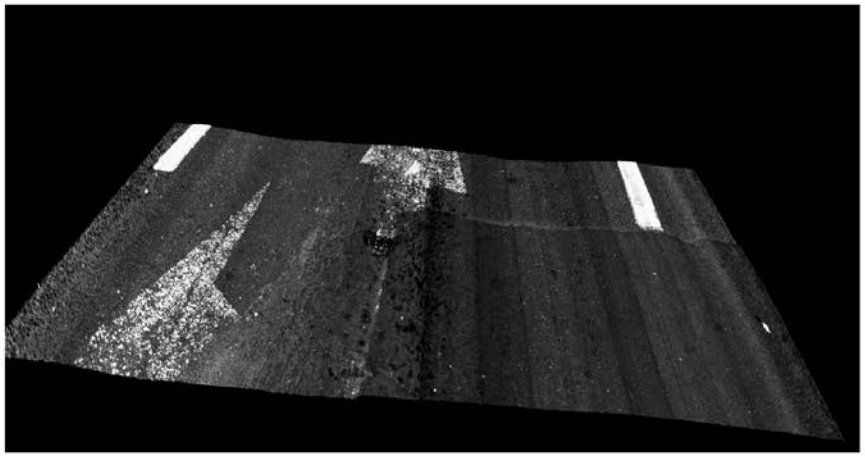


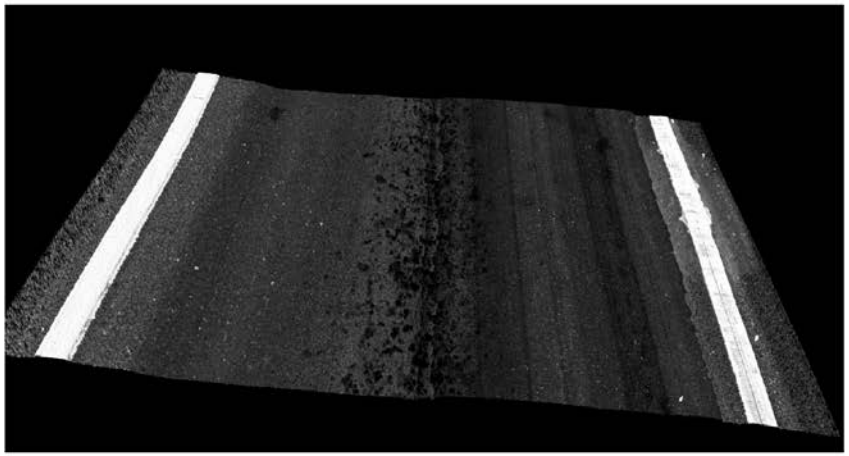


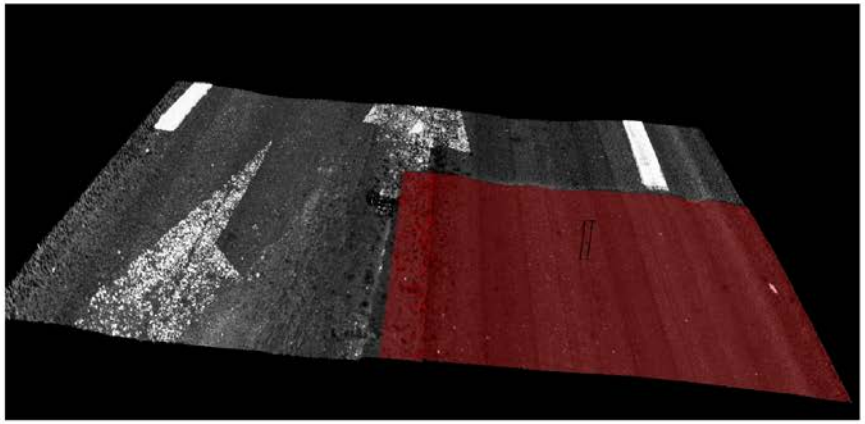


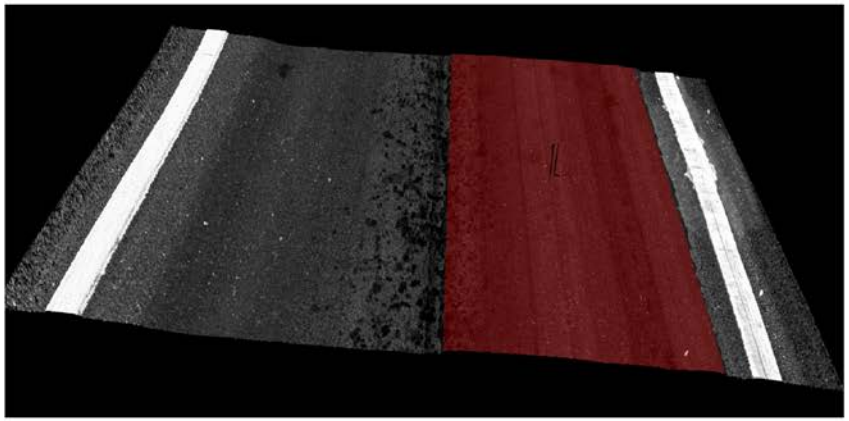


Patching Identification

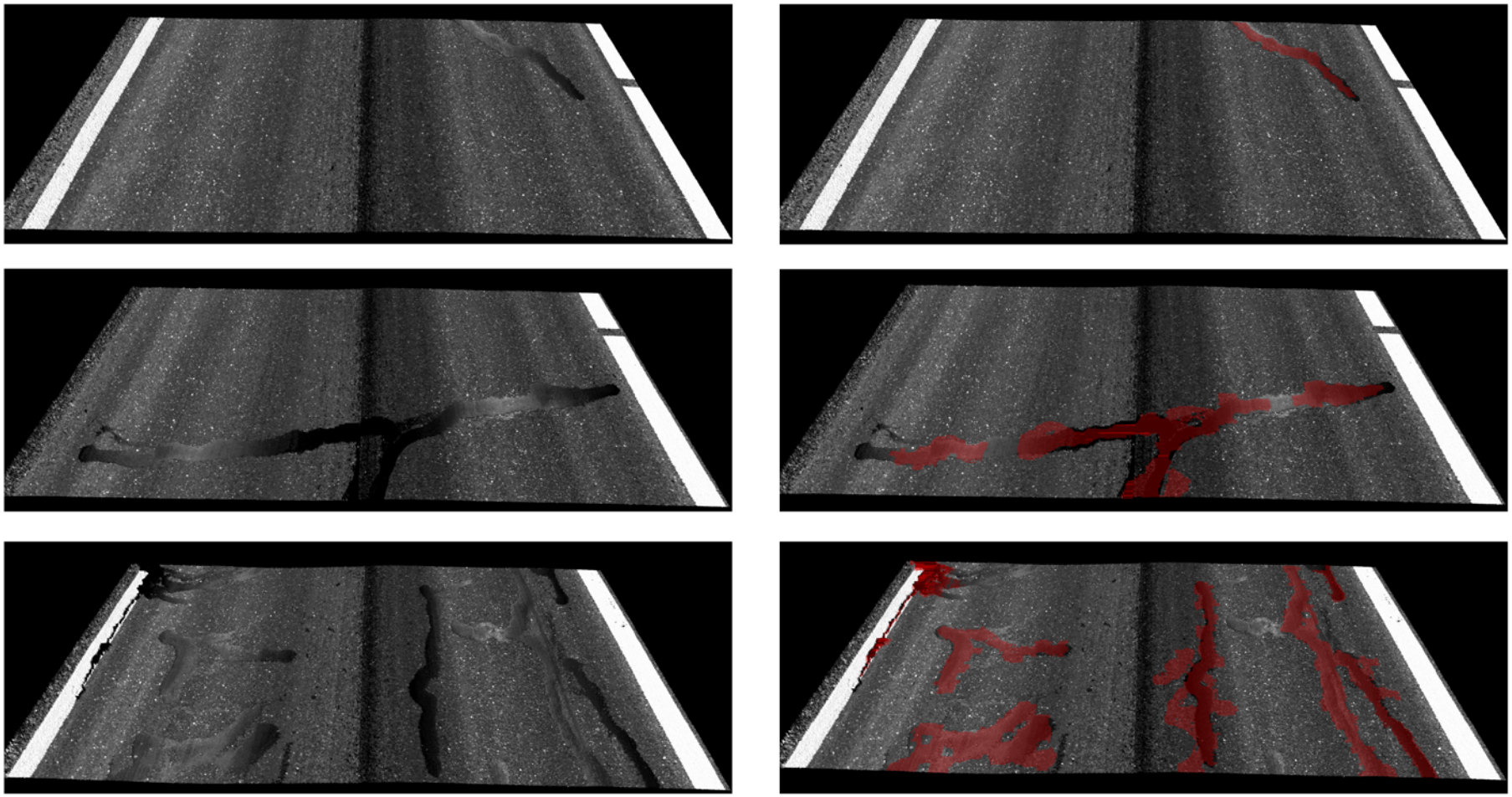




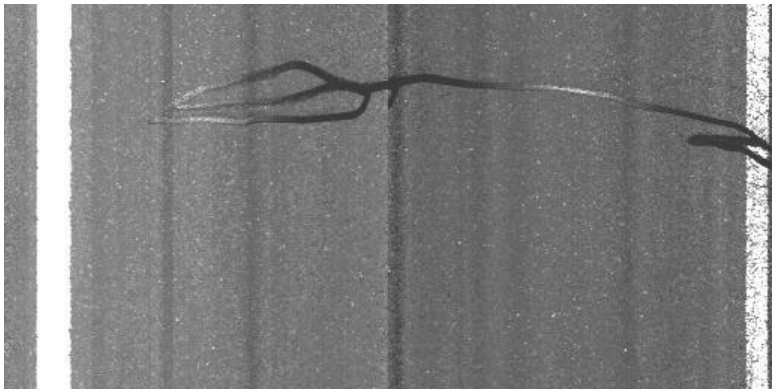


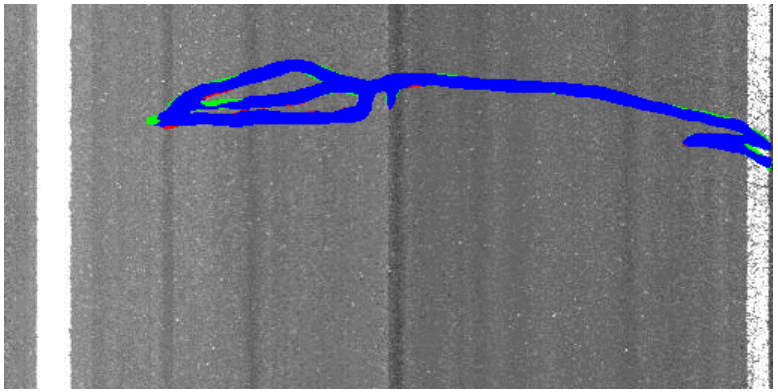


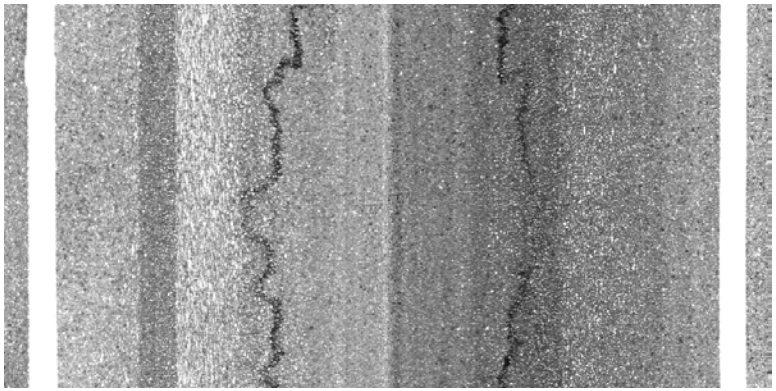
Sealed-Cracking Identification

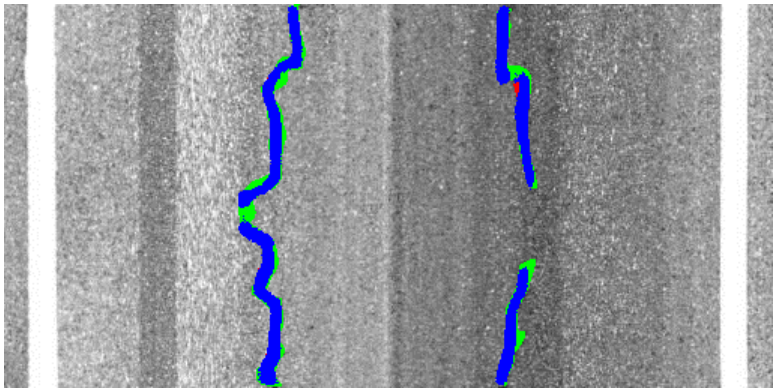


Sealed-Cracking Identification









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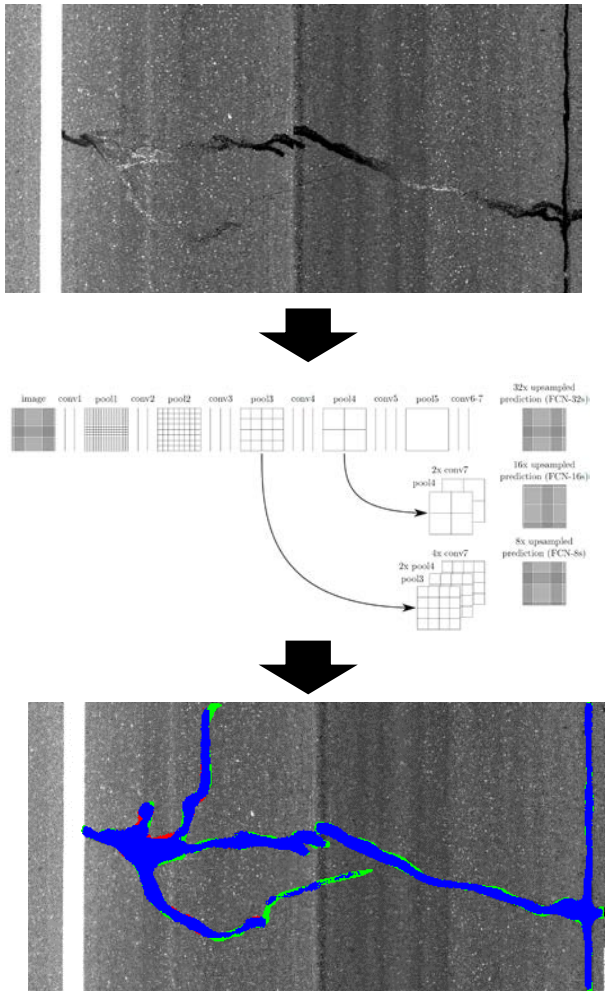
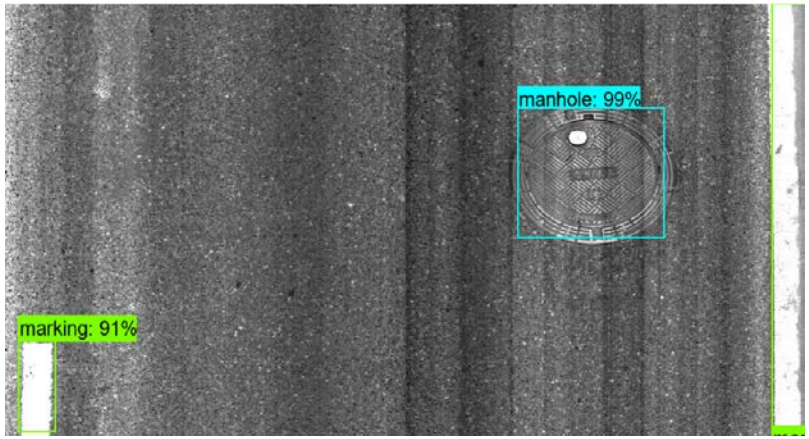
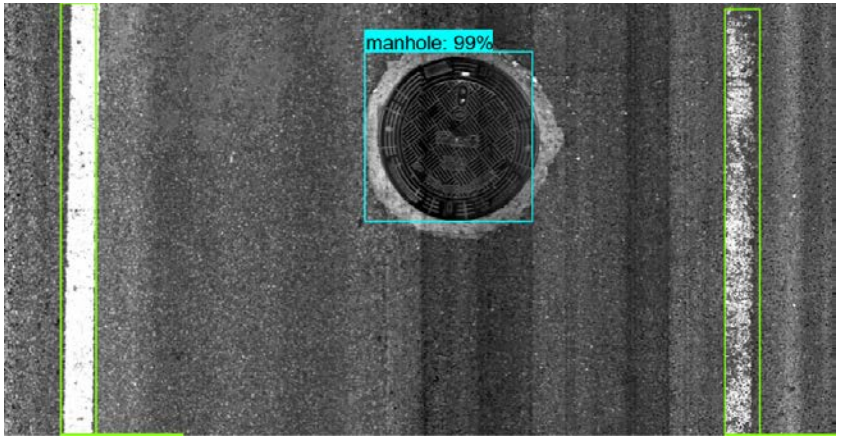
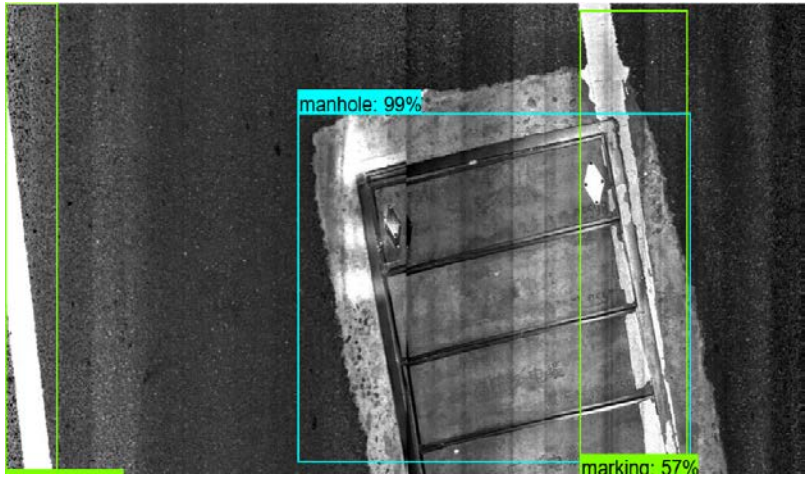


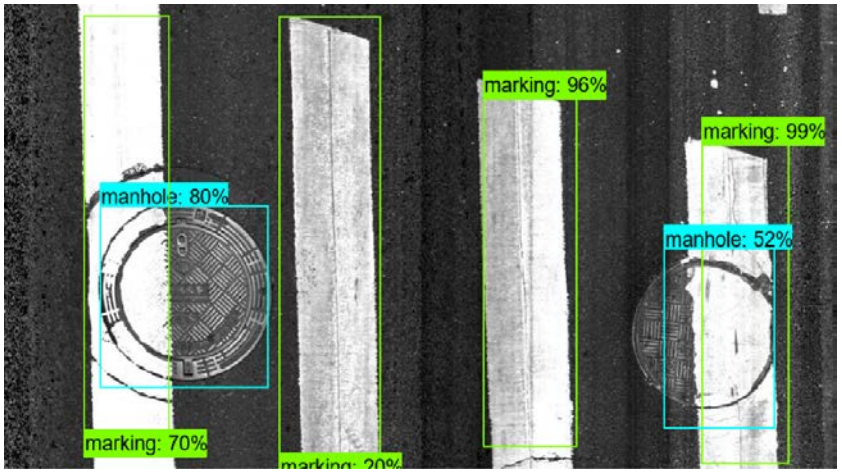
- Training & Testing Images Library
  - 3,500 manually annotated sample images
- Deep Learning for Semantic Segmentation
  - Pixel-level accuracy
- Accuracy
  - **85.04%**
- Processing Speed
  - **>100 MPH**

Manhole Detection



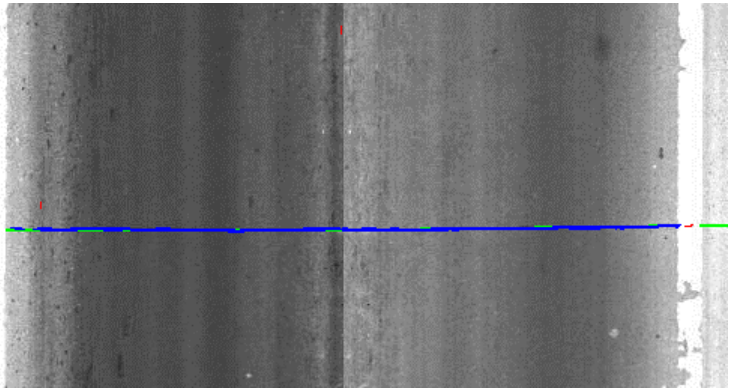


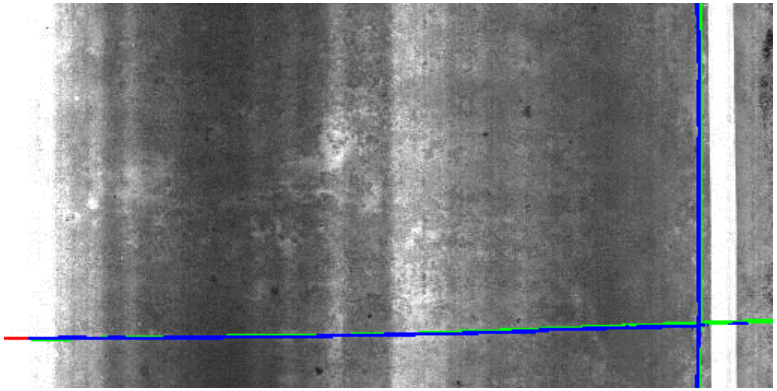


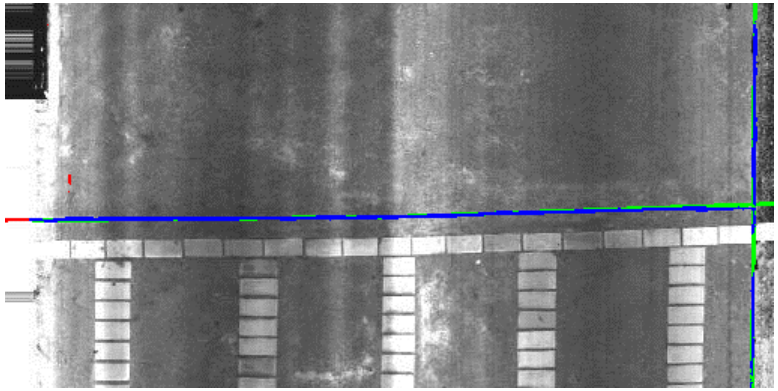


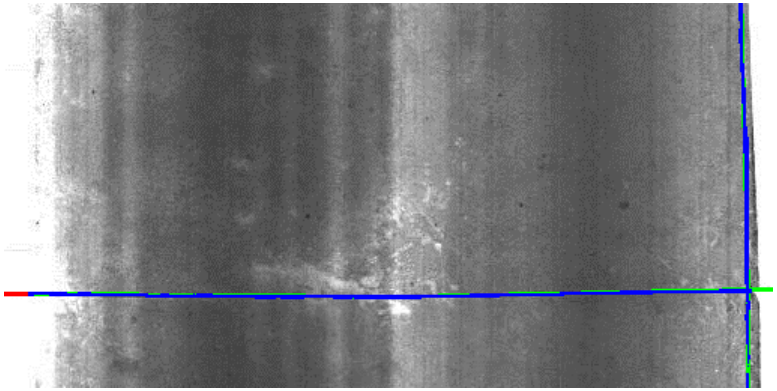
Accuracy: >80% **Processing Speed: 80 MPH**

Faulting Detection: Joint First

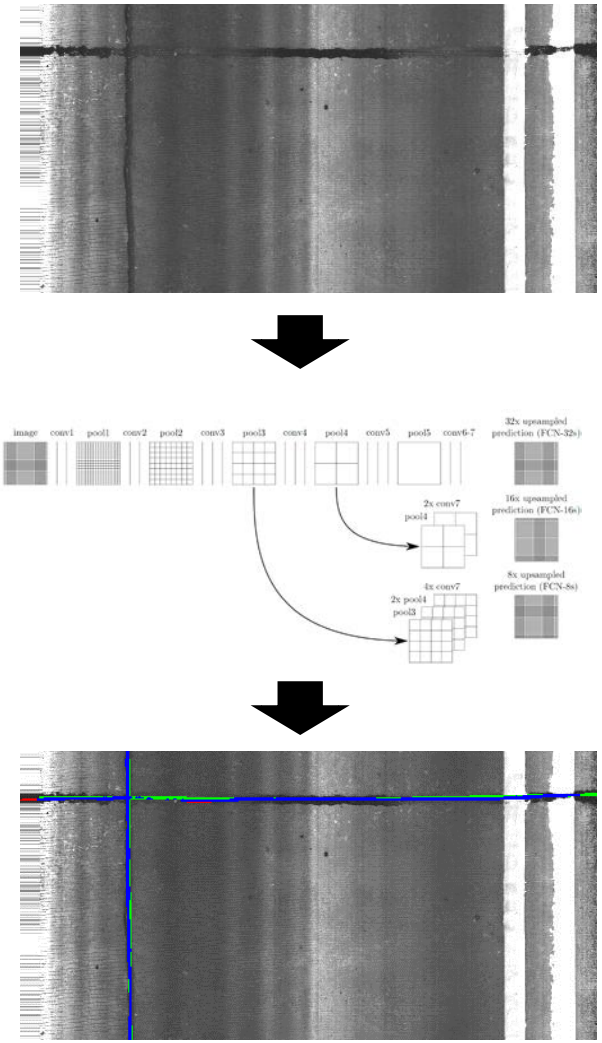








Faulting Detection

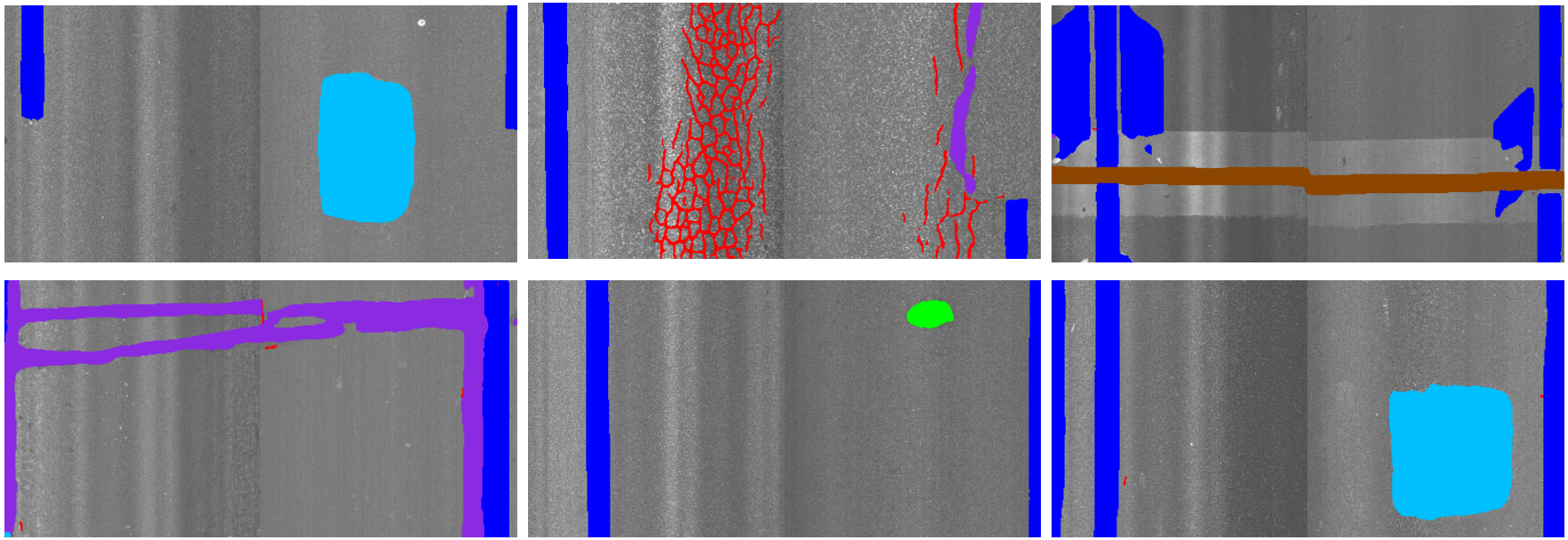


- Pavement Joint Detection via Deep Neural Network
  - 3,000 manually annotated sample images
  - Accuracy: >85%
  - Processing Speed: >100MPH
- Faulting Detection based on Full-lane 3D Pavement Surface Data

Future CrackNet: Multiple-Distress

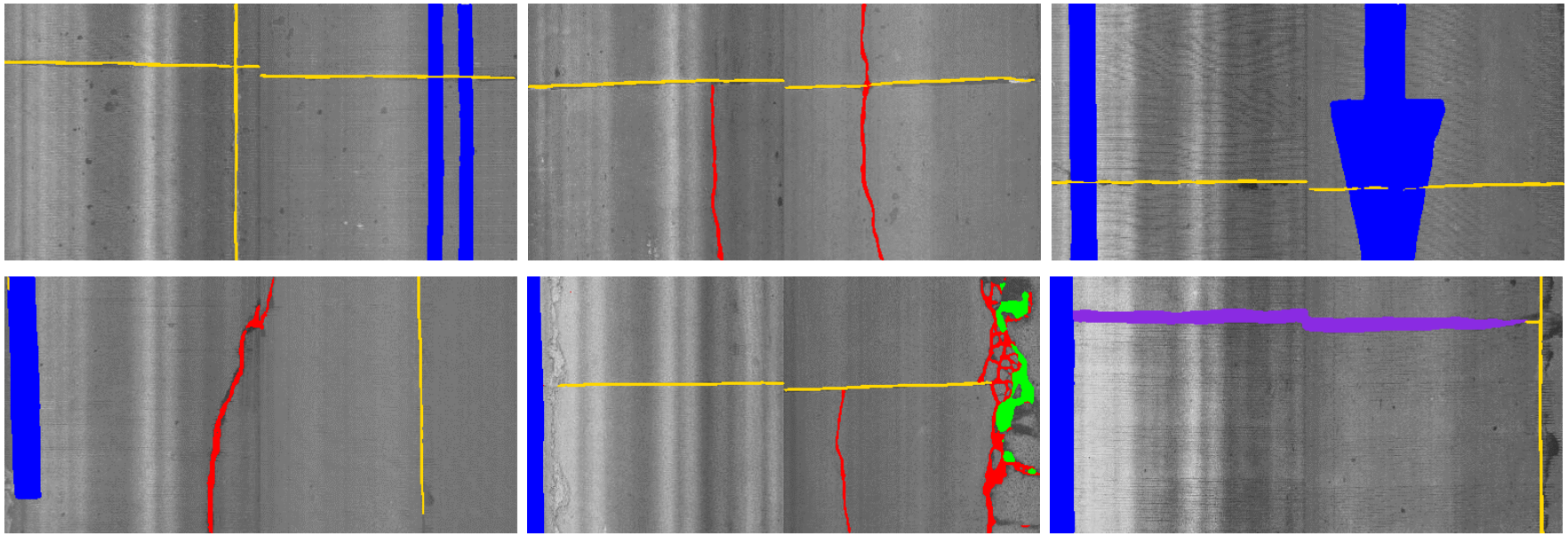
- Pixel-Level Accuracy
- Diverse Training Data
- Deep Neural Networks
- Parallel Computing
- Efficiency
- Non-Cracking Distresses
- Real-Time Processing
- Consistent Accuracy (Precision & Bias)
  - Better than 90% All the Time

Multi-Distress Single-Network on AC



- Distresses and typical patterns
  - Crack, Pothole, Patch, Sealing, Marking, Expansion joint, Manhole
- Performance
  - Pixel-level accuracy: 91%
  - Processing Speed: 125 MPH

Multi-Distress Single-Network on Rigid



- Distresses and typical patterns
  - Crack, Pothole, Corner break, Divided slab, Sealing, Patch, Joint spalling, Joint, Marking, Manhole
- Performance
  - Pixel-level accuracy: 88%
  - Processing Speed: 125 MPH

Conclusions

- AI for Pavement Distress Survey
  - In Production for Full Automation
- Multiple-Objective DL
  - Near Future in Production > 100MPH
- Deep Sub-mm (0.1-mm) 3D Pavement
  - Safety and Friction
- Frontier: Self-Learning
  - Build Networks to Generate Training Data Sets (Labeling Data) with No or Limited Human Intervention

Acknowledgement

- USDOT UTC Programs
- FHWA
- FAA Tech Center
- NCHRP
- INDOT, ARDOT, ODOT
- Other Users & Sponsors Worldwide