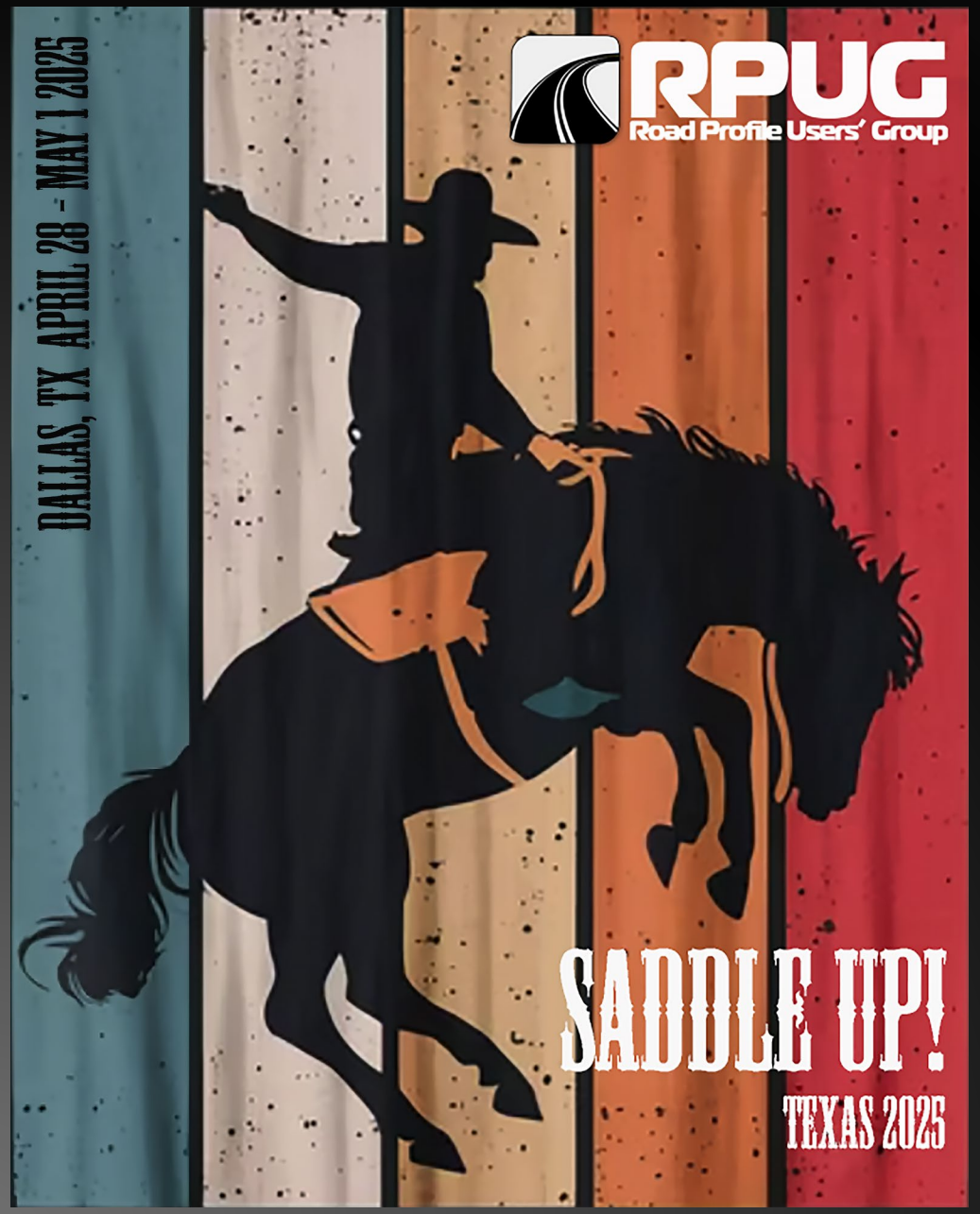

CRACKING DATA QUALITY ASSESSMENT USING GROUND REFERENCES: DEVELOPING A STANDARD METHODOLOGY

ZHONGYU YANG(GEORGIA INSTITUTE OF TECHNOLOGY), **HAOLIN WANG (PRESENTER)**, RYAN SALAMEH, MOHSEN MOHAMMADI, AND YI-CHANG (JAMES) TSAI

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OUTLINE

- Background
- Design Strategy
- End-to-end Assessment
- Decomposed Assessment
- Case Study
- Conclusion

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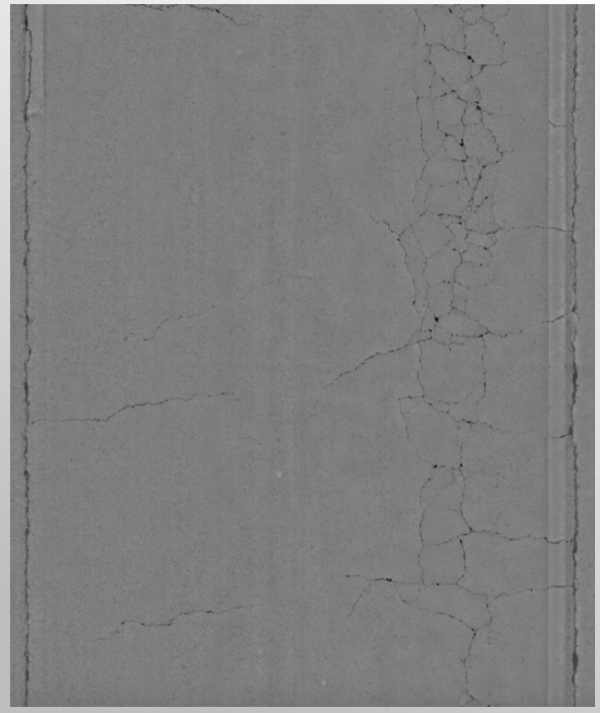
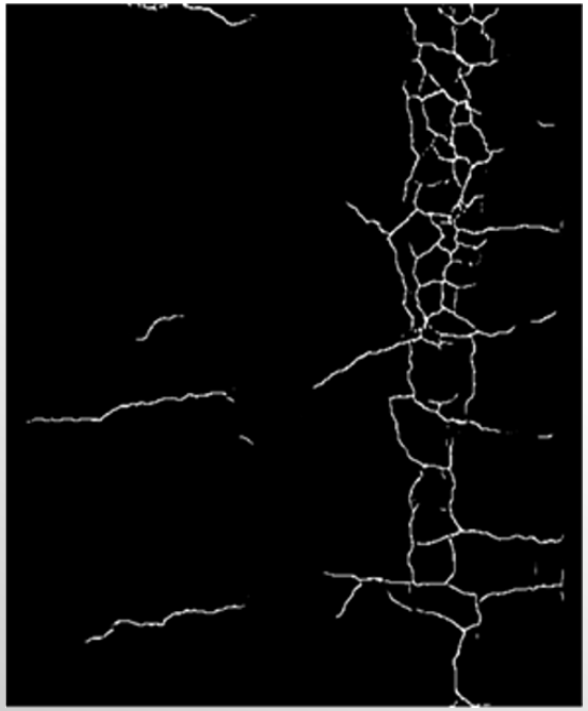
DETAILED CRACK INFORMATION = CRACK MAP

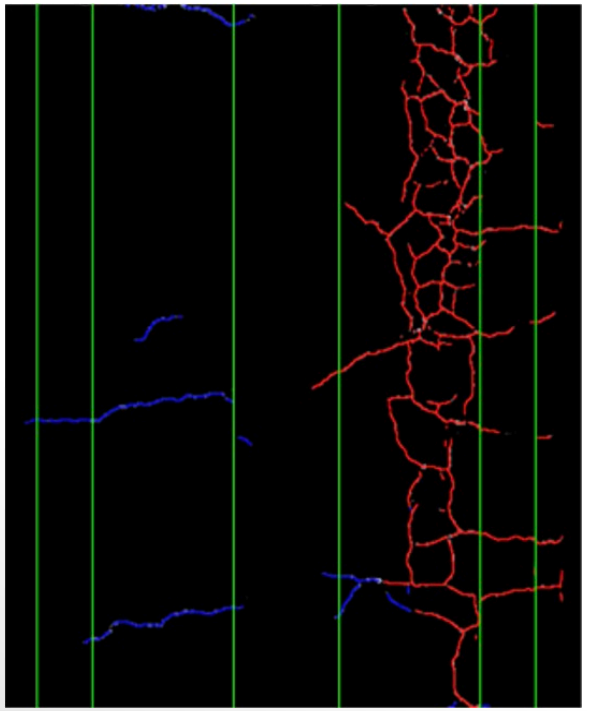
- Crack map (crack segmentation) could provide detailed information such as geometry, width, length, position. Better than 0/1 detection and bounding box.
- Ongoing NCHRP 01-57B defines standard crack definition using crack maps as input.



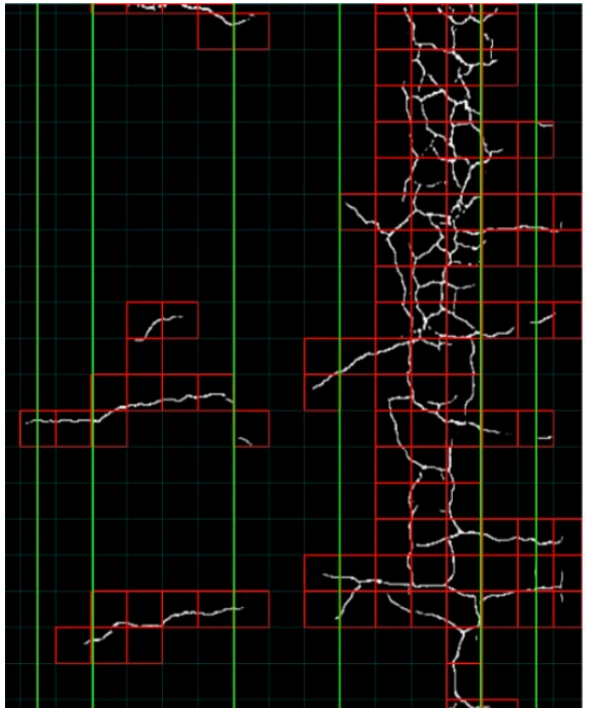
a) Range/Elevation Image



b) Crack Map



c) Classify Alligator Crack (Red) Using Crack Map



d) Report Crack Extend (Grid-based %) Using Crack Map

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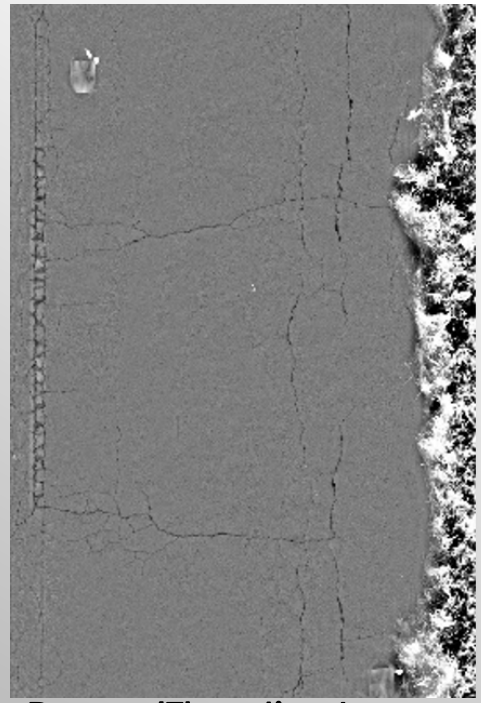
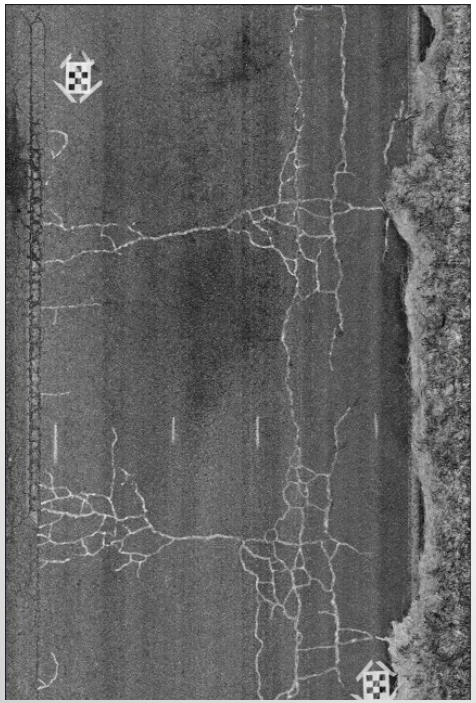
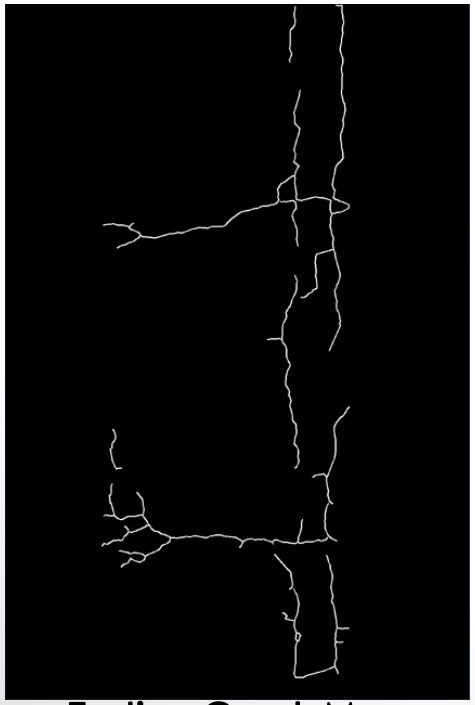
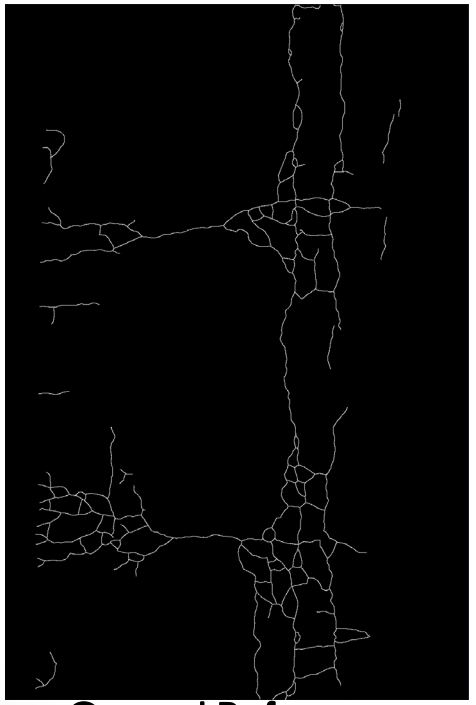
CRACK MAP QUALITY IMPACT CRACK ANALYSIS

- GIVEN STANDARD DEFINITIONS FOR CRACK INFORMATION EXTRACTION, VARIATION IN CRACK MAP QUALITY WOULD IMPACT THE RESULT.


Range/Elevation Image

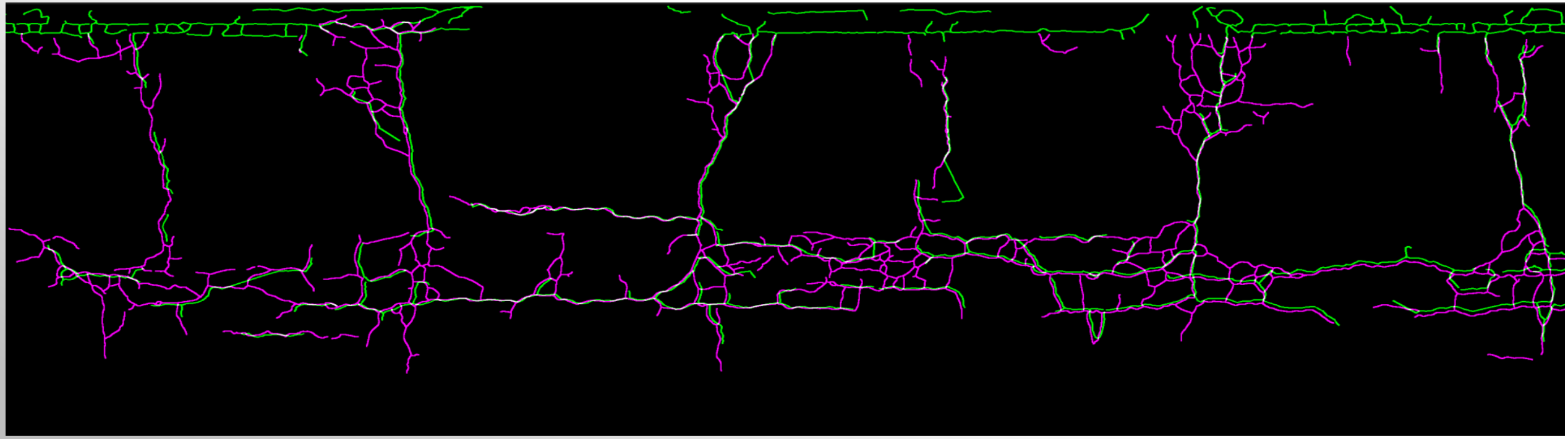

Intensity Image with Manual Annotation on Pavement


Testing Crack Map


Ground Reference Crack Map

CRACK MAP QUALITY IMPACT CRACK ANALYSIS

- GIVEN STANDARD DEFINITIONS FOR CRACK INFORMATION EXTRACTION, VARIATION IN CRACK MAP QUALITY WOULD IMPACT THE RESULT.
- IT IS IMPORTANT TO ASSESS CRACK DATA QUALITY.



Comparison Between Different Crack Maps
(Green-Testing, Purple-Manual Label, White-Overlap)

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ASSESSMENT DESIGN STRATEGY

- TWO STRATEGIES ARE PROPOSED TO ASSESS QUALITY OF CRACK MAPS AT DIFFERENT GRANULARITY:
  - **END-TO-END ASSESSMENT:** HIGH-LEVEL CRACK MAP COMPARISON FOR GENERAL QUALITY ASSESSMENT.
  - **DECOMPOSED ASSESSMENT:** GRANULAR ANALYSIS TO IDENTIFY POTENTIAL SOURCES OF DATA QUALITY ISSUES, SUCH AS SENSOR QUALITY AND DETECTION ALGORITHM ACCURACY.

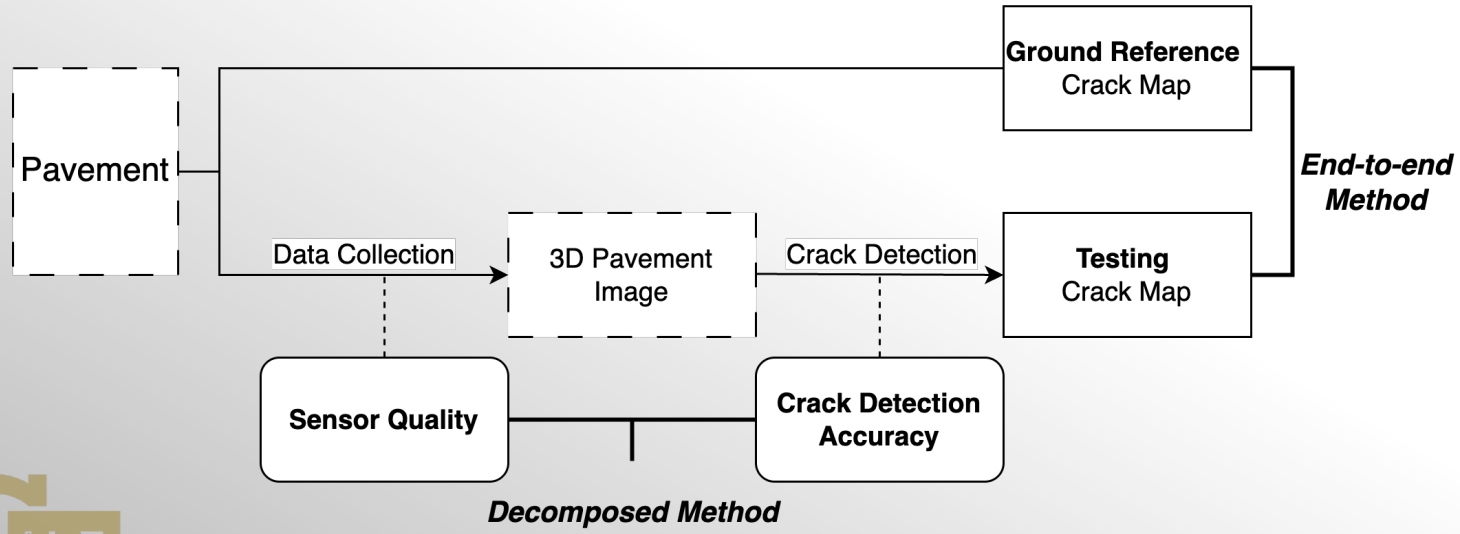


Illustration of Assessment Design Strategy

END-TO-END ASSESSMENT

- PROPOSED GROUND REFERENCE (GR) METHODS: AIM TO ESTABLISH GROUND REFERENCE CRACK MAPS FOR COMPARISON WITH TESTING SYSTEM CRACK MAPS.
  - GR METHOD 1 (TRADITIONAL METHOD) – CRACK SURVEY ON ENGINEERING SHEET (MODIFIED LTPP METHOD)
  - GR METHOD 2 (INNOVATIVE METHOD) – CRACK AMPLIFICATION ON PAVEMENT SURFACE (DRAWING WITH PAINT)
- COMPARE THE CRACK MAPS THROUGH VISUAL INSPECTION AND QUANTITATIVE ASSESSMENT.

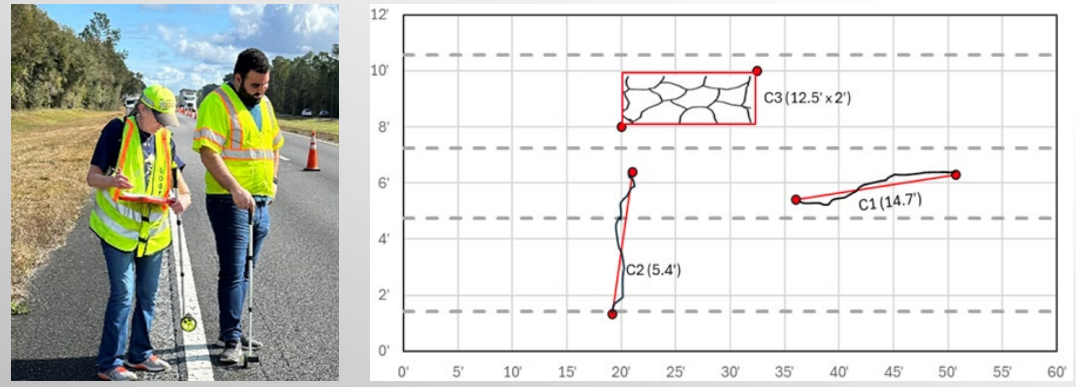


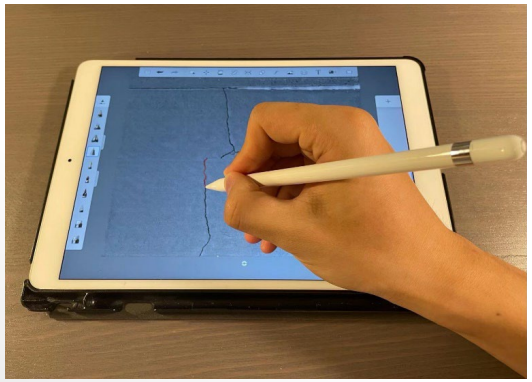
Illustration of Crack Survey on Engineering Sheet

Illustration of Crack Amplification

DECOMPOSED ASSESSMENT

- DECOMPOSED ASSESSMENT (ADOPTED FROM NCHRP 01-60) AIMS TO IDENTIFY POTENTIAL ISSUES OF TESTING SYSTEM'S CRACK MEASUREMENT, THE FOLLOWING TWO METHODS DECOMPOSE THESE ISSUES INTO SENSOR FACTOR (E.G., IMAGE QUALITY) OR CRACK DETECTION FACTOR.
  - METHOD 1 – SCANNING KNOWN OBJECTS (I.E., GROUND REFERENCE BOARDS) TO EVALUATE THE SENSOR QUALITY.
  - METHOD 2 – CRACK ANNOTATION ON PAVEMENT IMAGES WITH INTER-RATER CONSENSUS TO EVALUATE THE CRACK DETECTION ACCURACY.
- LEVERAGE THE METHODS TO IDENTIFY IMPACTING FACTORS OF TESTING SYSTEMS' CRACK DATA QUALITY.

Ground Reference Boards Set-up



Crack Manual Annotation

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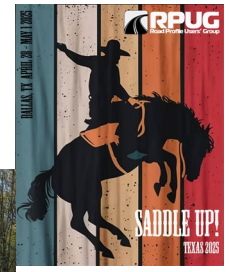
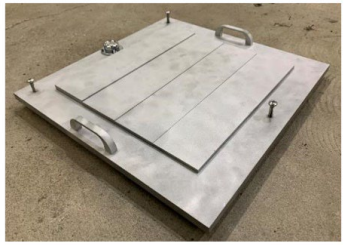
SENSOR QUALITY- GROUND REFERENCE BOARDS



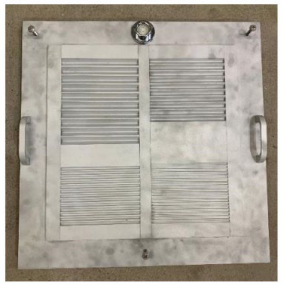
- Set up, collect, and analyze 3D data of ground reference boards on pavement.
- Three types of boards:
  - Step Board: Consists of 3 steps of sizes 0.5mm, 1mm, and 2mm.
  - Gap Board: Consists of five gaps of widths: 1mm, 2mm, 3mm, 4mm, and 5mm
  - Groove Board: Consists of four groove zones with depths of 1mm, 2 mm, 4mm, and 6mm.

Set up and Collection of Ground Reference Boards



Step Board (40 x 40 cm)

Gap Board (40 x 40 cm)



Groove Board (45 x 45 cm)

CRACK DETECTION ACCURACY- MANUAL ANNOTATION

- EVALUATED USING MANUAL ANNOTATED CRACK MAPS THAT PASSES INTER-RATER CONSENSUS.
- ASSESSMENT IS PERFORMED USING EHD SCORES BETWEEN TESTING CRACK MAPS AND MANUAL ANNOTATIONS.

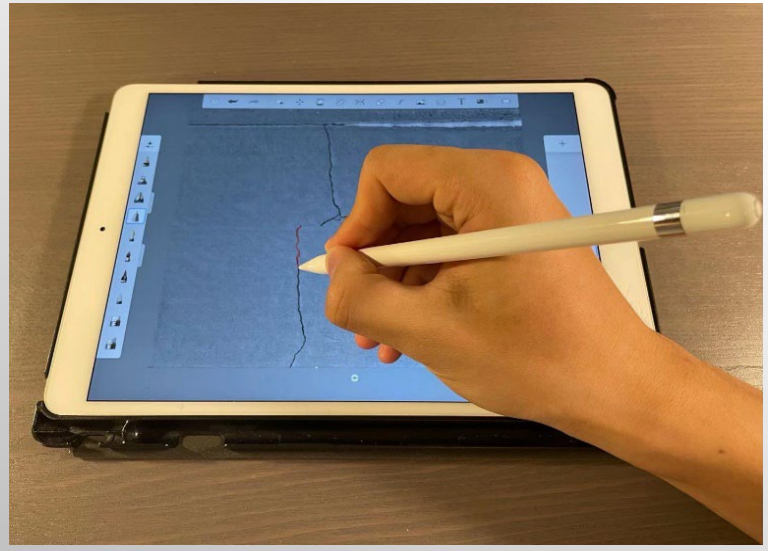
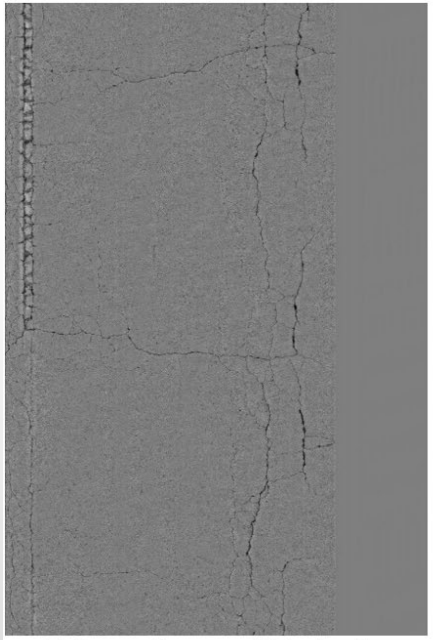
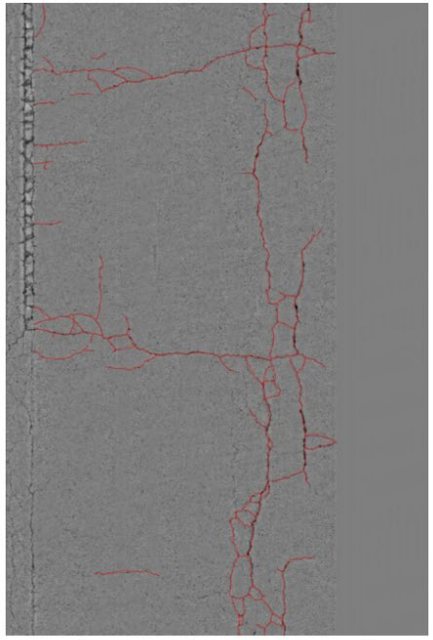


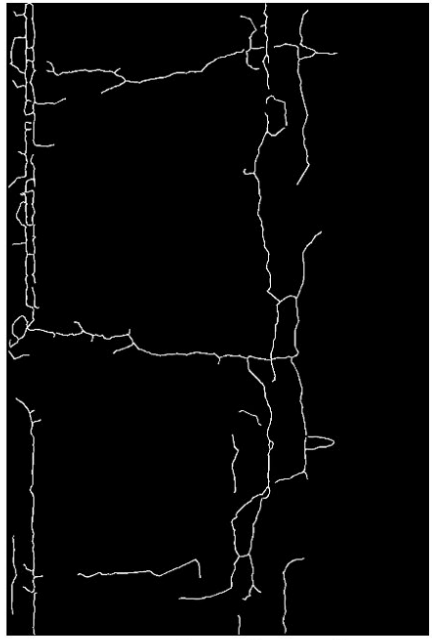
Illustration of Crack Manual Annotation



(a) Range Image of Evaluation Example



(b) Manual Annotation of Evaluation Example (in Red)



(c) Detected Crack Map from Testing System of Evaluation Example

CASE STUDY ON DIVERSE PAVEMENT TYPES

- RESEARCH TEAM COLLECTED FIELD DATA AT GAINESVILLE, FL (DEC. 2024) AND JACKSON, MS (MAR. 2025) COOPERATING WITH FDOT AND MDOT.

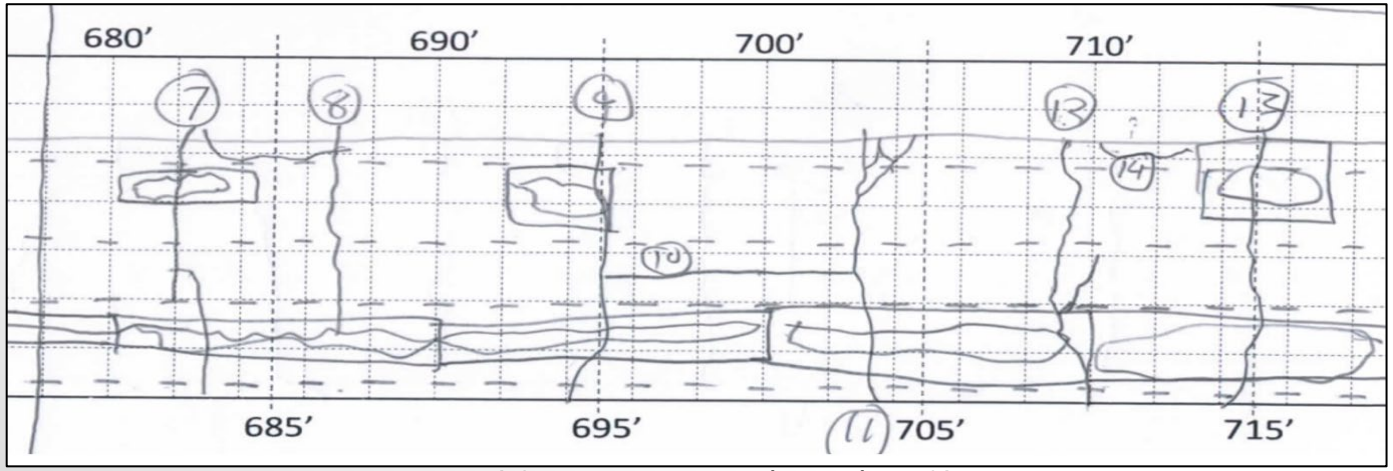
(a) Field Working on the OGFC Site

(b) Field Working on the JPCP Site

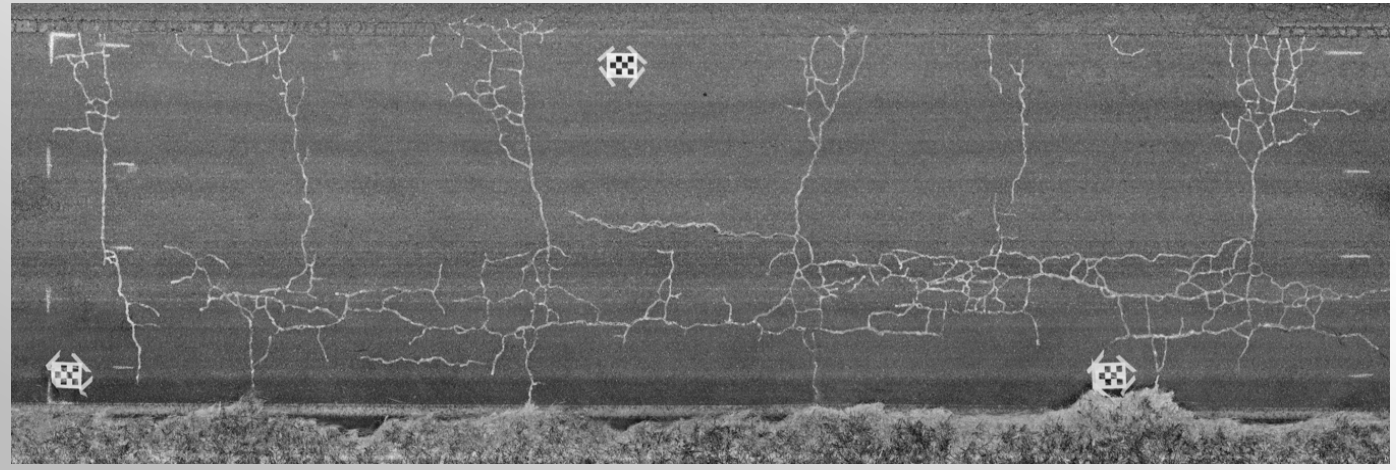
(c) Field Working on the CRCP Site

(d) Field Working on the Dense-graded Site

DIFFERENT GROUND REFERENCES

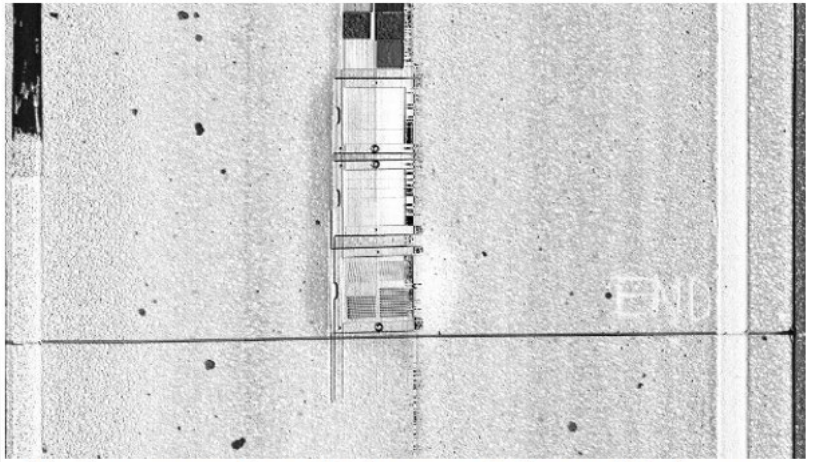


Manual Survey on Engineering Sheet



Manual Crack Amplification on Pavement Surface

(a) Illustration of Known Objects and Layout on Pavement for Scanning

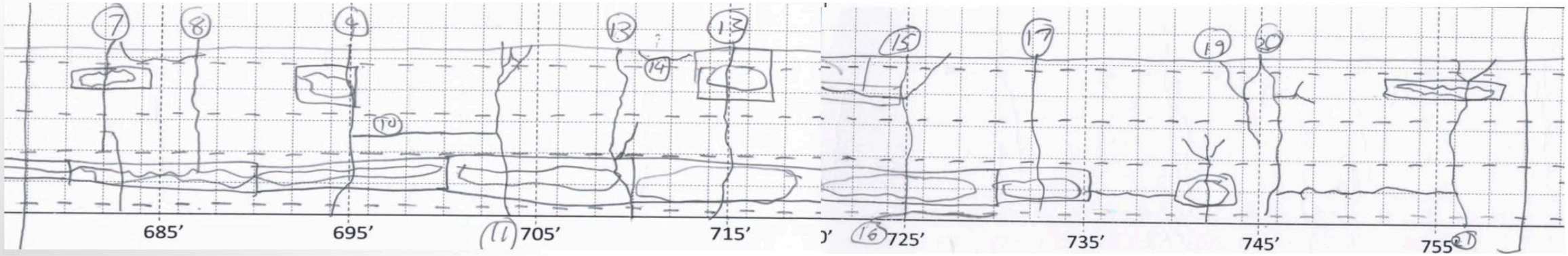


(b) Corresponding 3D Image of Ground Reference Boards

Referencing Board Data Collection

CASE STUDY ON DIVERSE PAVEMENT TYPES

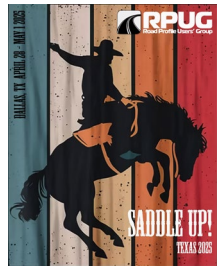
- MANUAL CRACK SURVEY RESULT



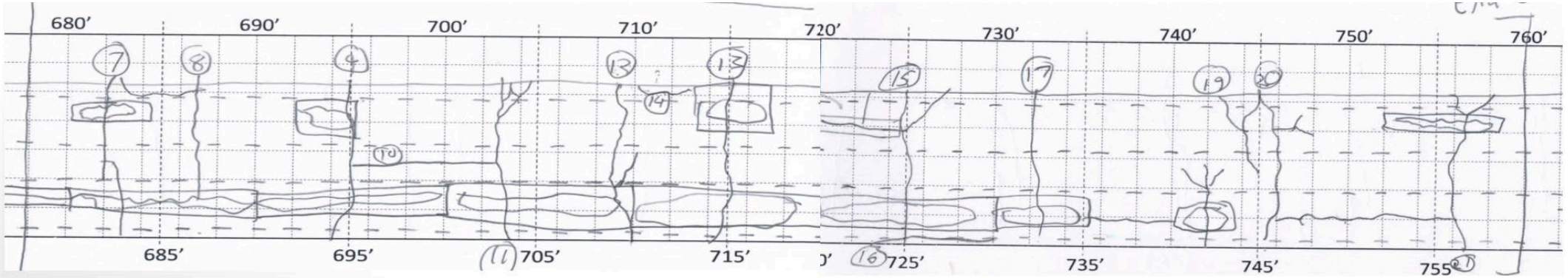
- TESTING CRACK MAP

Manual crack survey as the ground reference, is difficult to quantitatively assess the quality of the testing crack data.

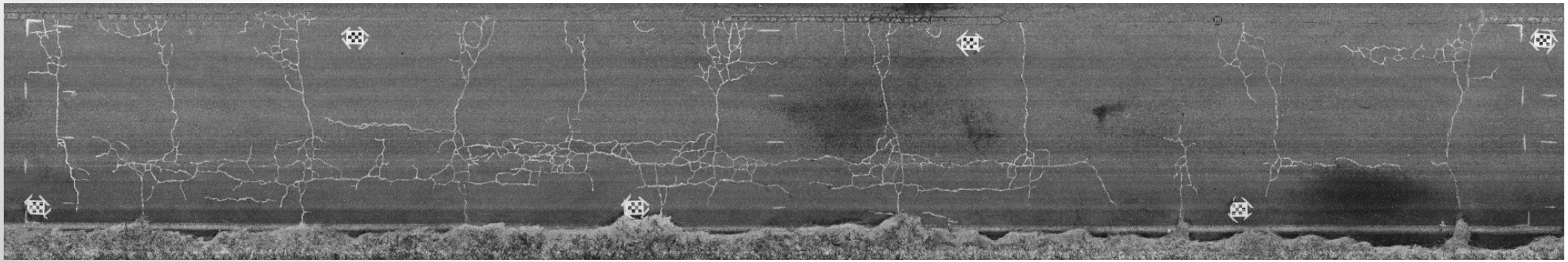
CRACK MAPS COMPARISON FOR END-TO-END ASSESSMENT



GR 1 – SURVEY DRAWING



GR 2 – CRACK AMPLIFICATION



TESTING DATA

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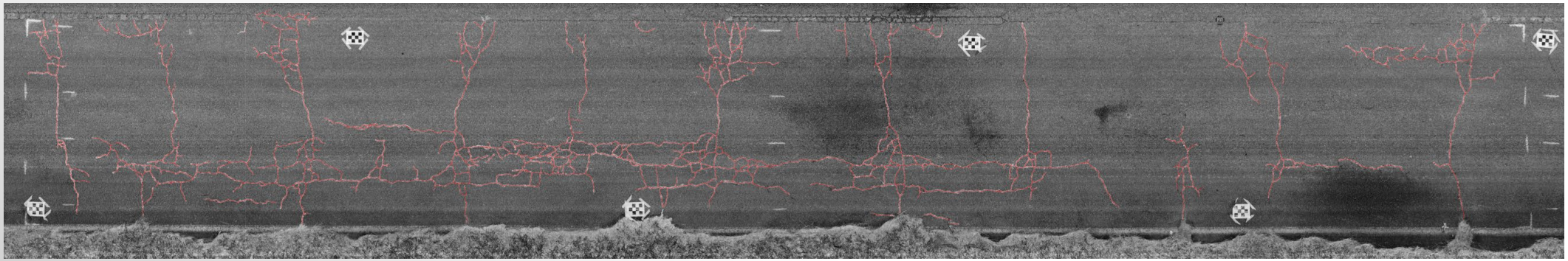
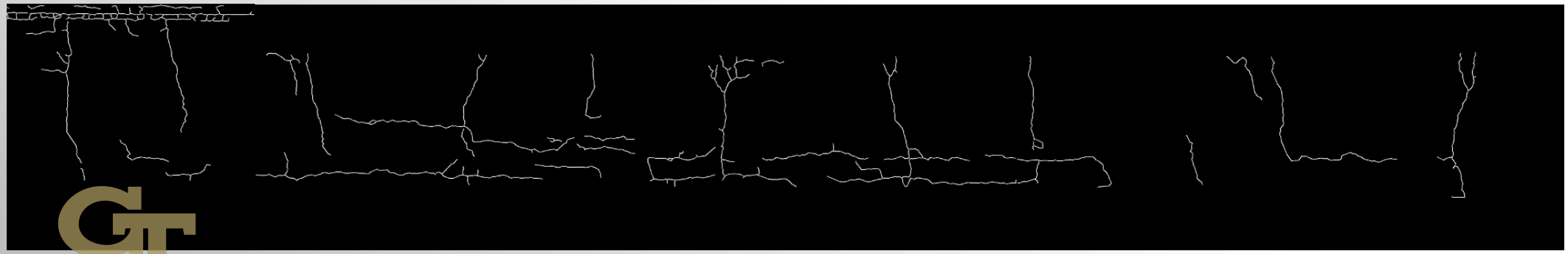
CRACK MAPS COMPARISON FOR END-TO-END ASSESSMENT

Crack augmentation method makes it possible to quantitatively assess the quality of the automatic crack detection.

GR 2 – CRACK AMPLIFICATION

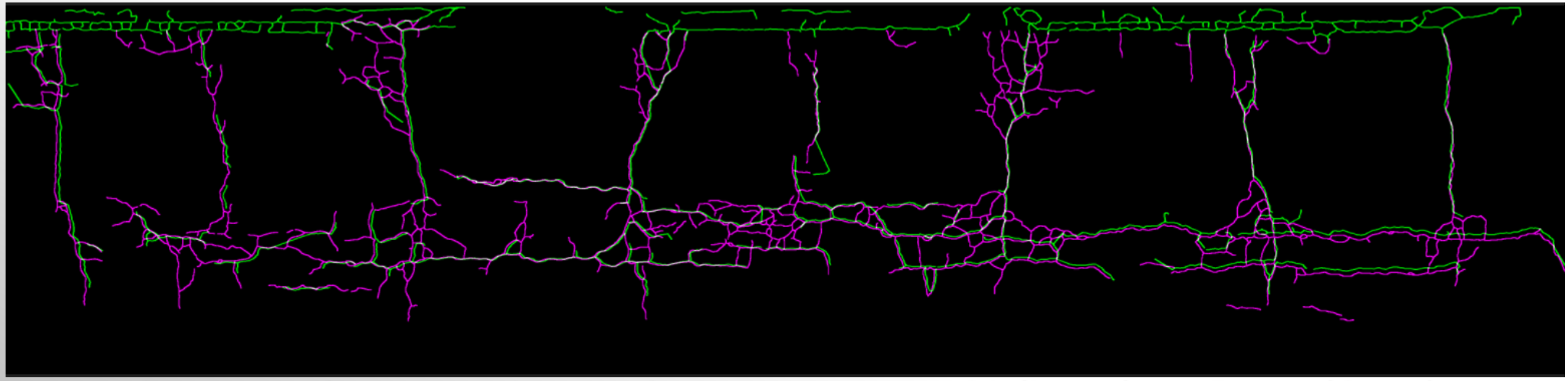


TESTING DATA



END-TO-END ASSESSMENT RESULTS

- Visual Assessment:
  Crack augmentation method is better on detail (short, thin connecting cracks) than traditional manual surveys and testing data.



Crack Map Comparison Between Crack Amplification GR (Purple) and Testing (Green)
White is overlapping

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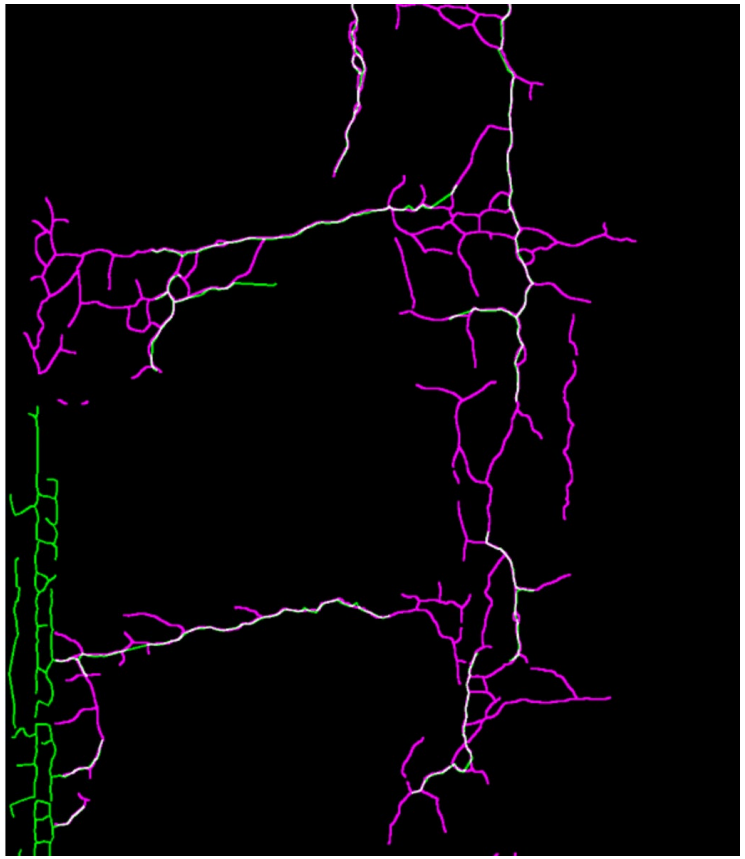
END-TO-END ASSESSMENT RESULTS

- Quantitative Assessment:
  - **EHD** between <u>crack augmentation</u> and <u>testing data</u>: 34.45 (Overlapping Part)
    - moderate alignment.
  - **False Positive: ~32%** (Green (Testing)-only Part)
    - primarily from cracks outside or on lane markings (acceptable).
  - **False Negative: ~66%** (Purple (GR)-only Part)
    - majorly the short, thin cracks, consistent with visual assessment.

The quantitative values only reflect the testing system's performance on the selected pavement section.

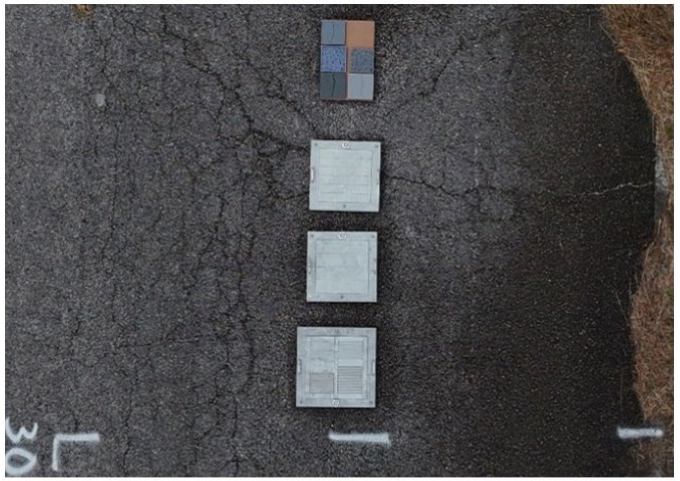


Crack Map Comparison Between
Crack Amplification GR (Purple) and Testing (Green)

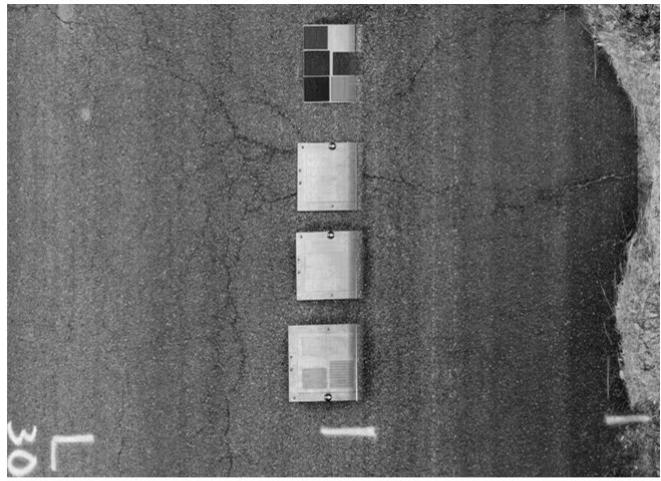
CASE STUDY OF REFERENCE BOARD SCANNING

- VISUAL ASSESSMENT:
  - ONLY A PORTION OF THE BOARDS' TEXTURE IS VISIBLE, LEADING TO THE CRACK DETECTION ISSUE.
  - THE PROFILE STITCHING OF THE TESTING SYSTEM LEADS TO THE MISMATCH ISSUE OF THE BOARDS.

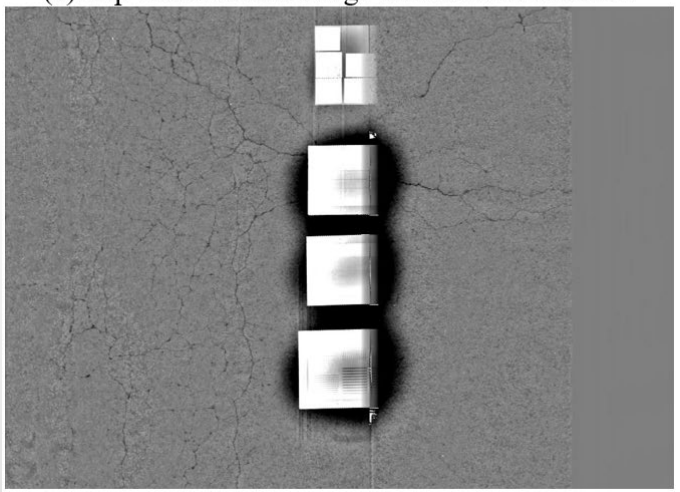
The quantitative assessment requires the data to be in the point cloud format, which is inaccessible given the current data collected.



(a) Top-down Drone Image for Reference Boards



(b) Intensity Image of Reference Boards



(c) Range Image of Reference Boards

(d) 3D Image of Reference Boards

DATA COLLECTED FROM TESTING SYSTEM ON GROUND REFERENCE BOARDS

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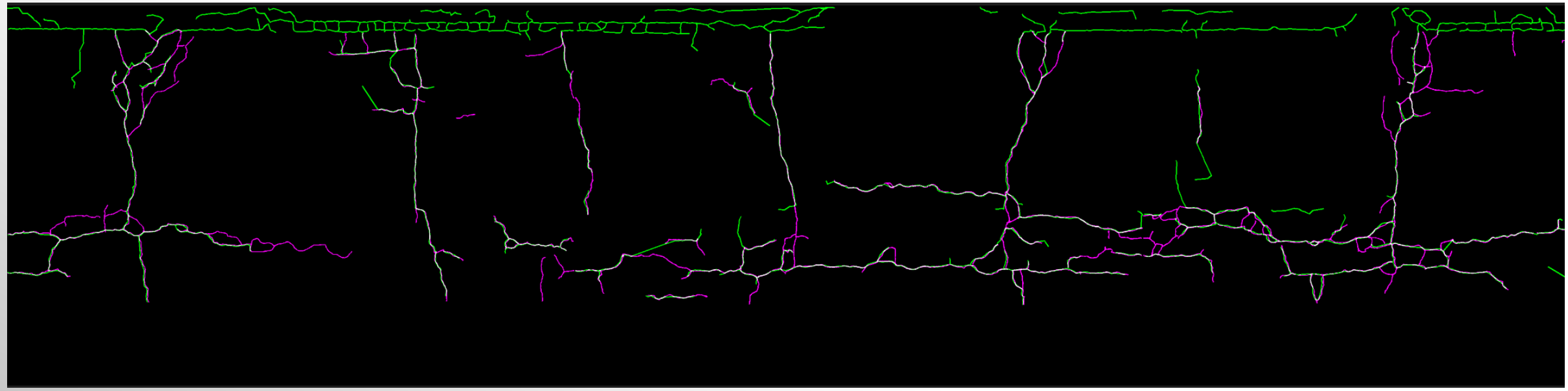
CASE STUDY OF CRACK DETECTION ACCURACY

- VISUAL ASSESSMENT:
  TESTING SYSTEM IS ABLE TO DETECT MOST OF THE CRACK-IN-INTEREST (WITHIN LANE MARKING), THOUGH THE DIFFICULTY IN DETECTING SHORT, FINE CRACKS EXISTS.



CRACK MAP COMPARISON BETWEEN MANUAL ANNOTATION (PURPLE) AND TESTING (GREEN)
WHITE REPRESENTS OVERLAPPING

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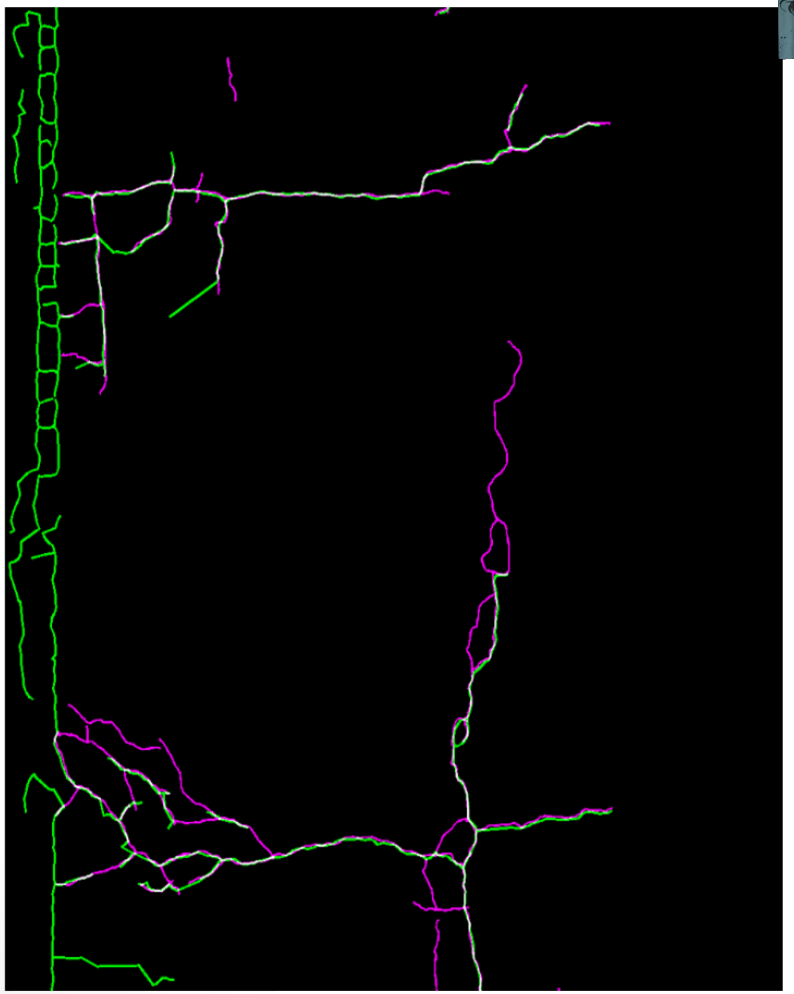
CASE STUDY OF CRACK DETECTION ACCURACY

- Quantitative Assessment:
  - **EHD**: 37.99 (Overlapping Part)
    - Moderate alignment.
  - **False Positive: ~62%** (Green (Testing)-only Part)
    - Primarily from cracks outside or on lane markings (acceptable).
  - **False Negative: ~51%** (Purple (GR)-only Part)
    - Majorly the short, thin cracks.



Crack Map Comparison Between Manual Annotation (Green Purple) and Testing (Green)

The quantitative values only reflect the testing system's performance on the selected pavement section.

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CONCLUSION

- Manual Survey Method:
  - Lacks detailed crack maps, hindering identification of missing detections.
  - Labor-intensive for high crack density on longer sections (e.g., 0.3 miles).
- Crack Amplification Method:
  - Efficient for quantitative assessment of crack data quality.
  - Recommended 15-meter (~50 ft) testing section for representativeness and efficiency.
- Decomposed Method (Adopted from NCHRP 01-60):
  - Sensor quality and crack detection accuracy methods can help identify data quality impacting factors.

THANK YOU!

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