Automatic Pavement Crack Evaluation Using 3D Laser Data and Crack Fundamental Element Model

Yichang (James) Tsai
Zhaohua Wang (Presenter)
Chenglong Jiang

Georgia Institute of Technology

March 26, 2015

Georgia Department of Transportation

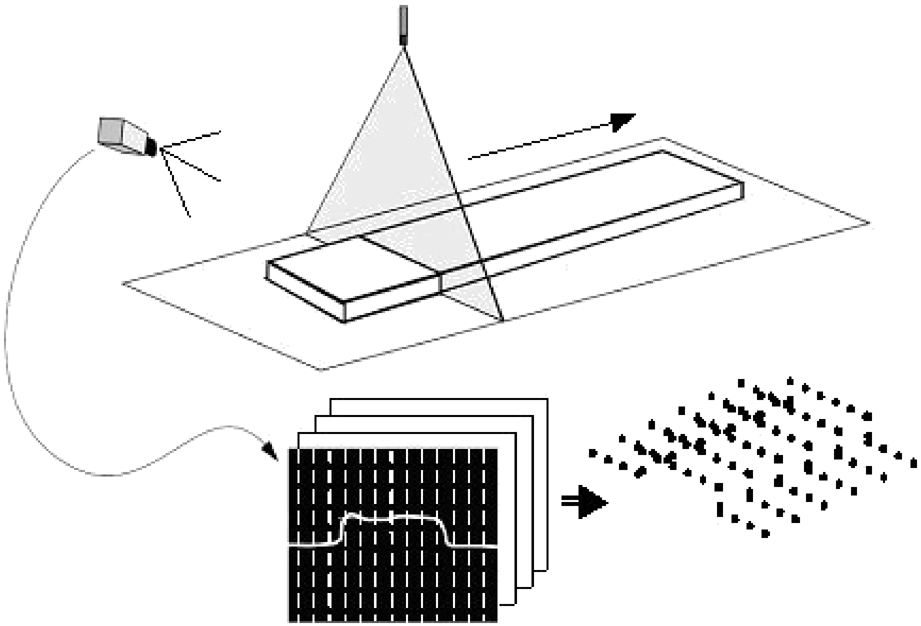
Outline

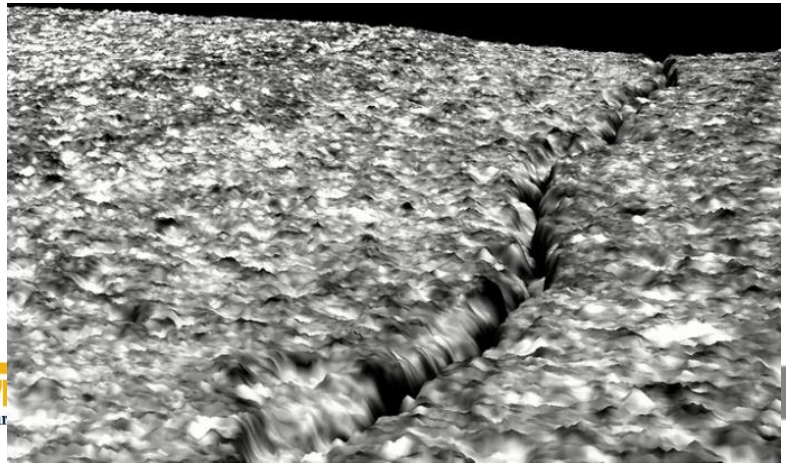
- Research objective
- 3D Line Laser Imaging Technology and Georgia Tech Sensing Vehicle
- GDOT pavement distress protocol
- Crack Fundamental Element (CFE) model
- Algorithms for automatic crack classification
- Case study
- Conclusions

Research Objective

- To validate the feasibility of applying the emerging 3D line laser imaging technology on automatic pavement crack evaluation
- To propose a multi-scale crack representation method using Crack Fundamental Element (CFE) model
- To propose an automatic crack classification method using GDOT distress protocol (PACES)

3D Line Laser Imaging Technology





1. Transverse direction : 1 mm

2. Elevation: 0.5 mm

3. Data points collected per second and width covered:

2 (lasers) * 2048 (points/profile/laser) * 5600 HZ = 22,937,600 points

2 (lasers) * 2048 (points/profile/laser) * 1 (mm) = 4.096 m

Georgia Tech Sensing Vehicle

GDOT Pavement Distress Protocol

- GDOT PACES (Pavement Condition Evaluation Systems) defines 10 types of distresses
  - Load cracking
  - Block cracking
  - Reflection cracking
  - Rutting
  - Corrugation/Pushing
  - Edge distress
  - Raveling
  - Bleeding/Flushing
  - Loss of section
  - Patches and Potholes

Need of Automatic Data Collection

- GDOT (similar to almost all other state DOTs) currently uses manual, visual survey
  - Time consuming
  - Subjective
  - Safety concern
  - Data completeness
- 3D line laser imaging data has great potential to automate the pavement distress data collection
  - Data collected in one run can be used to extract all the distress data
  - Advancement of signal processing and machine learning makes it possible
  - Cracking, rutting, raveling, and potholes have been studied

Load Cracking

Level 1	Level 2
Level 3	Level 4

Block Cracking

Level 1	Level 2
Level 3	

Challenges of Crack Classification

- Features for crack classification
  - Location
  - Orientation
  - Length/density
  - Pattern
- Crack definition varies from agency to agency
  - Lack of a common crack presentation
  - Difficult to develop algorithms that are flexible and scalable

Crack Fundamental Element

CFE Cluster Geometrical Properties

Clustered CFEs
(CFE location, CFE orientation, and CFE extent)

Aggregated Crack Properties

Crack Network
(location, density of curves and pieces)

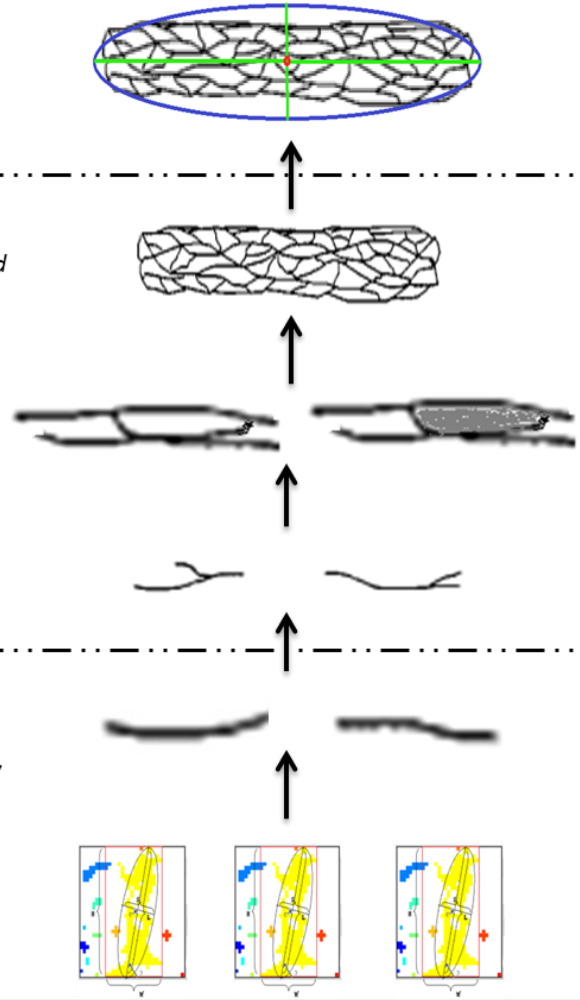
Crack Piece
(polygon or spall type, angle and area)

Crack Intersection
(number and location of key points)

Fundamental Crack Properties

Predominant Crack Curve
(location, extent, width, depth, and orientation)

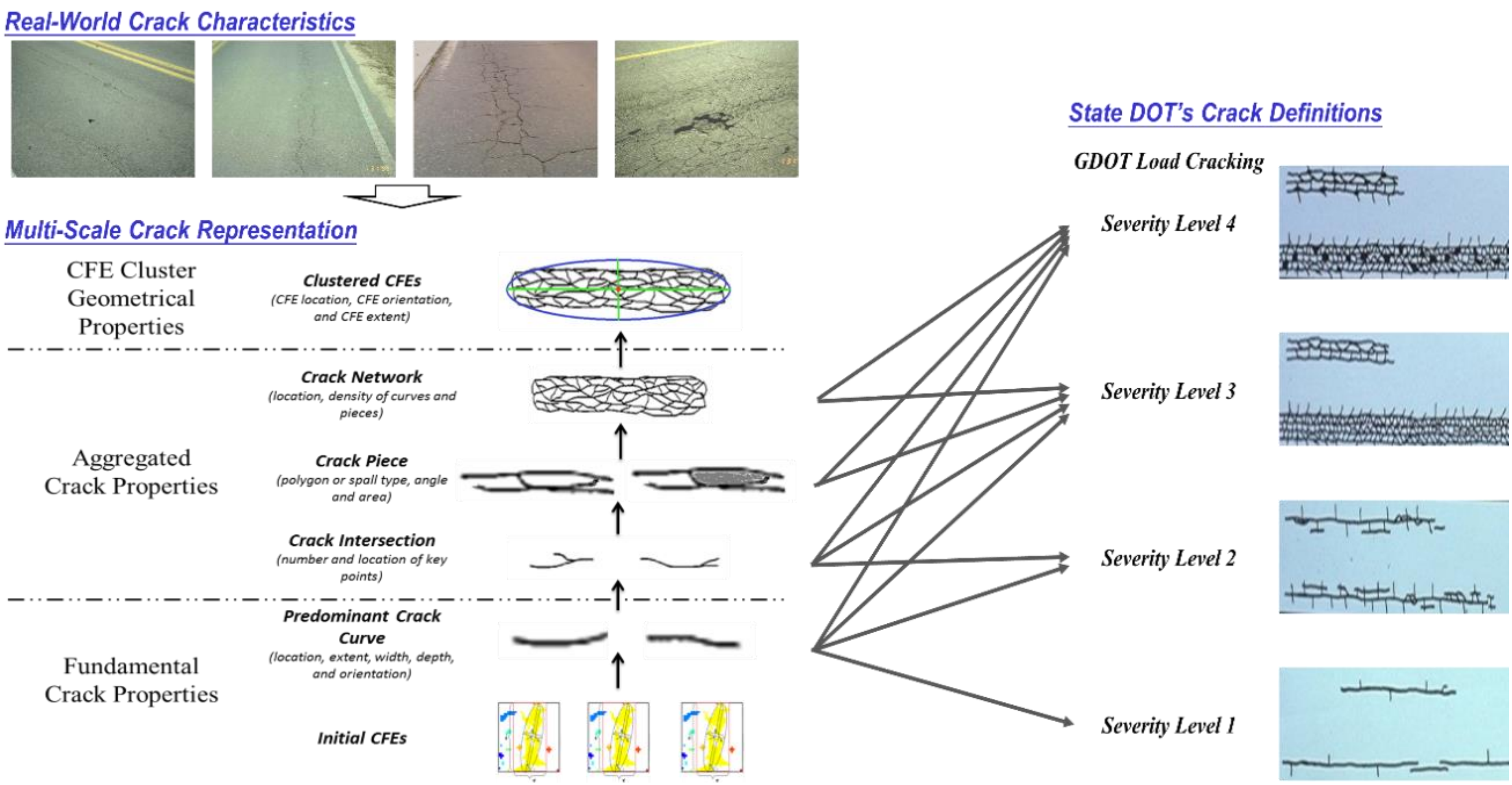
Initial CFEs



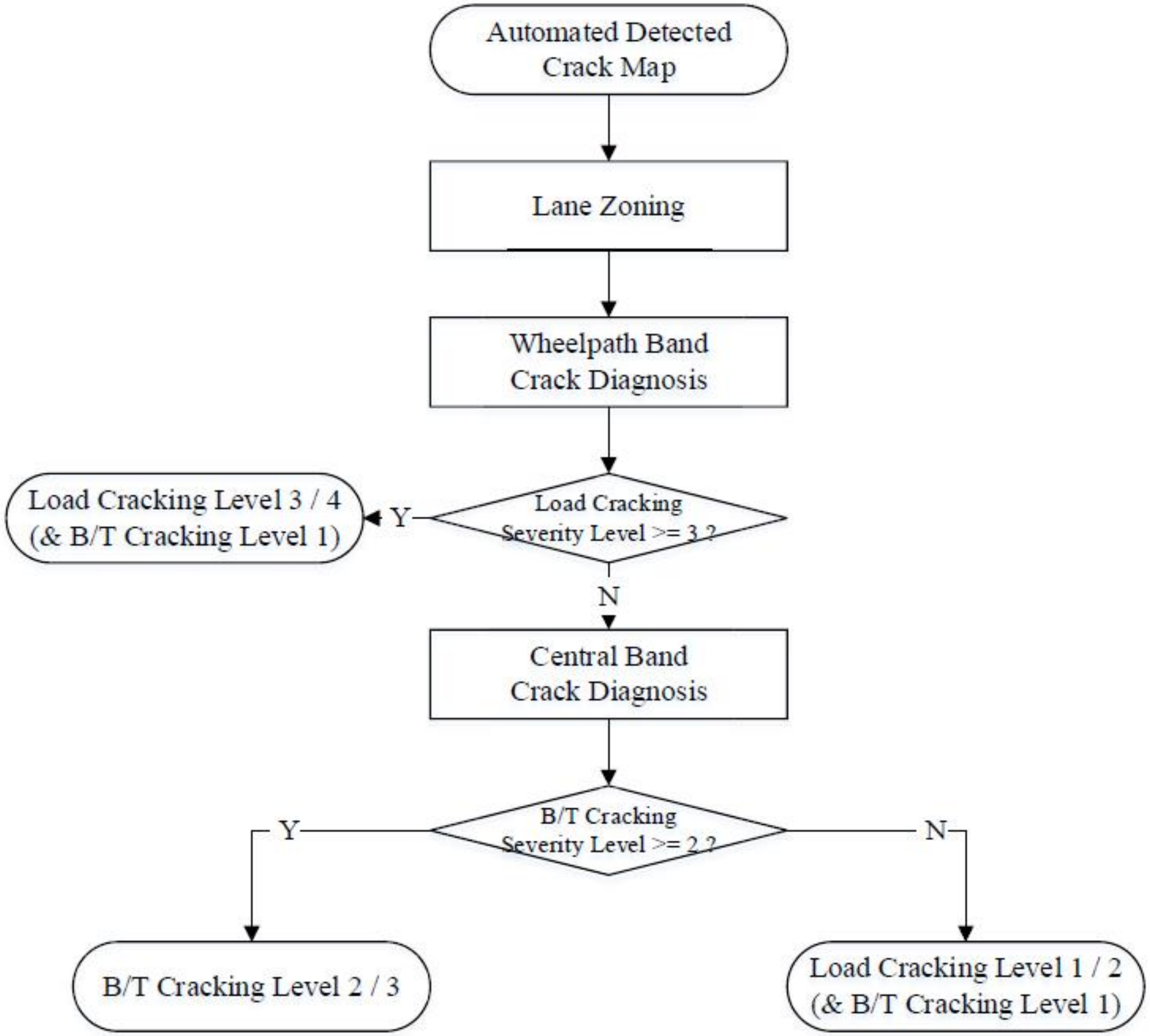
Multi-scale Crack Presentation

- **Fundamental crack properties** focus on each crack segment and describe the fundamental and physical properties of cracks, such as crack location, length, width, orientation, etc.
- **Aggregated crack properties** focus more on crack patterns inside the clustered CFE and represent how cracks interact with each other, including intersections and polygons
- **CFE cluster geometrical properties** treat each CFE cluster as a whole and describe its overall properties. These geometrical properties are also used to cluster CFEs from low scale to high scale.

Using CFE in Agency's Protocol



Load/Block Cracking Classification



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Crack Classification Features

Fundamental Crack Properties	Length of longitudinal cracks
	Length of total cracks
	Ratio of longitudinal to total length
	Number of initial CFEs
	Number of continuous crack lines
	Average crack width
	Maximum crack width
Aggregated Crack Properties	Number of crack intersect points
	Area of surface loss
	Crack distribution based on orientations
CFE Cluster Geometrical Properties	Length of clustered CFEs
	Width of clustered CFEs

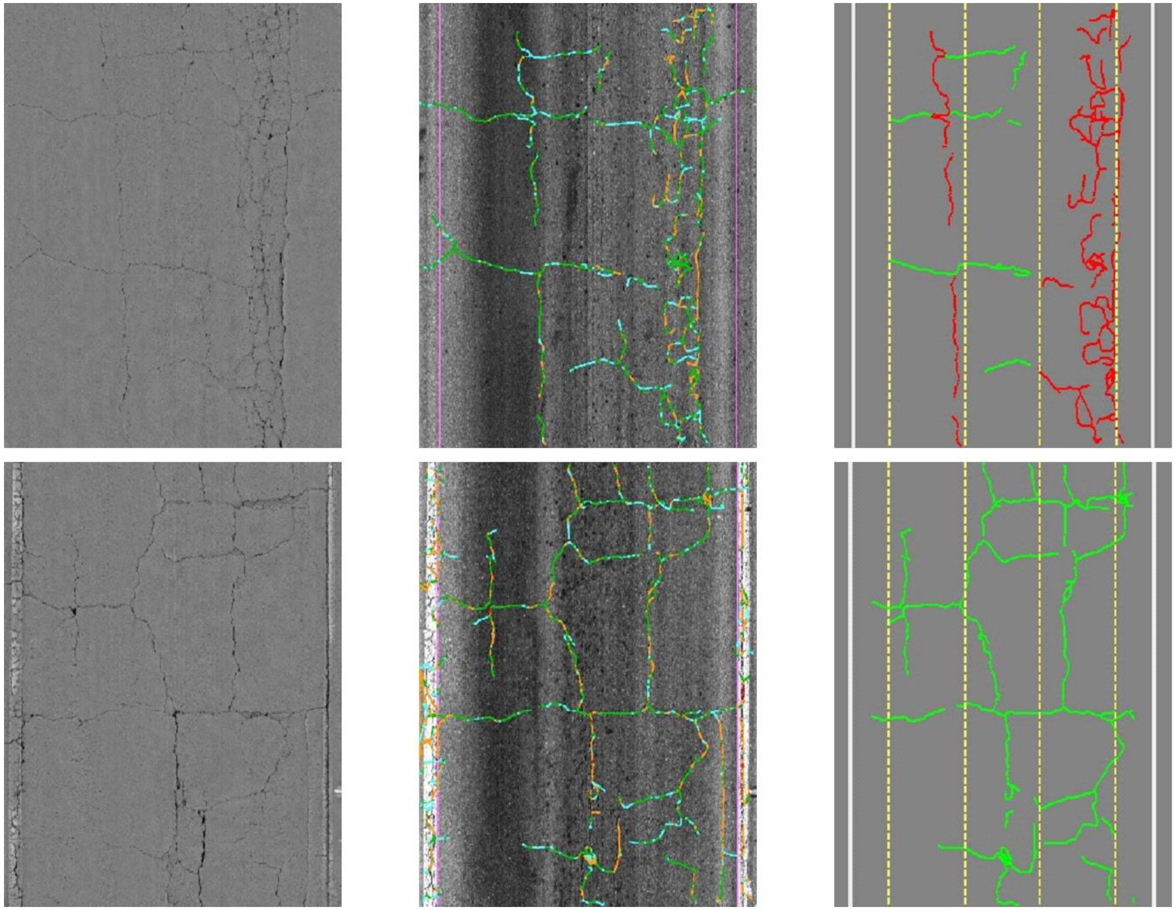
The features are used as input for a machine learning algorithm

Case Study

- Experimental tests are conducted on GA SR 236 to validate the proposed algorithm
- GDOT pavement maintenance liaison engineers help establish the ground truth through the validation process
  - Image-based in-house data collection
  - Field data collection on three 100-ft sections
- 70% of data was used for training dataset

  and the remaining 30% for testing

Testing Results (1)



Left Wheelpath	
LC Level 1	12.6
Right Wheelpath	
LC Level 3	15.9
Non Wheelpath	
BT Level 1	18.8

Left Wheelpath	
None	0
Right Wheelpath	
None	0
Non Wheelpath	
BT Level 2	N/A

Testing Results (2)

Site #1

	Field Measurement		Automatic Evaluation	
	Extent(%)	Deduct	Extent(%)	Deduct
Load Lvl 1	56	15	48	15
B/T Lvl 1	100	18	100	18
Overall		33		33

Site #2

	Field Measurement		Automatic Evaluation	
	Extent(%)	Deduct	Extent(%)	Deduct
Load Lvl 1	30	10	25	9
Load Lvl 2	7	9	7	9
Load Lvl 4	11	29	7	22
B/T Lvl 1	99	18	100	18
Overall		47		40

Site #3

	Field Measurement		Automatic Evaluation	
	Extent(%)	Deduct	Extent(%)	Deduct
Load Lvl 1	41	13	27	9
Load Lvl 2	2	2	0	0
B/T Lvl 1	100	18	100	18
Overall		31		27

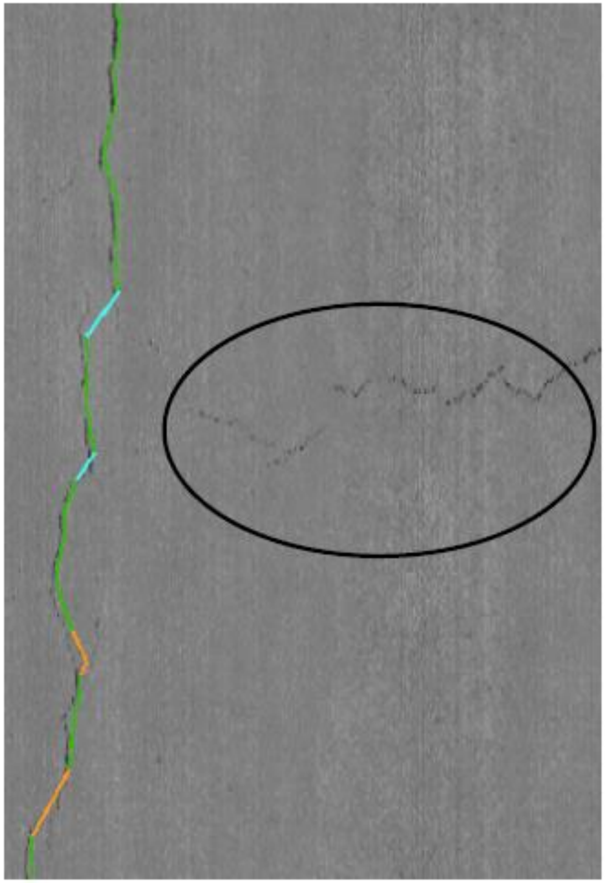
Note: the total deduct value is computed using the predominant deduct value for each crack type, following PACES.

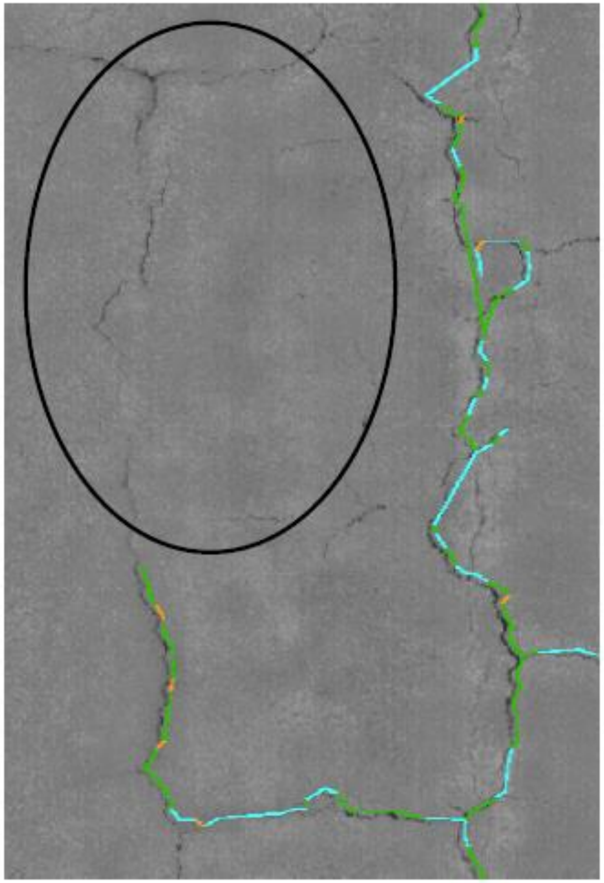
Testing Results (3)

		Predicted Level					
		None	Level 1	Level 2	Level 3&4	Total	Recall (%)
Actual Level	None	247	15	0	0	262	94.3
	Level 1	10	317	20	0	347	91.4
	Level 2	0	6	42	2	50	84.0
	Level 3&4	0	0	2	40	42	95.2
	Total	257	338	64	42	701	
	Precision (%)	96.1	93.8	65.6	95.2		92.2

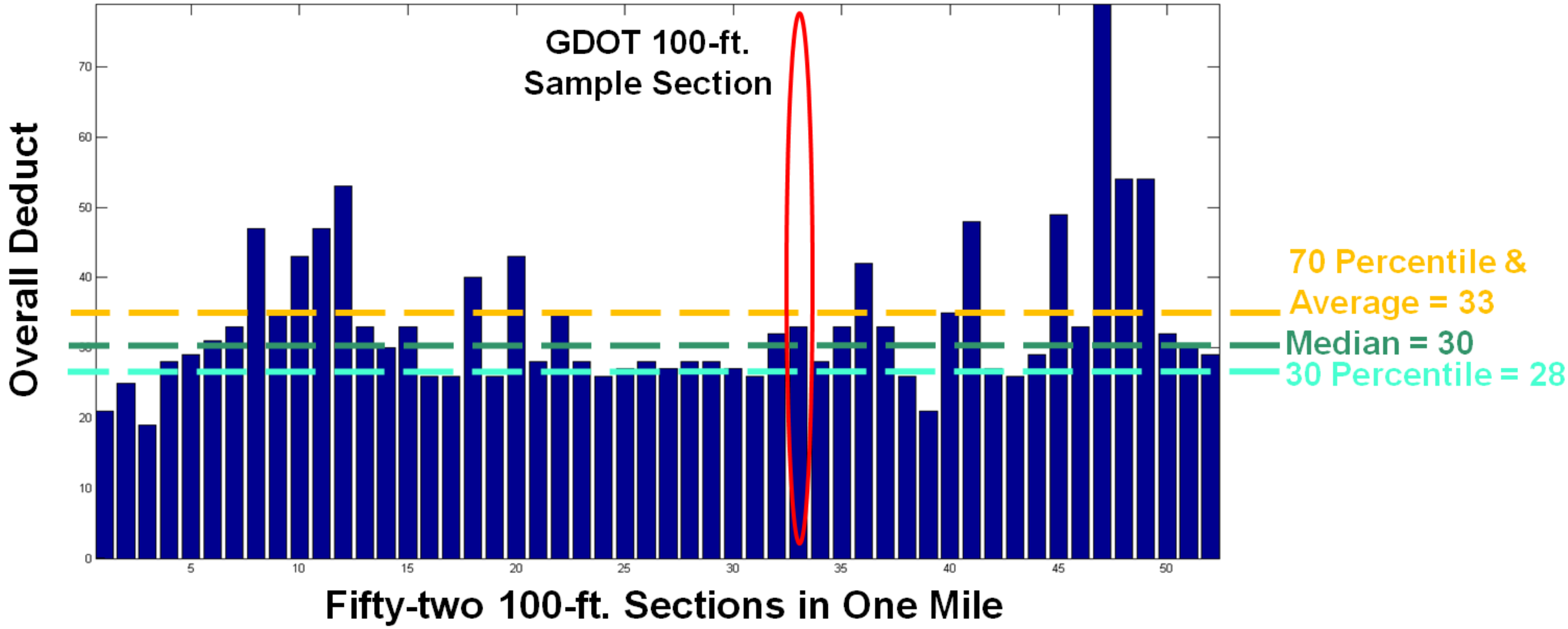
Note: This is the image-base classification result.

Reasons for Inaccuracy





More Detailed Cracking Data



Conclusions

- A multi-scale crack analysis concept based on CFE model is proposed, which can be applied to:
  - Maintain the legacy of GDOT historical data and pavement management practice; and
  - Integrate with standardized crack measures, e.g. LTPP protocol for MEPDG calibration.
- An automatic crack classification method is developed for GDOT load cracking and B/T cracking. The proposed method and application are promising tools to transform the sensing data and crack detection outcomes into useful decision support information.
- A large-scale validation on the interstate highways is recommended for future implementation.

Thanks!

Q/A