

IOWA STATE
UNIVERSITY

**Institute for
Transportation**



March 2024 MPO-RPA Quarterly Meeting

March 19, 2024

Trail Management Program



Introduction

- Trail management program is required to preserve the existing trail network.
- Create an inventory of condition data.
- Develop a data collection and assessment system suited to extensive trail network.



Source: 2018 Central Iowa Trail
Condition Report

Iowa Data-bike

Develop a bike-based data collection vehicle to improve the efficiency of collecting data on the extensive trail network.

iPhone



Go Pro Camera



360 camera



Source: Central Iowa Trail
Condition 2019 Report

What Data Bike Collects?

Go Pro Camera



iPhone + SensorLog App



- Accelerometer readings
- Gyroscope readings
- Magnetometer reading



Trail smoothness

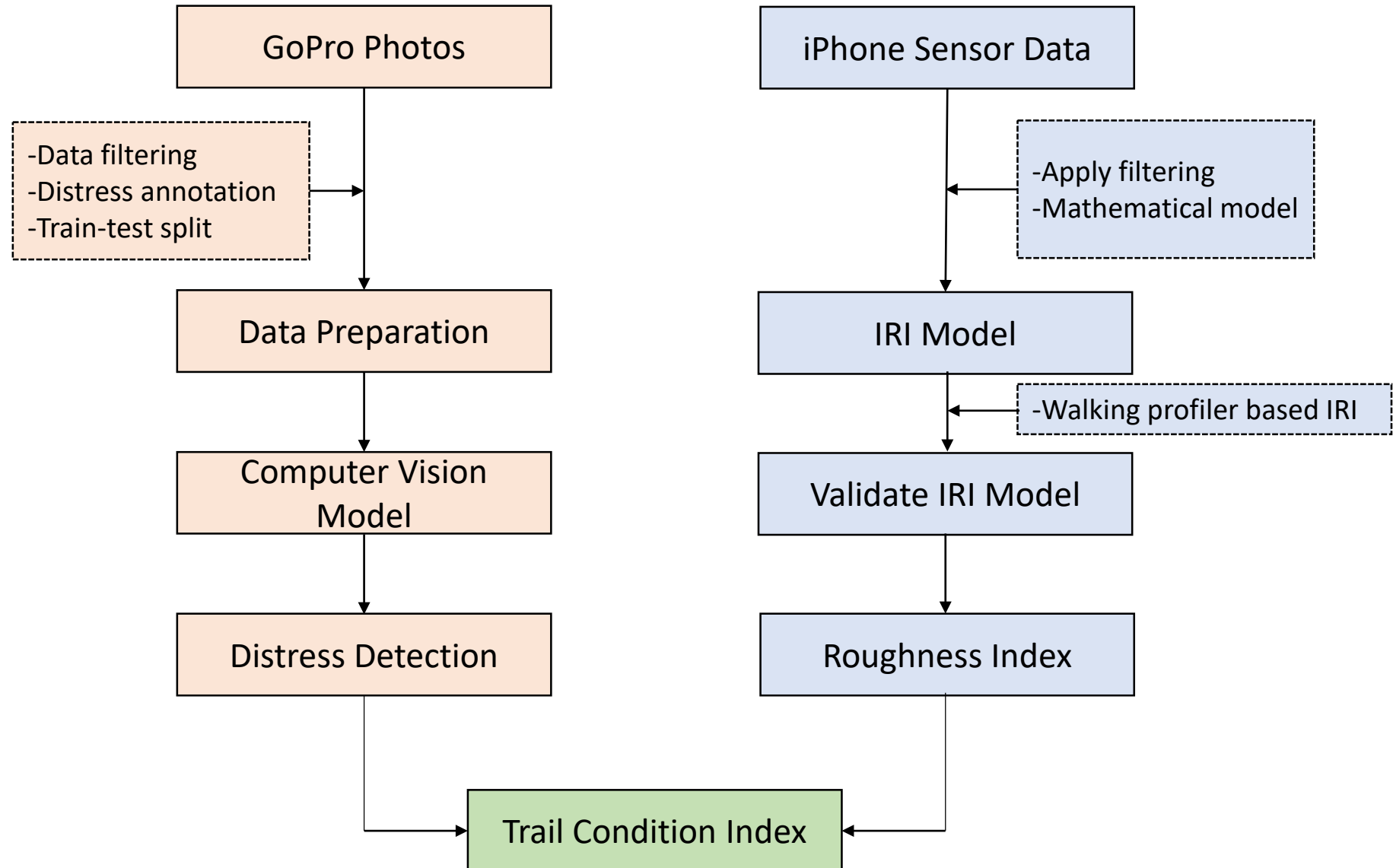
Reference Profiler

- Used as reference to the roughness measurements
 - To calibrate inertial profiler measurements.
- The device registers the longitudinal measuring profile of the pavement surface
 - by continuously lowered metal foot and for each measuring section reregisters the summed height in relation to the initial point.
- Measure surface roughness
 - Expected accuracy ~ **94-99%** depending on the walking speed



Photo courtesy: InTrans Team

Phase-I Workflow



Data Collection Program

Control Site Selection

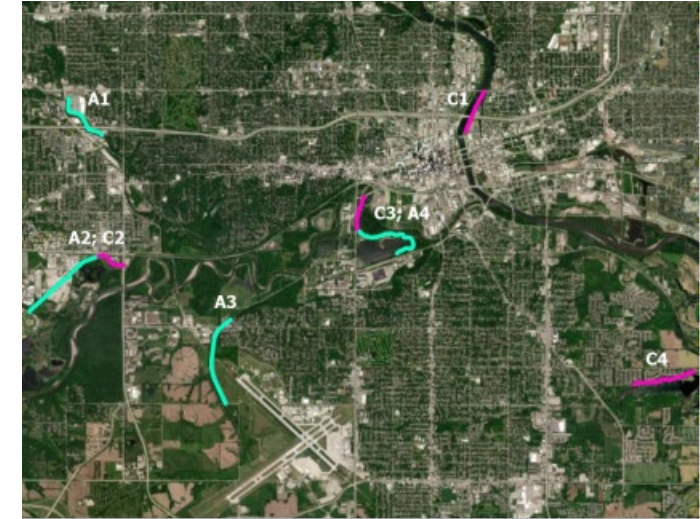
❖ Criteria for Site selection

- ✓ Geographic spread
- ✓ Region type- regional/local, urban/rural
- ✓ Condition range- Very good to very poor

❖ Description of the sites selected:

- ✓ Length: 0.3 mile
- ✓ # of Asphalt surface (AC) sites: 04
- ✓ # of Concrete Surface (PCC) sites: 04

Location of the sites on the map



Sites were marked with an unique ID



Control Sites Data Collection

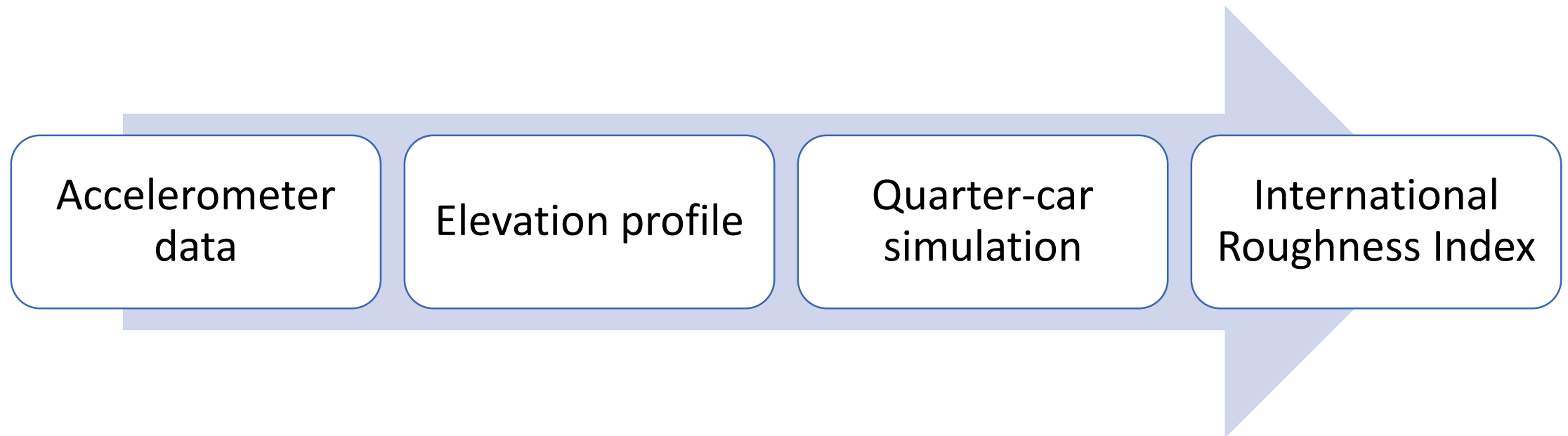
- Both Walking profiler and Data-bike
- Data collected at right lane path
 - 04 Runs per segment (2 runs in each direction)
- Walking Profiler
 - Walking speed- 1.8 mph
 - 3 runs per segment
- Control sites were collected in 2022 & 2023.



Development of a Roughness Index for Pedestrian Infrastructures

Background

- International Roughness Index (IRI) is a widely accepted measure of pavement condition.
- Surface roughness in terms of user experience while driving on the road.
- Measures suspension movement over some longitudinal distance (in./mile).



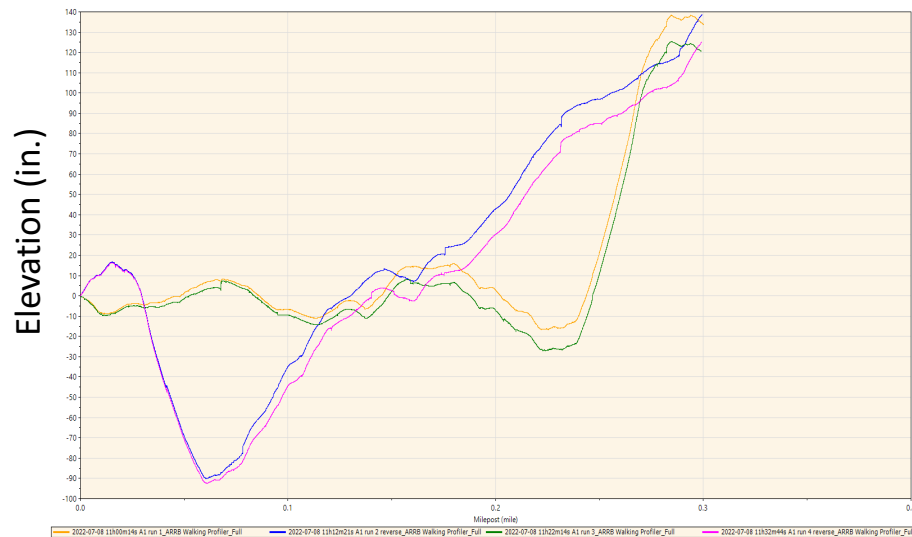
Objective

- To employ and calibrate a bicycle-based algorithm for quantifying surface roughness.
- To verify the roughness measurements from data-bike with a reference system.

Walking Profiler-based IRI

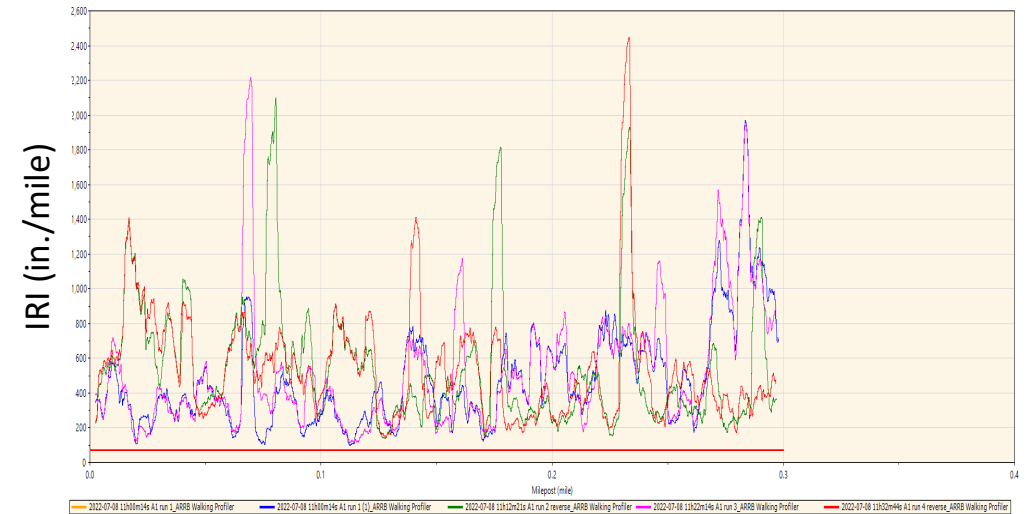
ProVAL software
(recommended by manufacturer)

Raw Elevation Profile



- Longitudinal elevation profile for 4 runs
 - ✓ 2 forward runs
 - ✓ 2 reverse runs

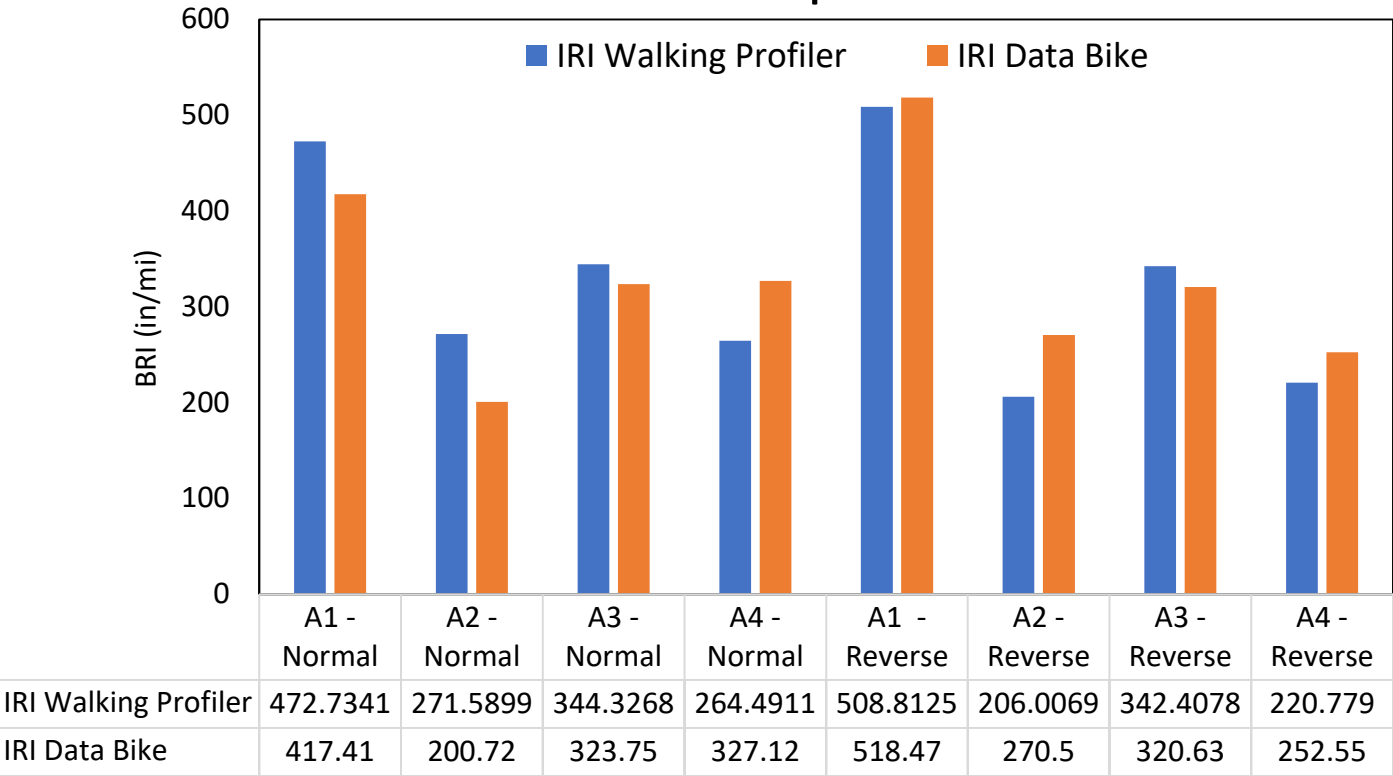
Estimated IRI



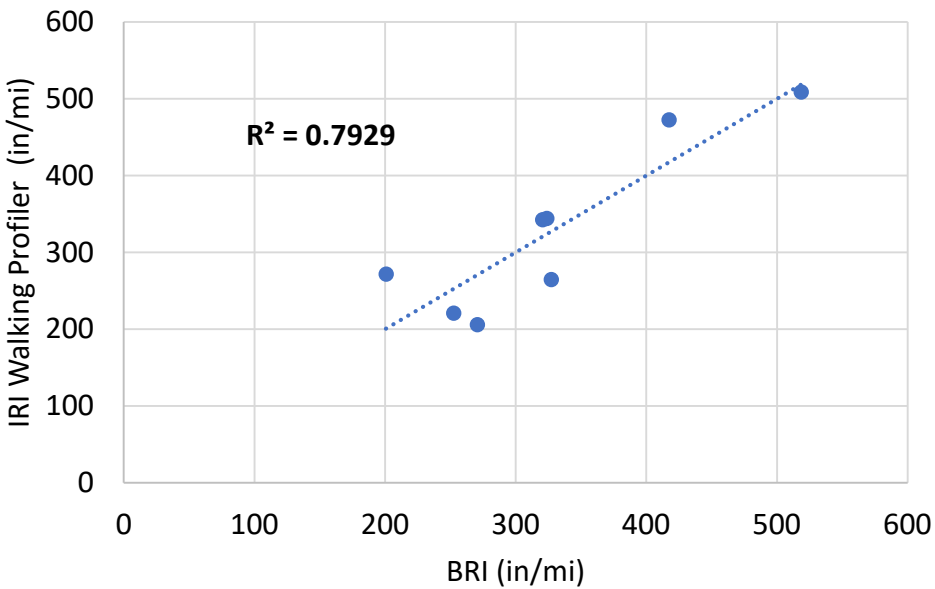
- Continuous IRI measurements
 - ✓ Overall IRI – 0.3-mile segment
 - ✓ Fixed interval IRI (specified interval)

Results: AC Trail

BRI Comparison

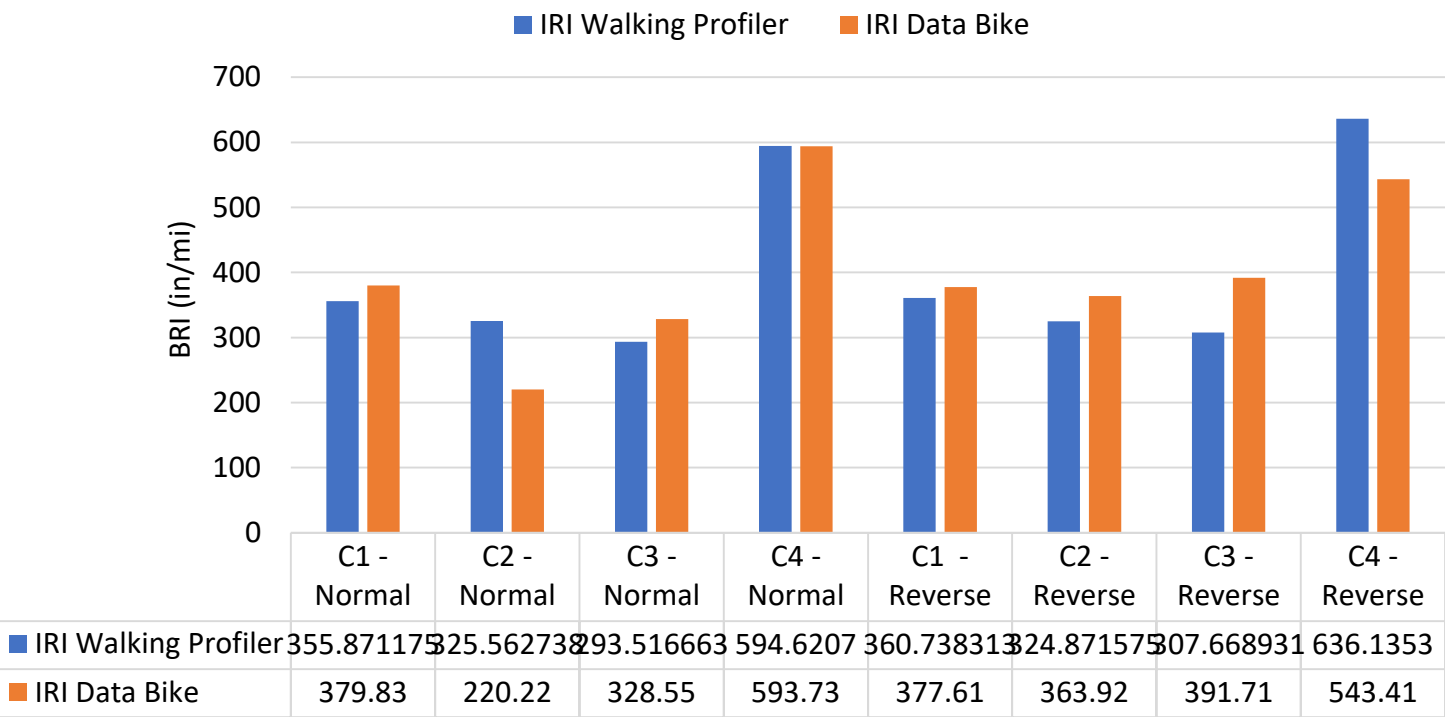


BRI Correlation

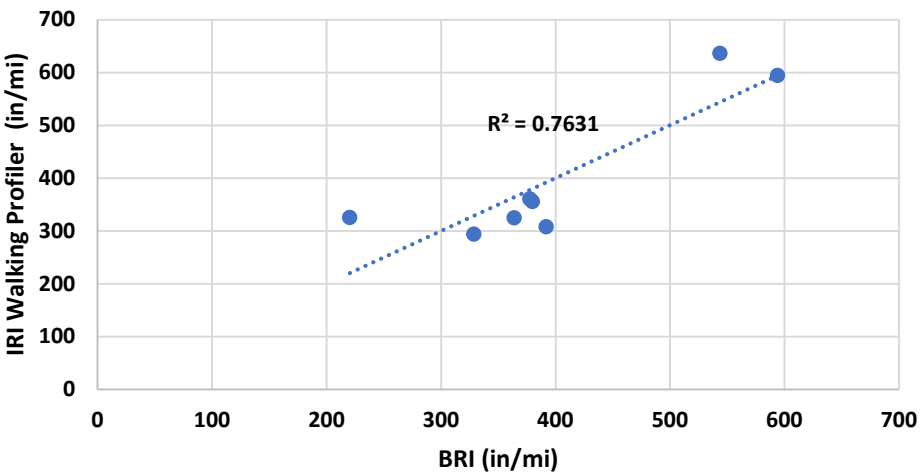


Results: PCC trail

BRI Comparison

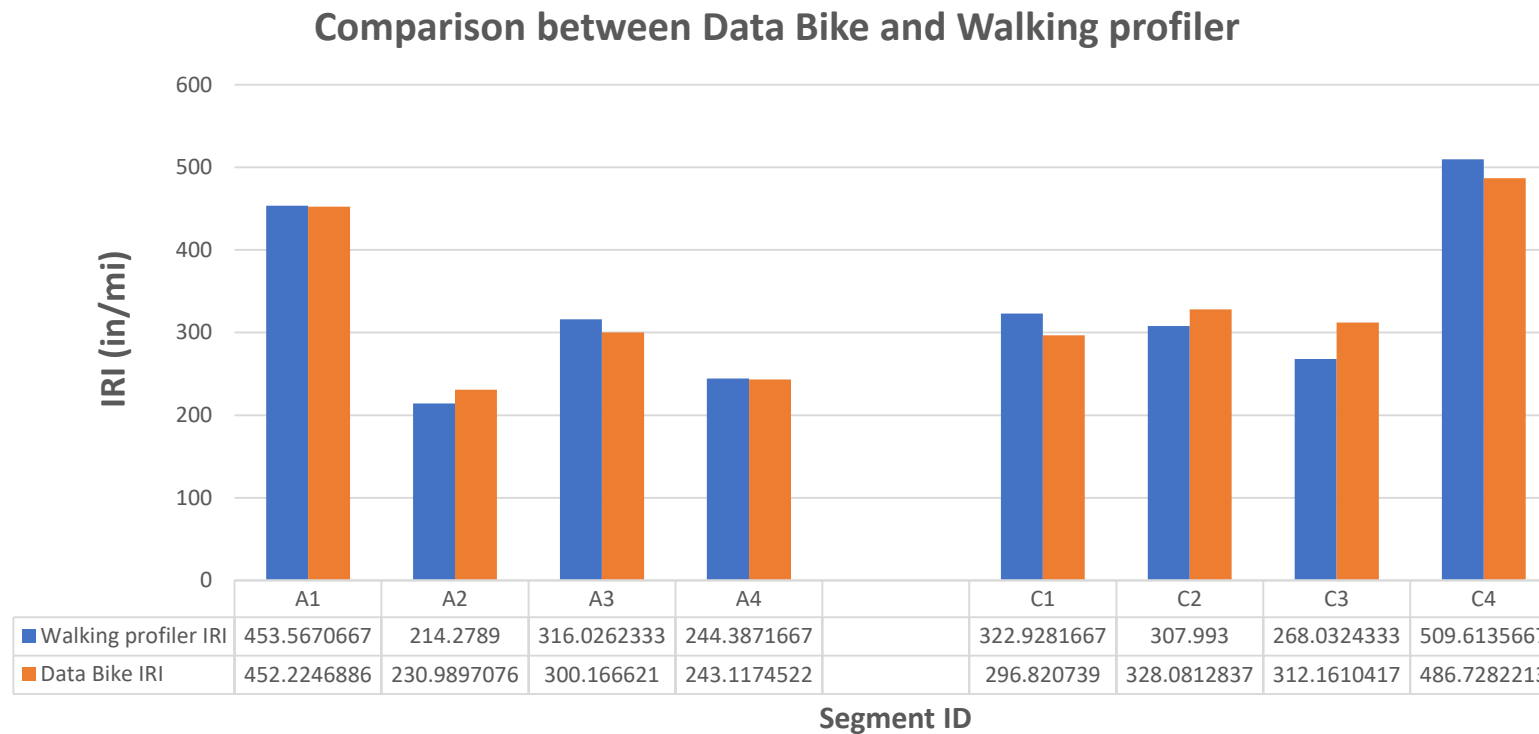


BRI Correlation



Control Sites 2023

- Satisfactory agreement with the reference profiler.



Network-level Deployment

Des Moines Trails Condition 2020 to 2022



Vision-based Trail Condition Assessment

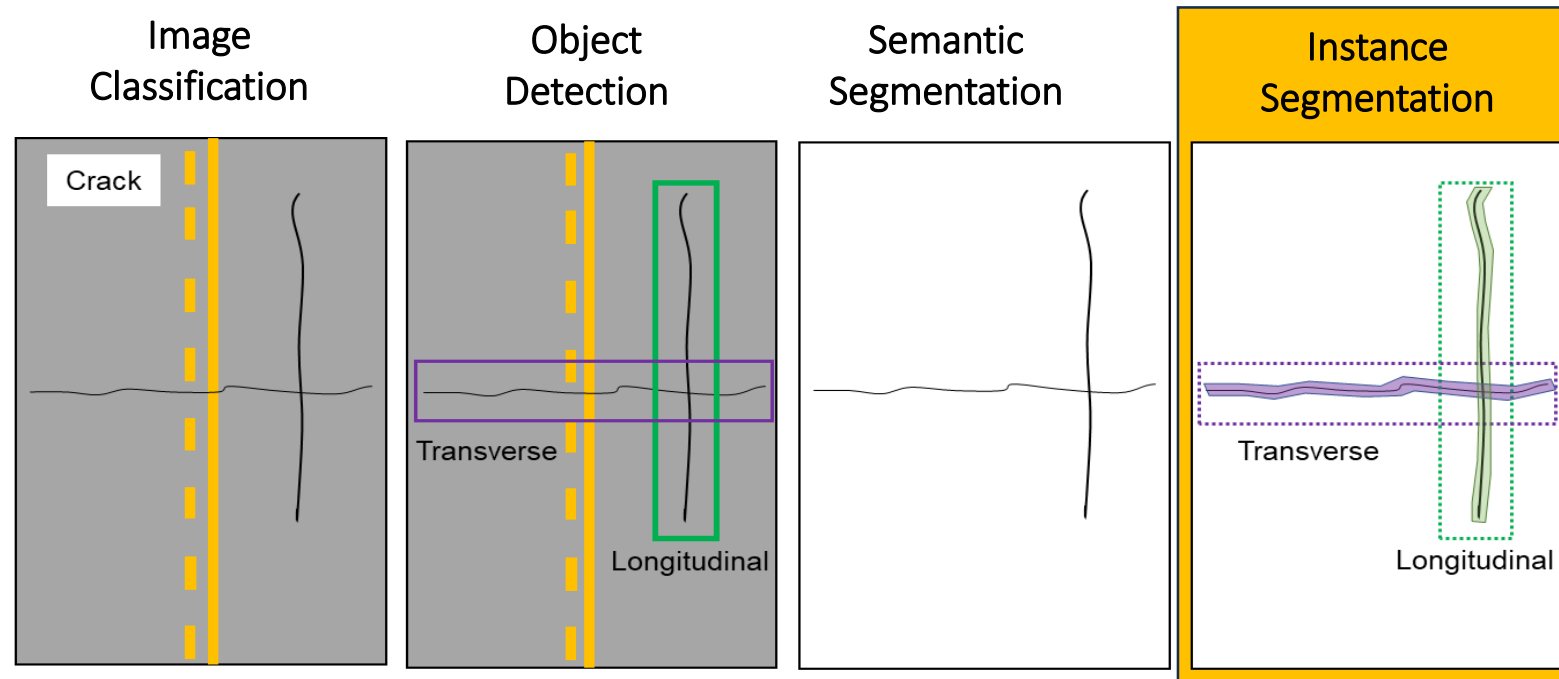
Vision-based Distress Assessment

- Manual Assessment

- Human-conducted measurement of distress size and extent from pavement images

- Automated Assessment

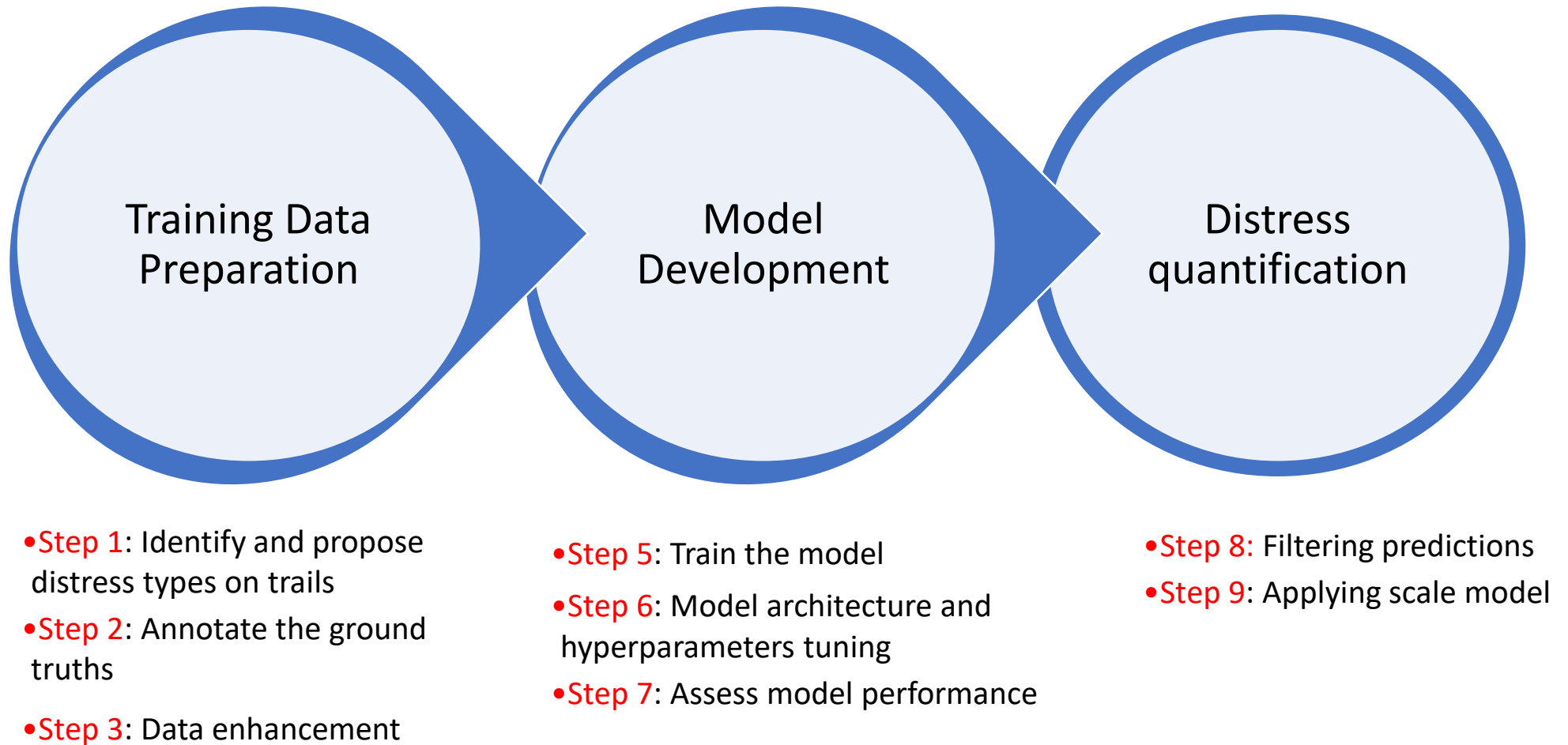
- Automated or semi-automated process minimizing human involvement
- Deep learning-based computer vision tasks



Objective

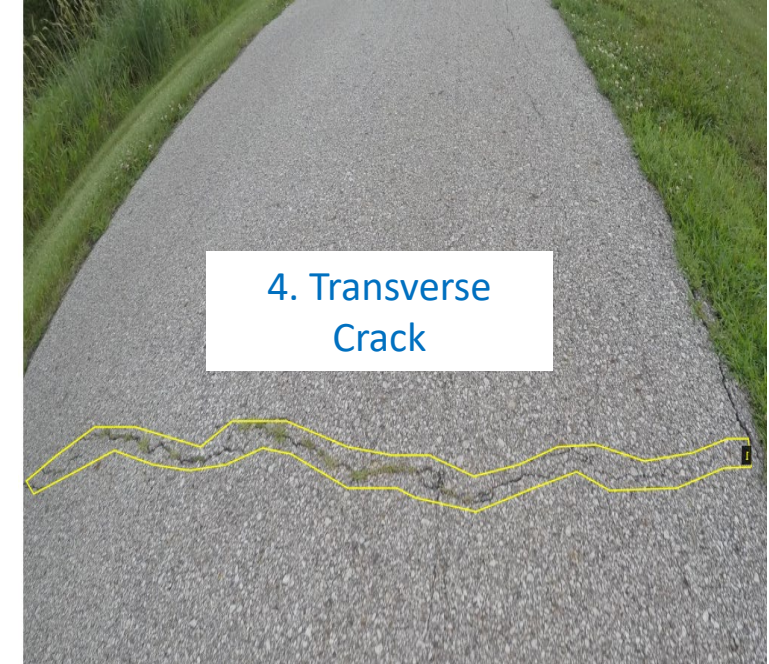
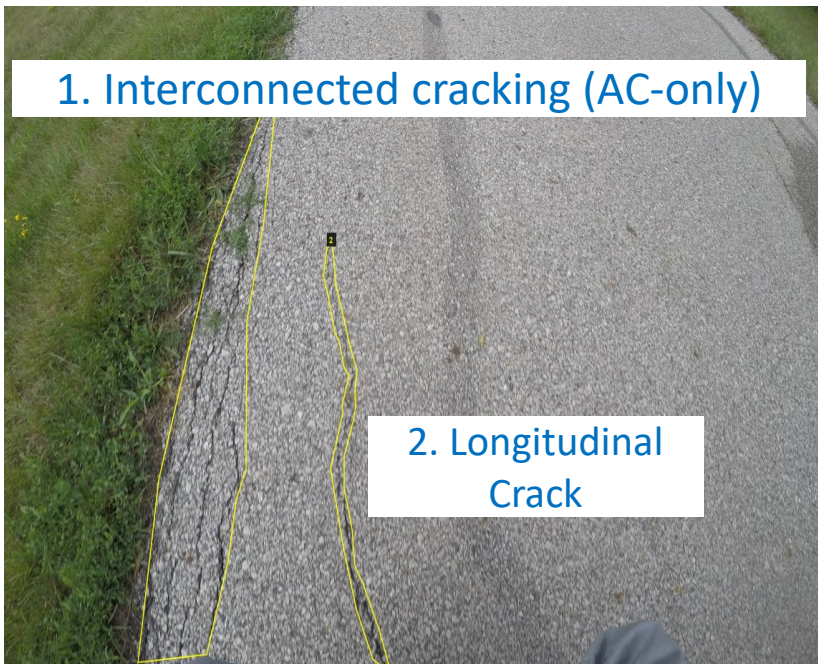
- Employ state-of-the-art computer vision task to localize, classify, and segment trail distresses.
- Quantify the distresses to allow comprehensive assessment of trail condition

Distress Quantification Workflow



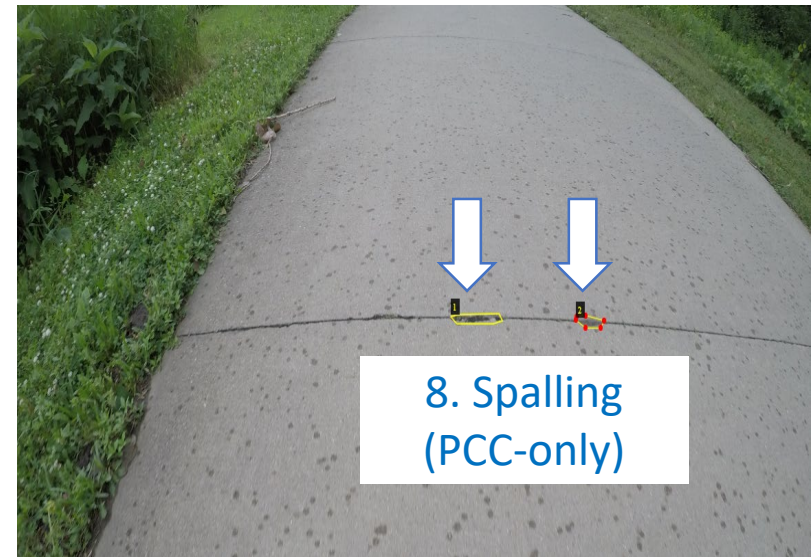
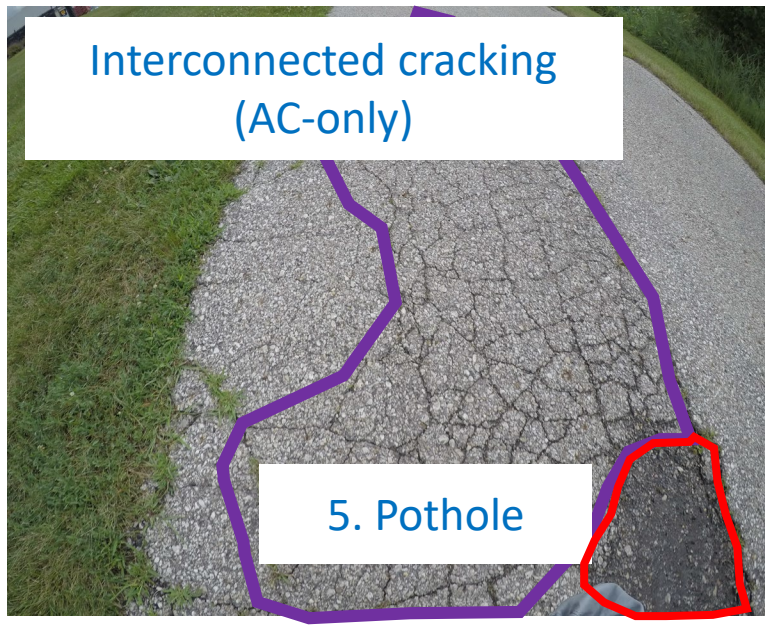
Proposed Trail Surface Distresses

- No standardized guidelines have been found in the literature to classify trail surface distresses.
- Eight (08) distress classes were proposed.



Proposed Trail Surface Distresses

- Some distresses are specific to surface type.



Data preparation

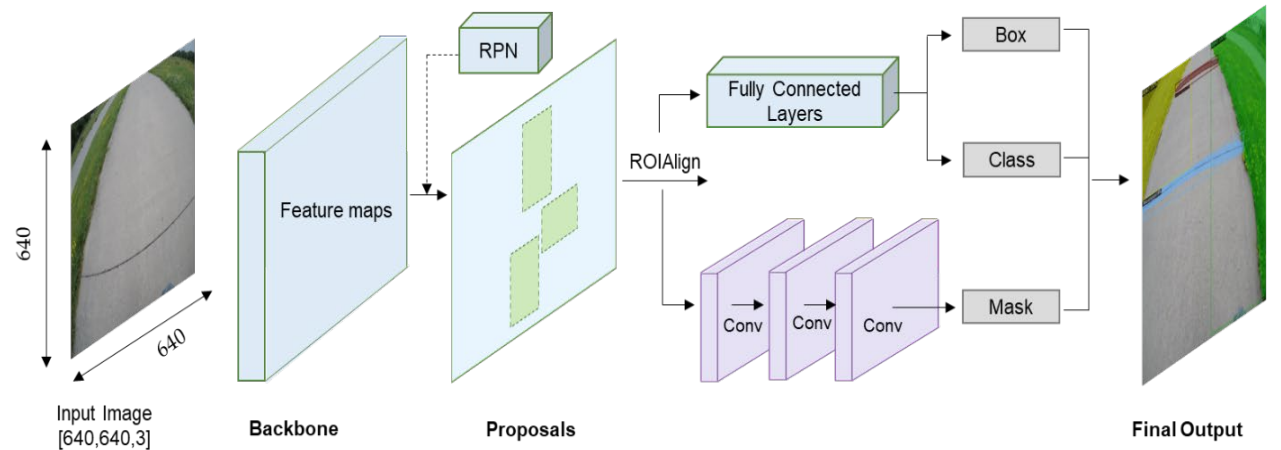
- Annotate with VGG Image Annotator
 - Draw polygon
 - Assign classes to each polygon



Model Training

- Total #images annotated= 4439
 - Training : 70%
 - Validation : 30%

Architecture of Mask R-CNN Model

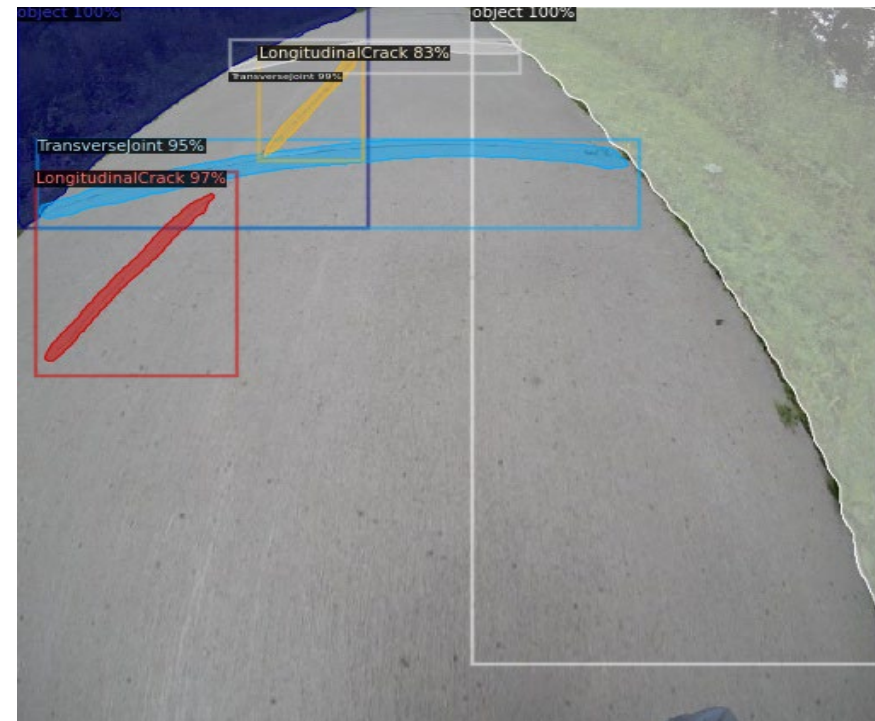


- Model trained for 80,000 iteration to improve the prediction performance.
 - Training time 16 hours.
 - Transfer learning using pre-trained COCO weights.

Model Prediction: PCC

✓ Performed robustly on concrete surfaces.

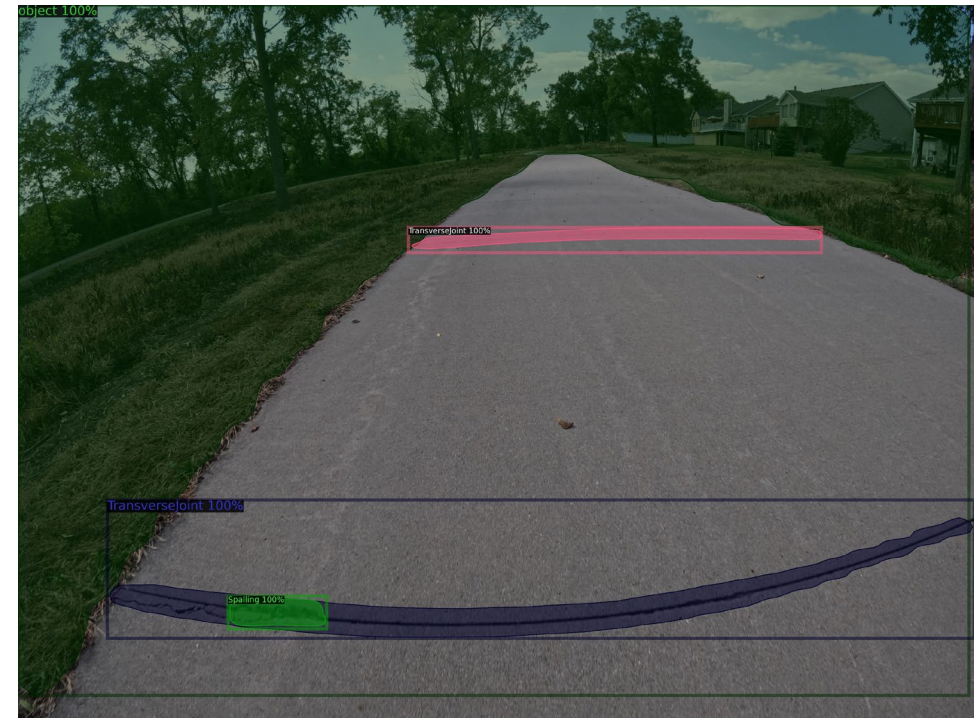
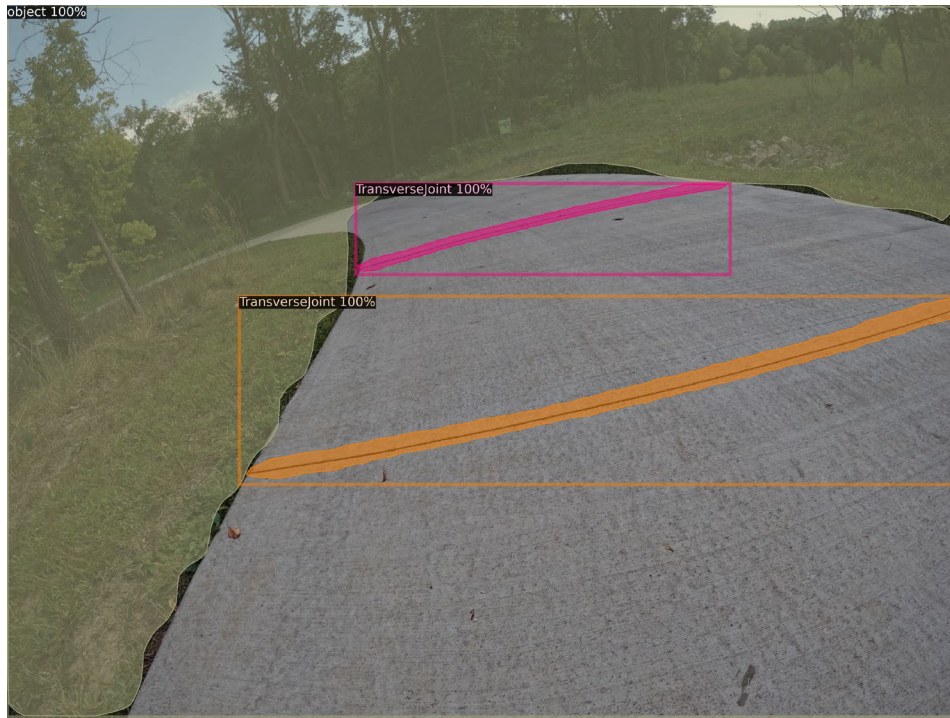
- Transverse Joints (left)
- Longitudinal cracks and Transverse joints (right)



Model Prediction: PCC

✓ Performed well on skewed images and even for smaller distresses such as spalling

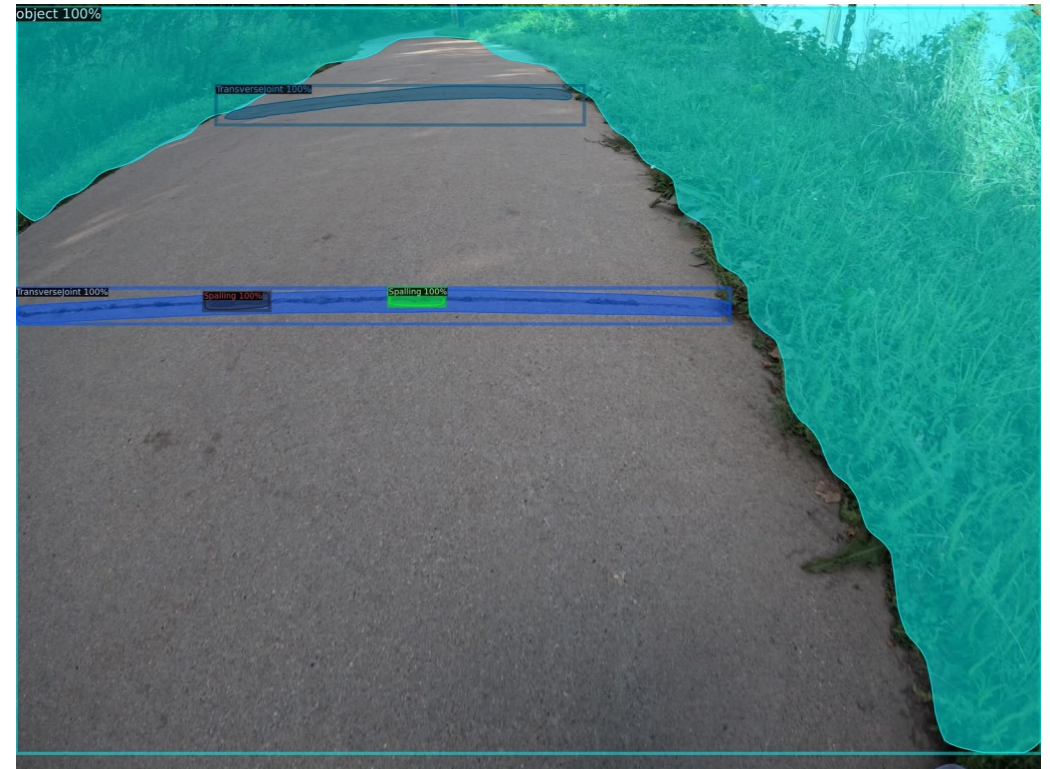
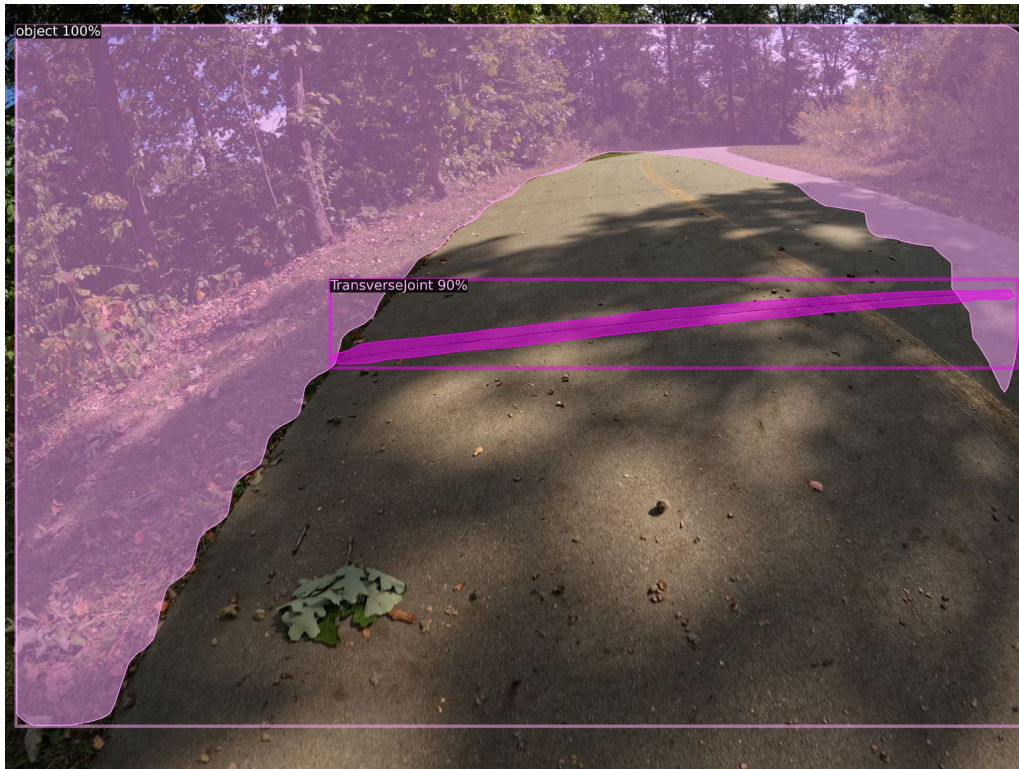
- Transverse Joints appearing skewed (left)
- Spalling detected (right)



Model Prediction: PCC

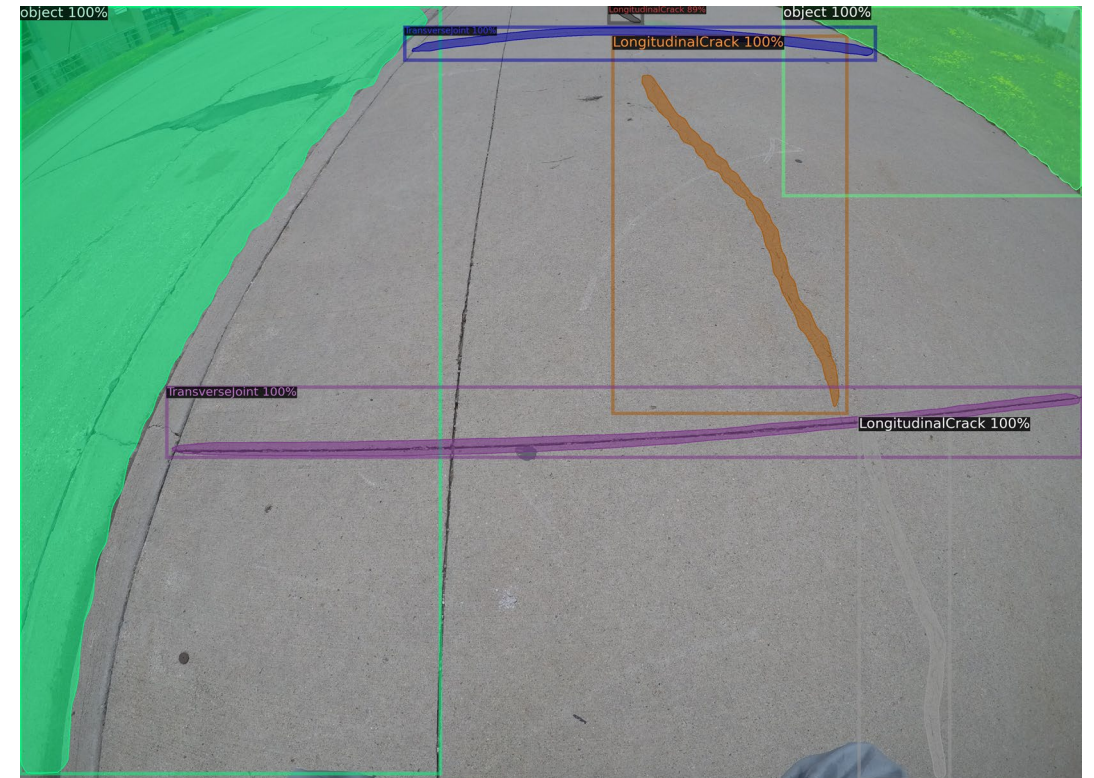
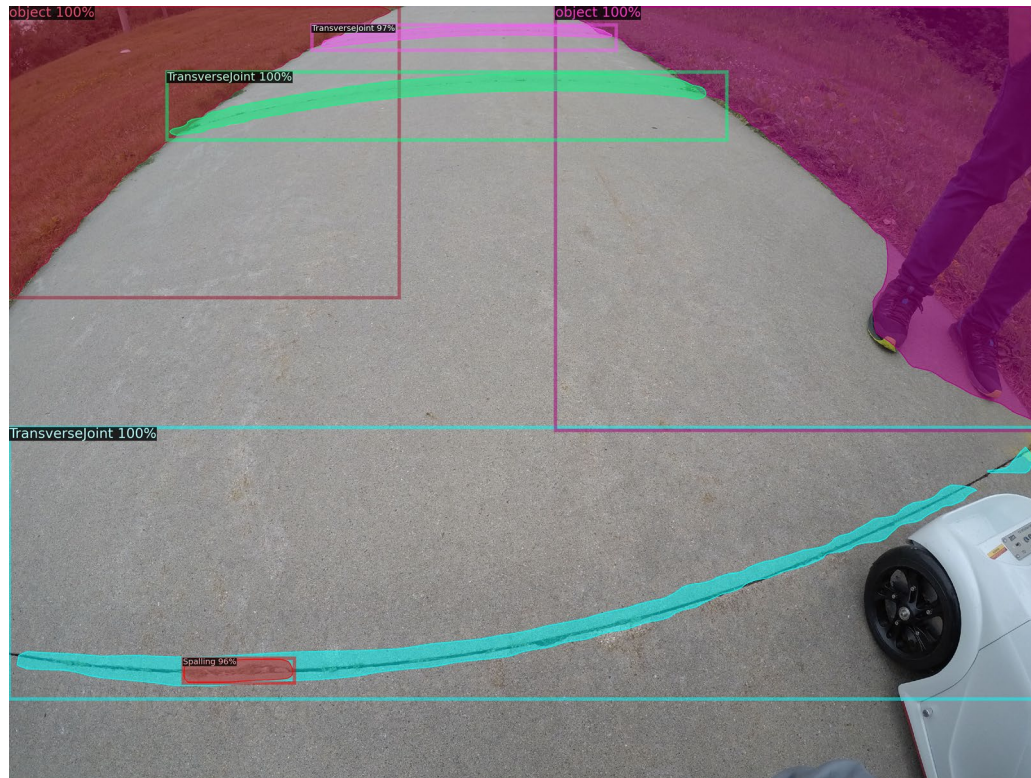
✓ Detection performance on shadowed images

- Transverse Joints (left)
- Spalling (right)



Model Prediction: PCC

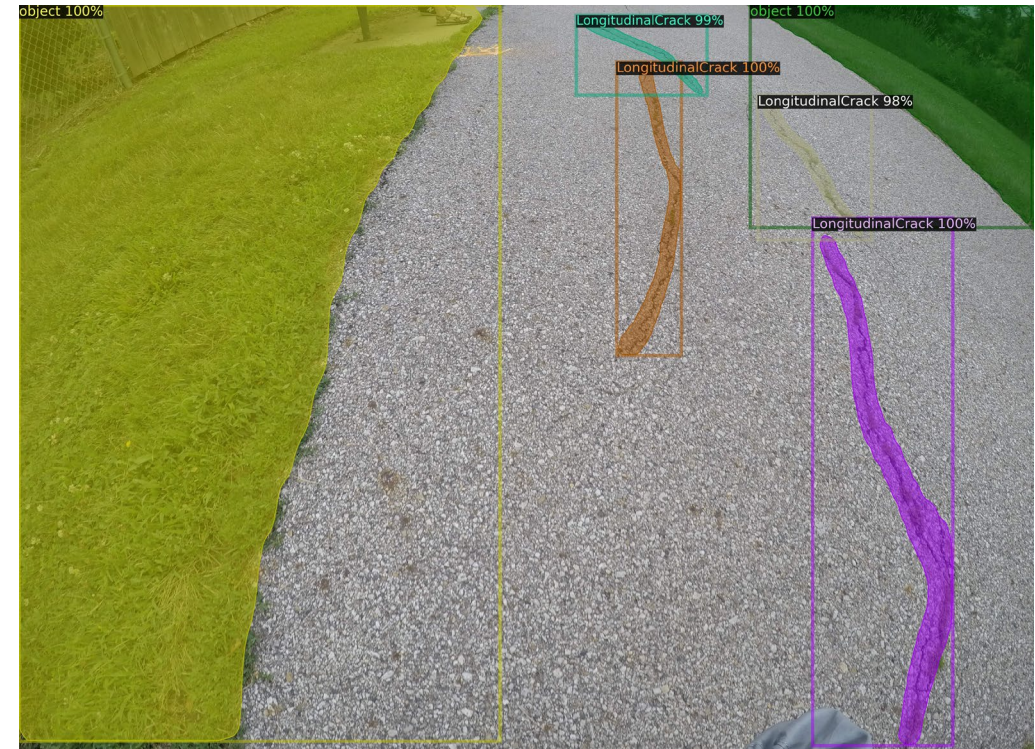
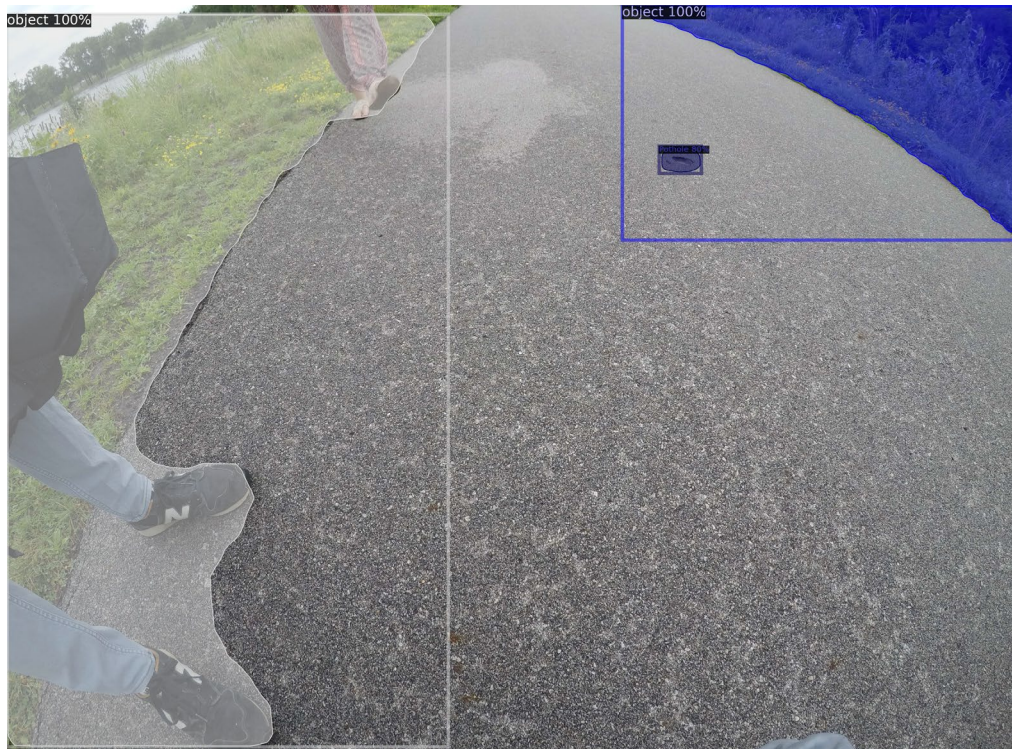
✓ More example of distress identification on PCC surface.



Model Predictions: AC

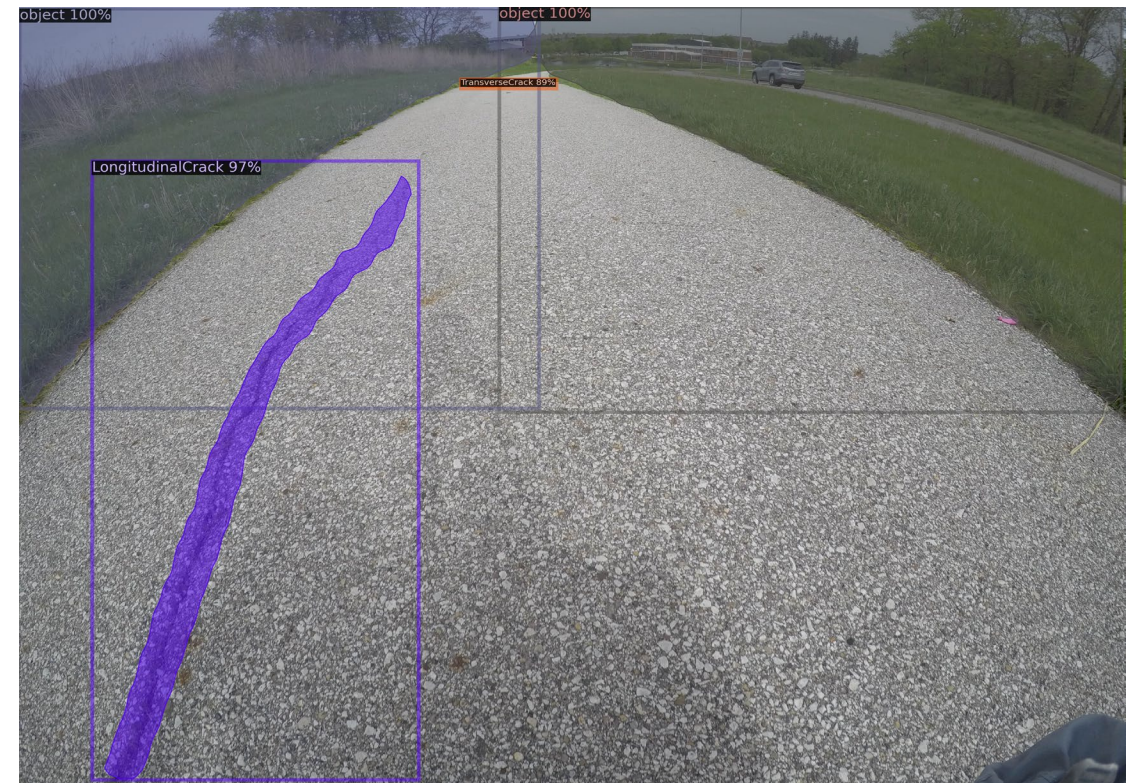
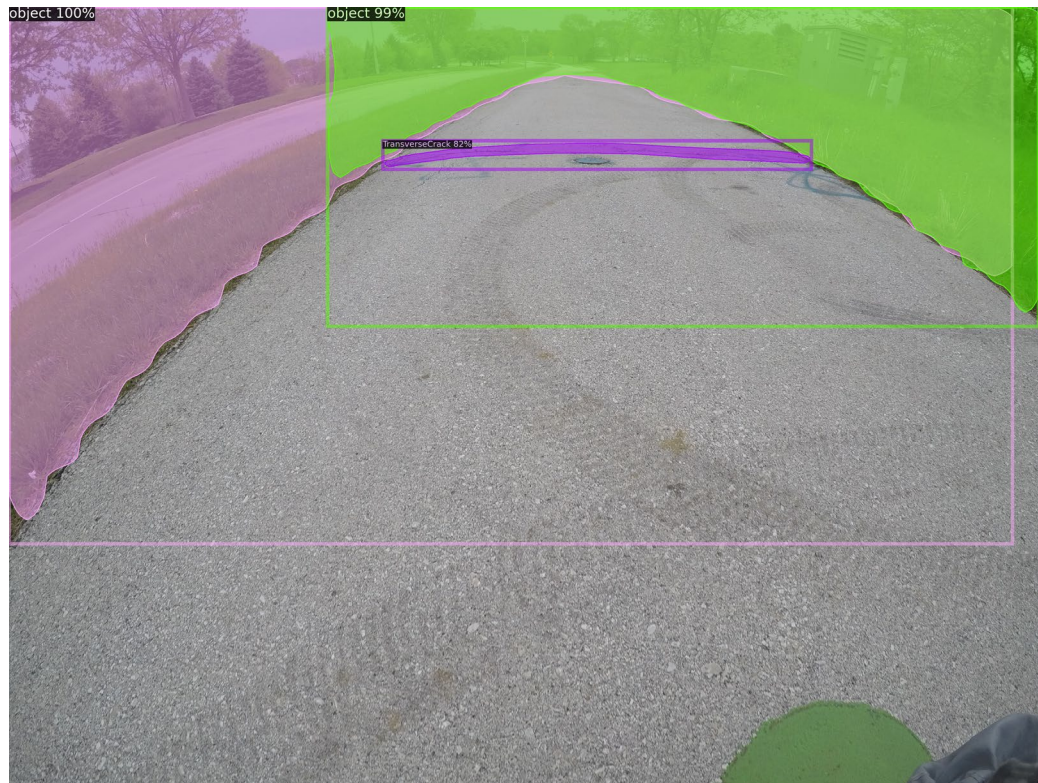
✓ Model performance on AC surface

- Pothole (left)
- Multiple longitudinal cracks (right)



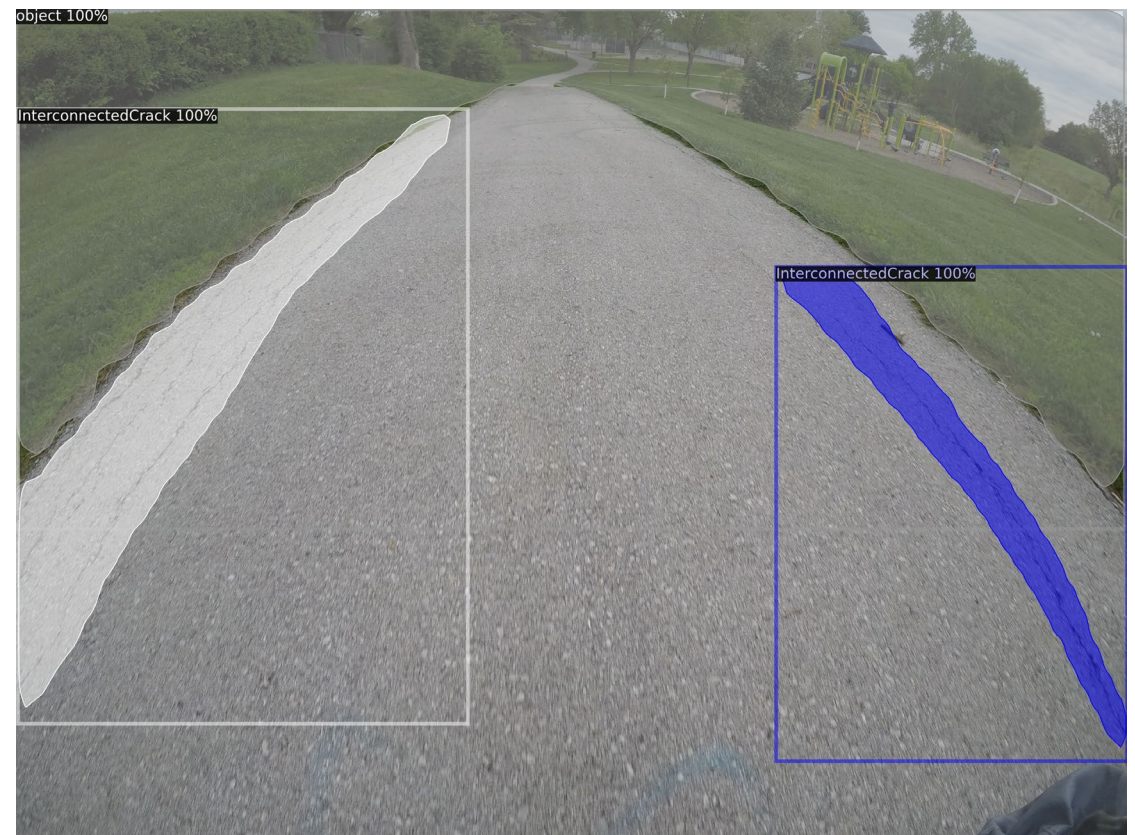
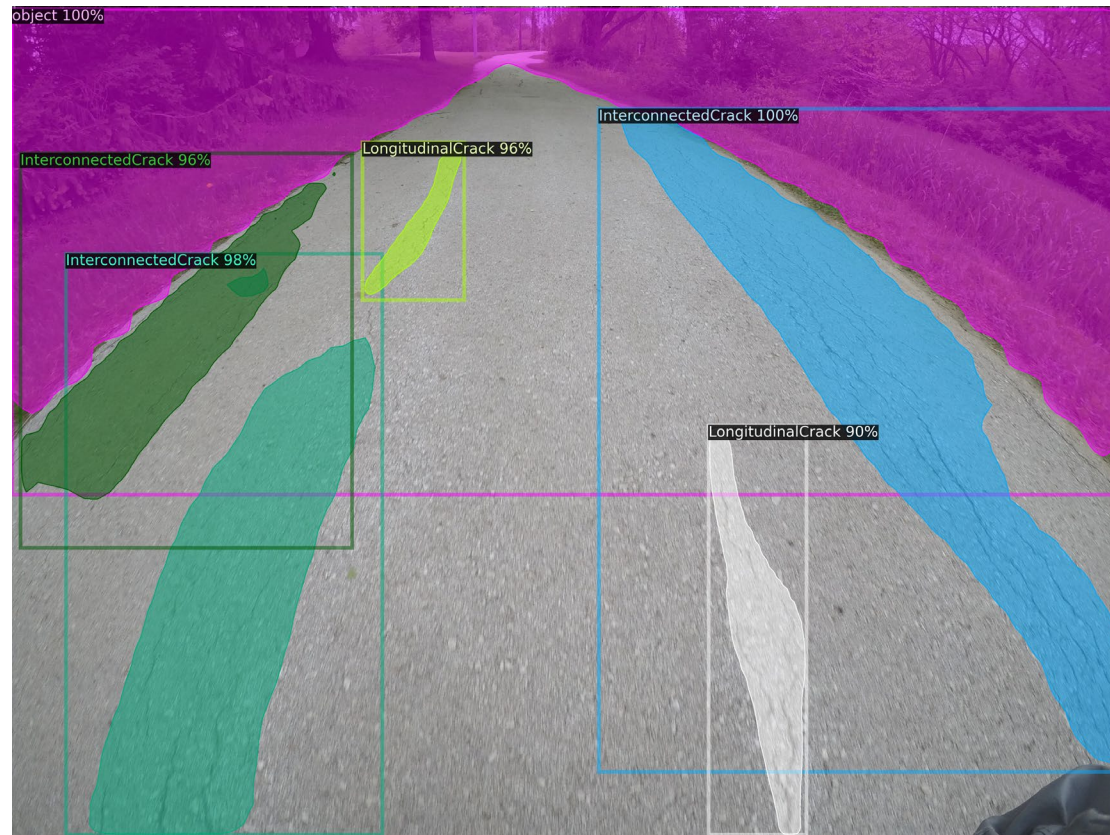
Model Predictions: AC

✓ Detection of far located transverse cracks.



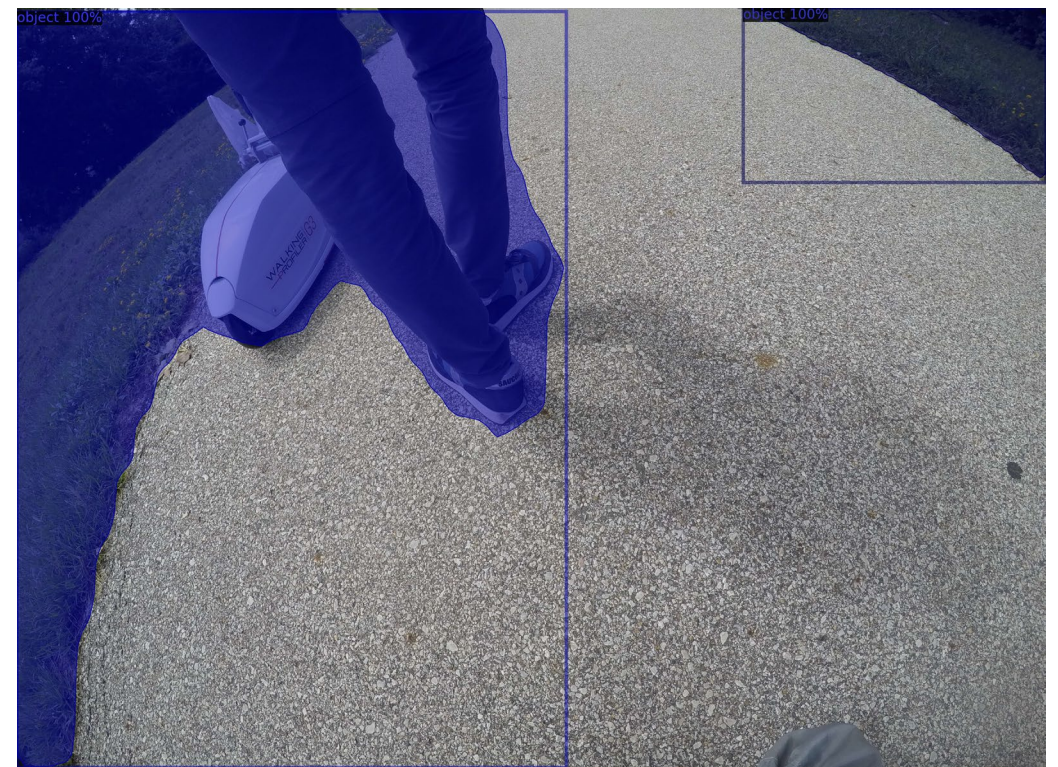
Model Predictions: AC

- ✓ Good detection capacity on critical distress type-
 - Interconnected cracks



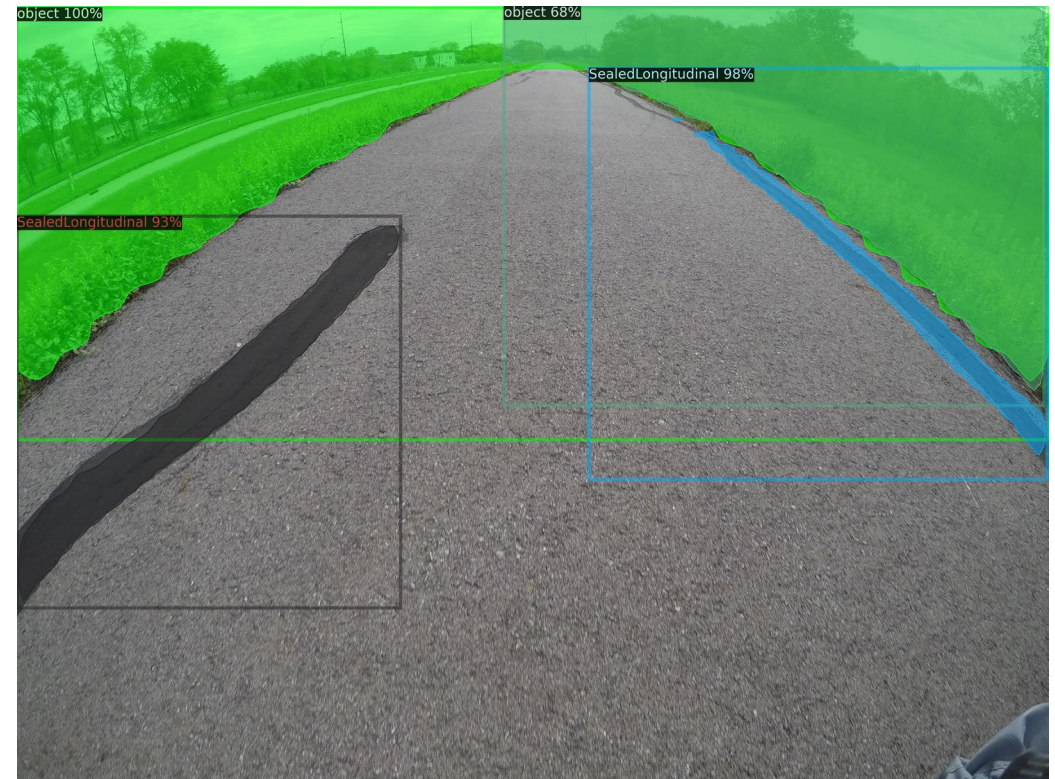
Model Predictions: AC

✓ Detection performance on trails with pedestrians!



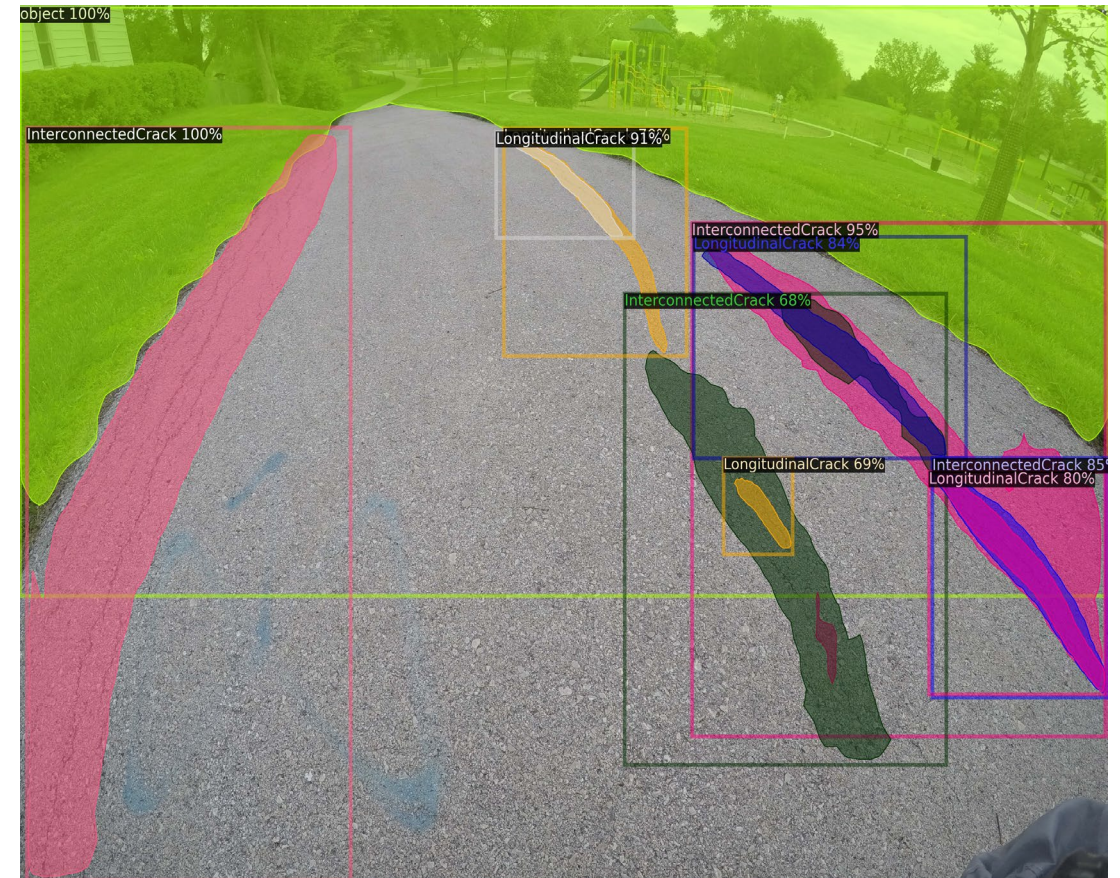
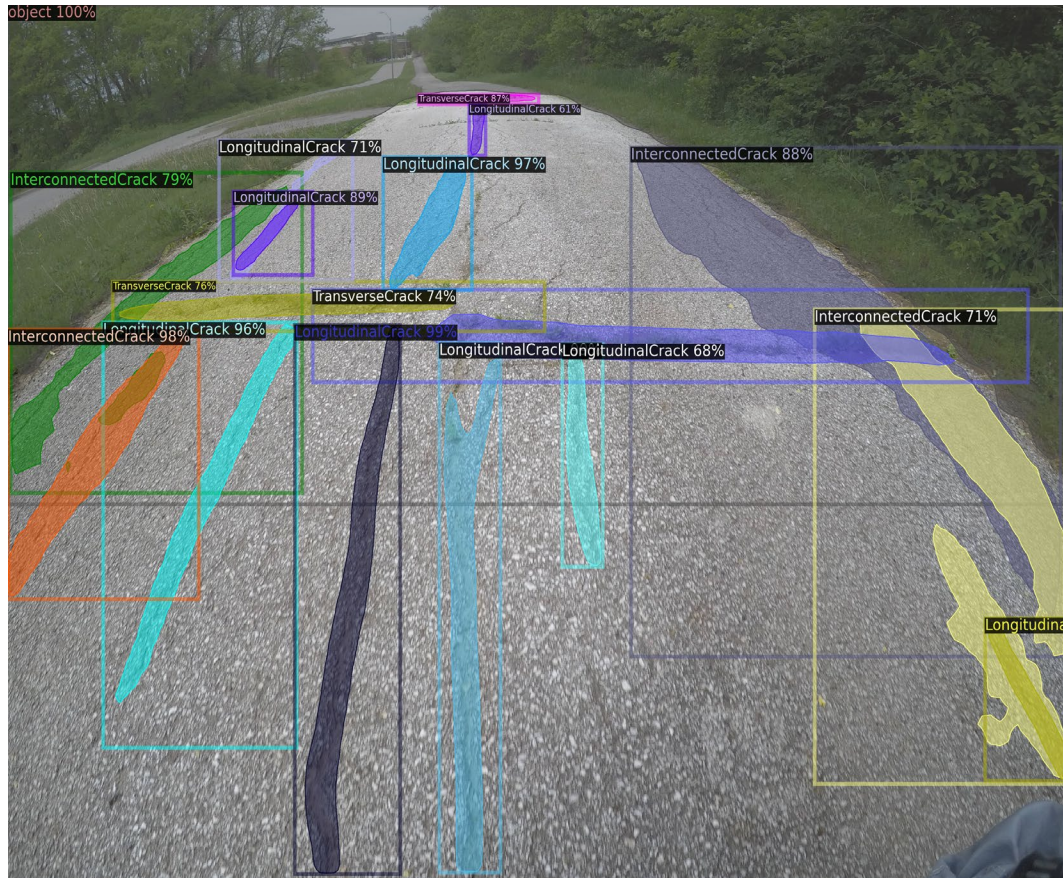
Model Predictions: AC

- ✓ Distinguishes the sealed longitudinal cracks that need no maintenance.



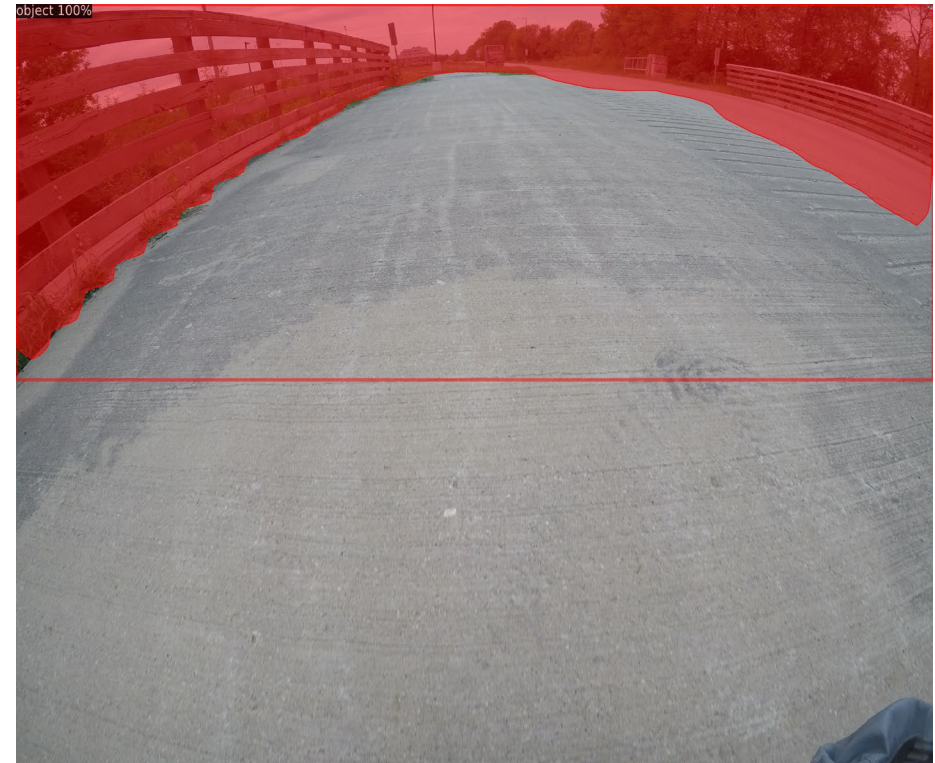
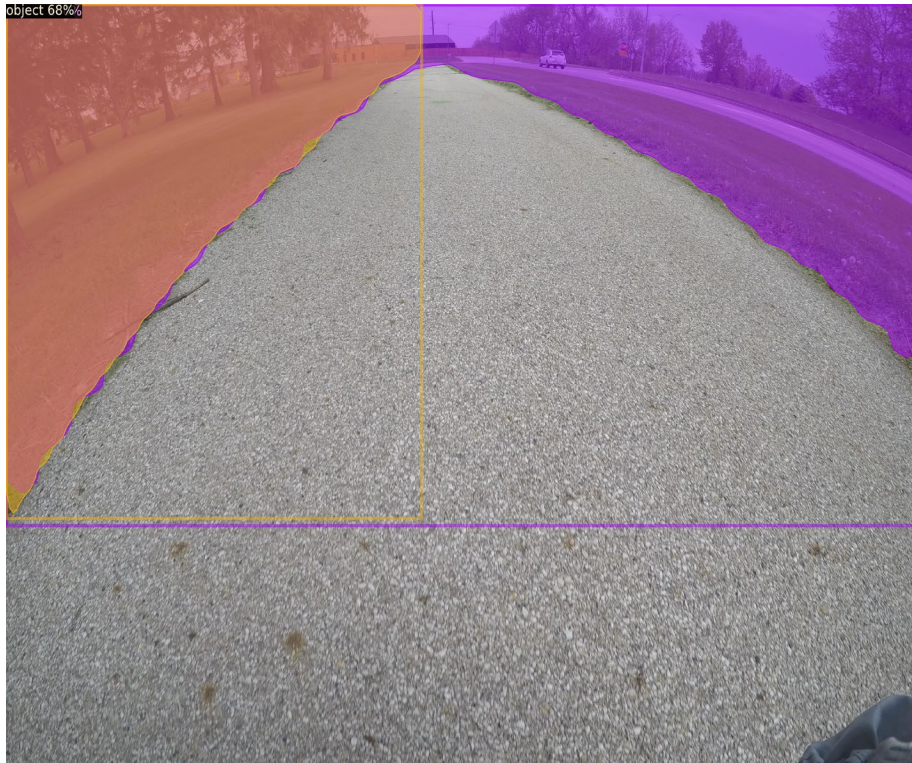
Model Prediction: AC

✓ Performance on heavily cracked areas.



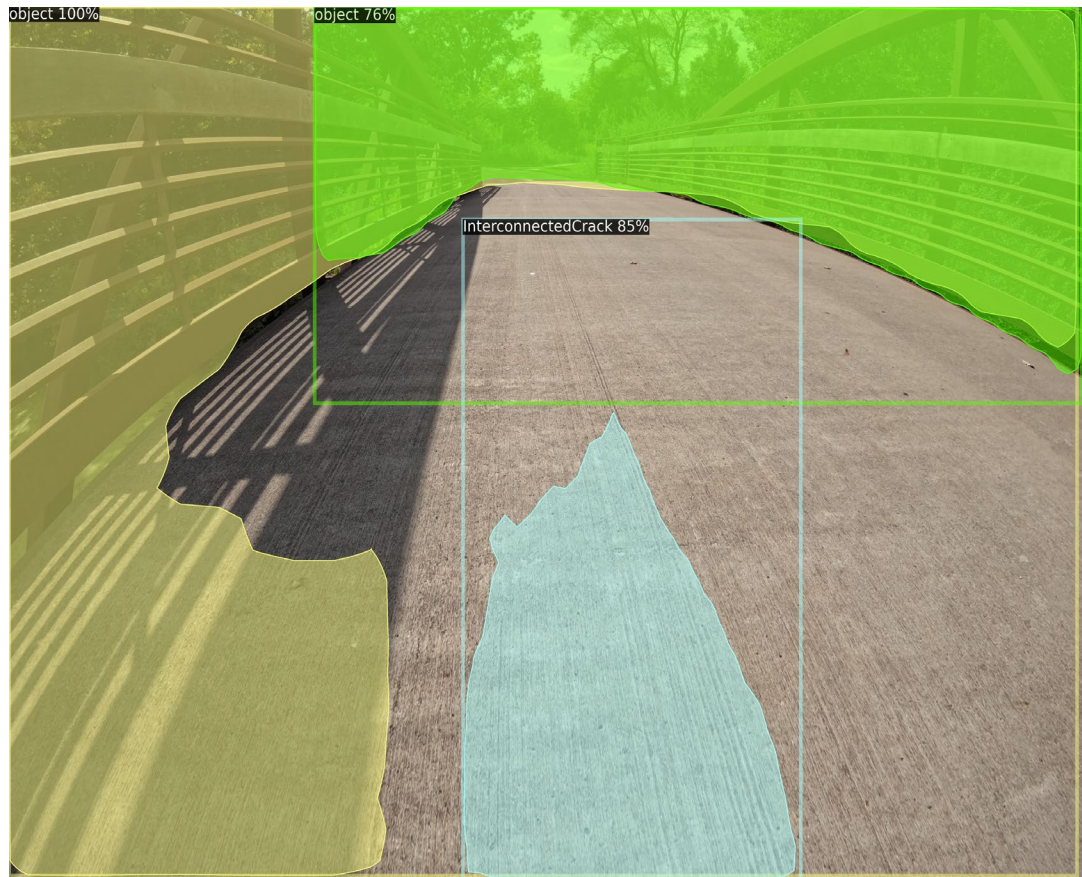
Model Prediction: AC & PCC

✓ Performance on trails in good condition

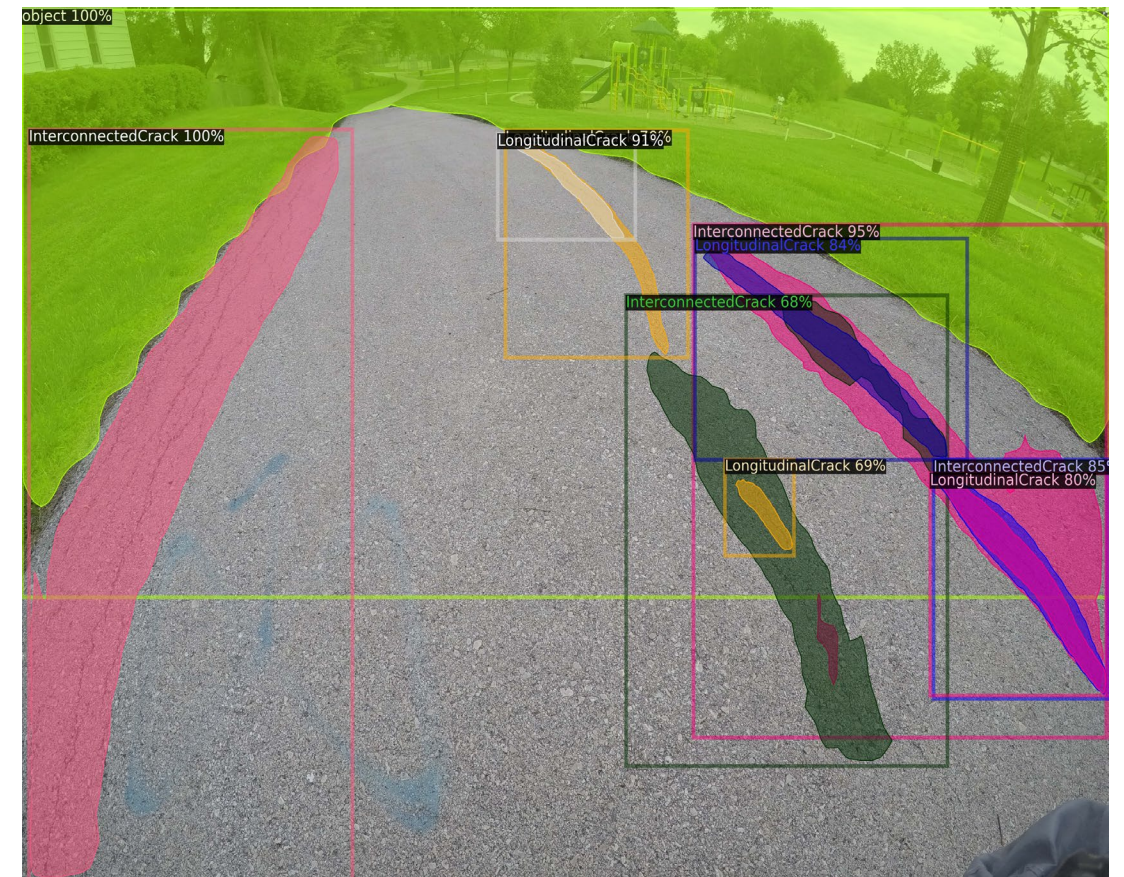


Model Limitations

- Crack-like surface texture caused it to predict Interconnected crack



- Overlap of prediction instances



Model Limitations

- Joints far-away not detected



- Two joints detected due to image distortion

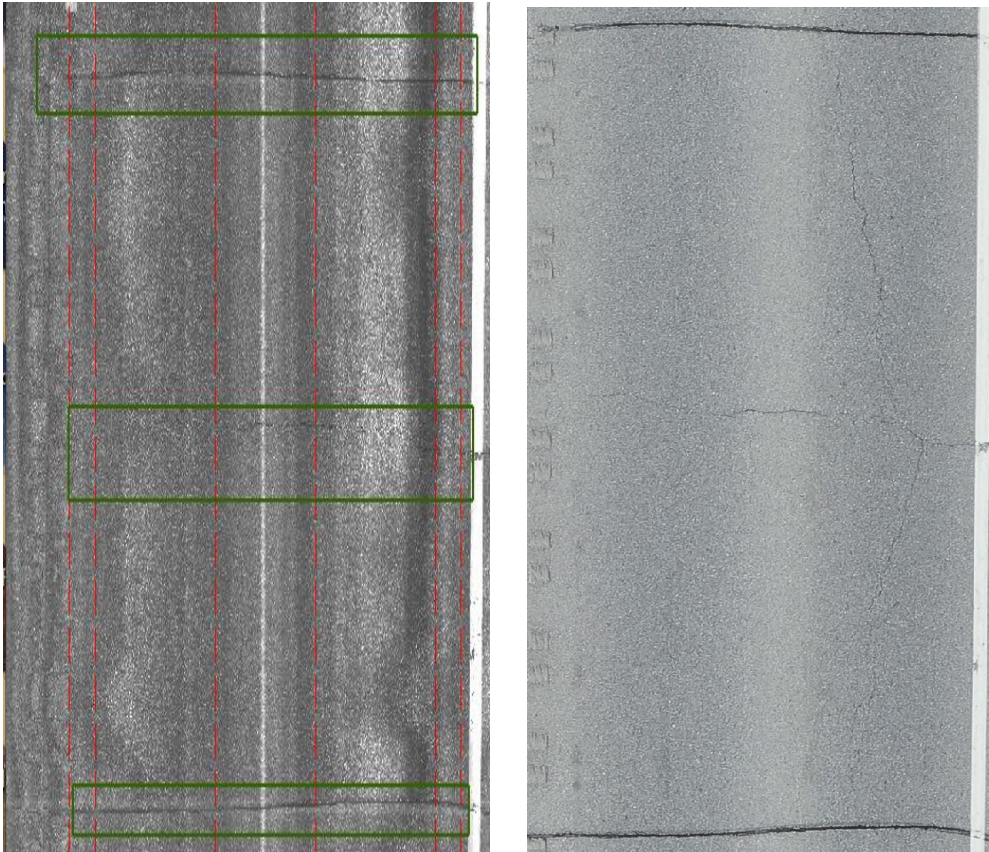


Distress quantification from GoPro Images

Distress quantification

Ideal Scenario

Aerial or Top view images



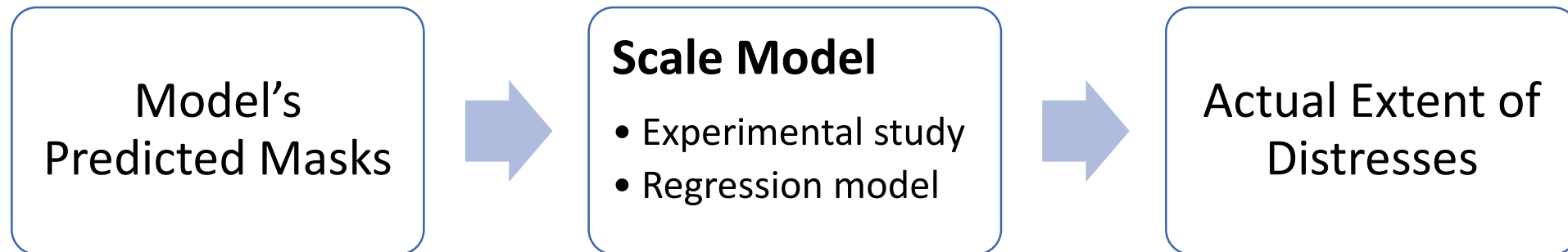
Go Pro

Wide-angle, Perspective of view



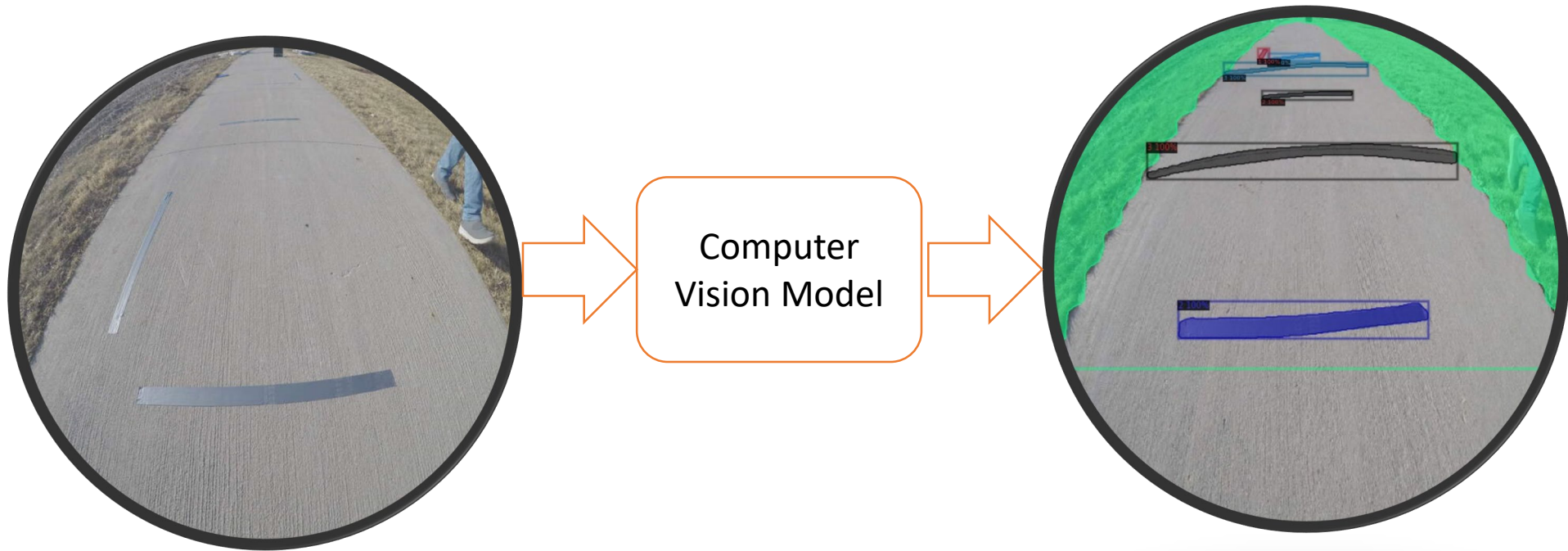
Distress quantification Methodology

- A scale model was developed to account for the distorted nature of GoPro images.
 - Accurately quantifies crack lengths from model's prediction.



Experimental Study

- ✓ Distresses were simulated on field using tapes.
- ✓ Model prediction on experimental images



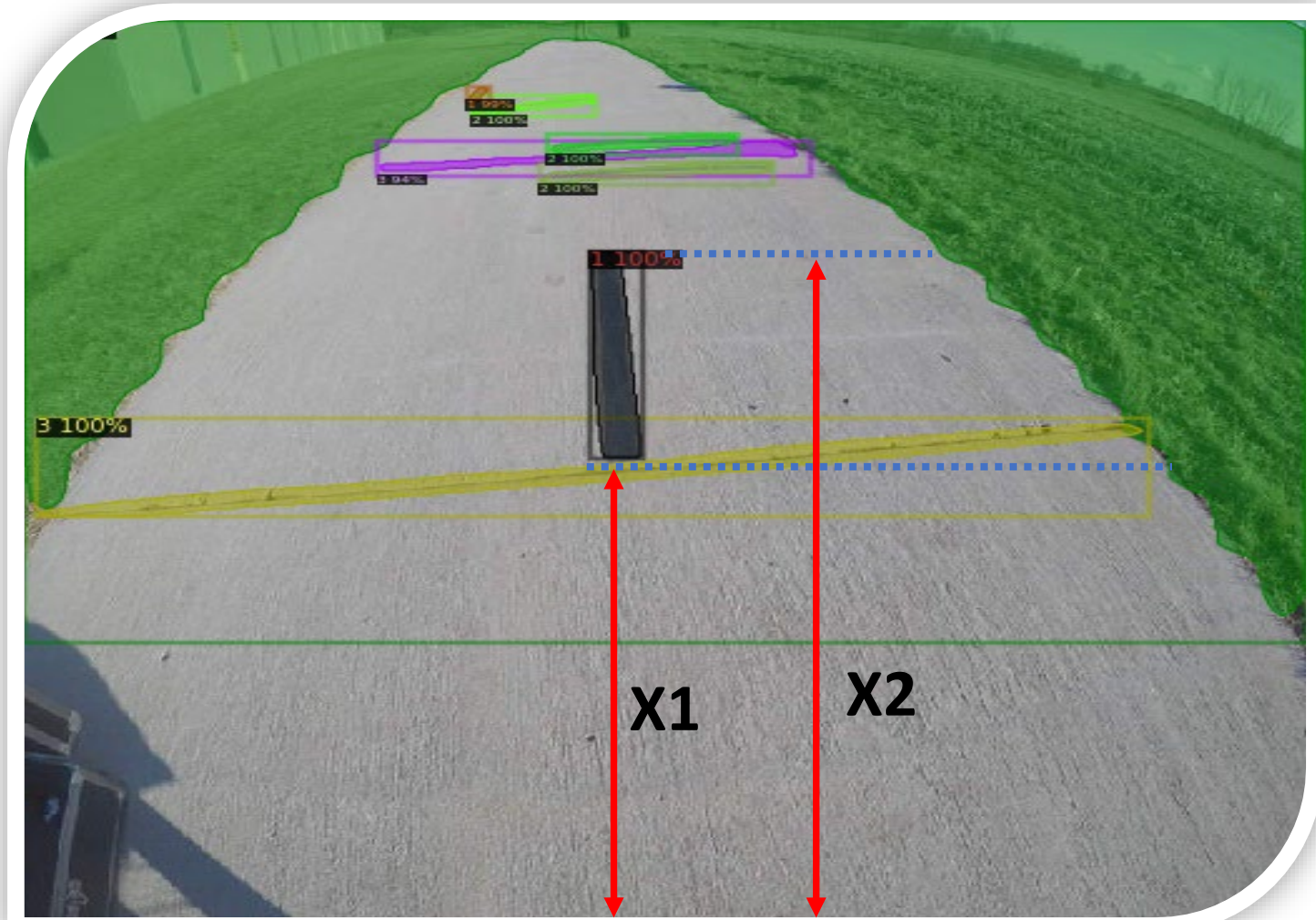
Scale Model Development

- Data Extraction

1. *Distance* = $X1$

2. *Avg. Distance* = $\frac{X1 + X2}{2}$

3. *Length(px)* or *Width (px)*



Scale Model vs Actual Length

0.5 Sec Interval- 45°

Longitudinal

Predicted: 31 in.
Actual: 24 in.

Transverse

Predicted: 29 in.
Actual: 24 in.

Longitudinal

Predicted: 29 in.
Actual: 36 in.

Longitudinal

Predicted: 33 in.
Actual: 24 in.

Transverse

Predicted: 17 in.
Actual: 24 in.

Longitudinal

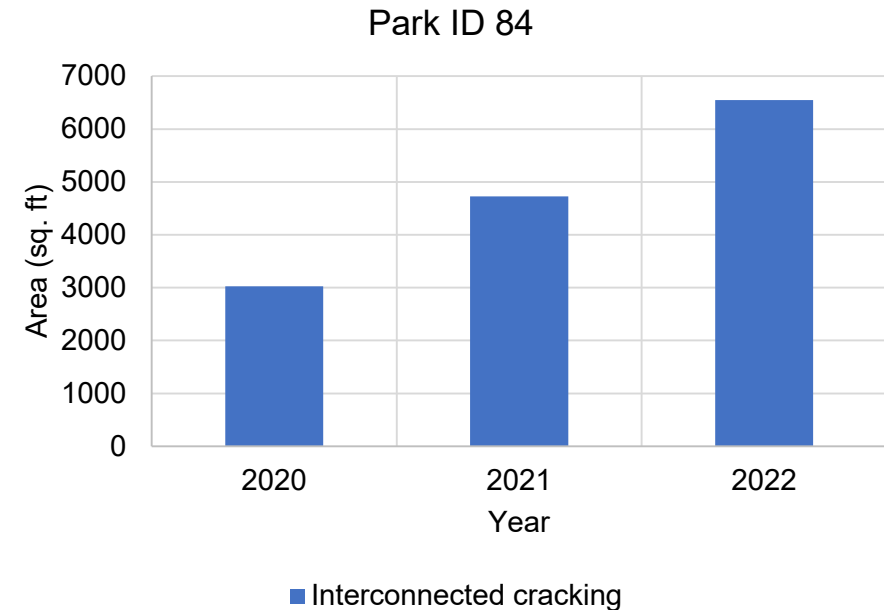
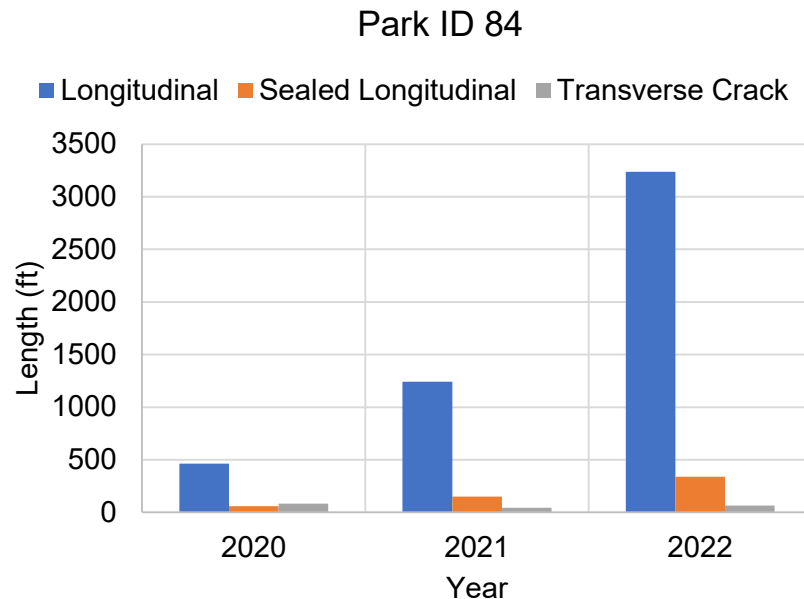
Predicted: 29 in.
Actual: 36 in.

Transverse

Predicted: 31 in.
Actual: 36 in.

Network-level Deployment

- Model was deployed at the network-level images.
- Distress quantity shown for Park ID 84.



Next Steps

- Developing a Trail Condition Index combining the roughness index and distress data.
 - Requires stakeholder involvement
- Ready for statewide deployment
 - Data collection guidelines to facilitate new agency addition

Site ID	Length (mile)	BIRI	Interconnected Cracking (sq. ft)	Longitudinal (ft)	Patching (sq. ft)	Pothole (count)	Scaled Longitudinal (ft)	Spalling (count)	T-Joint (count)	Transverse (ft)
1	0.39	97	-	35.4	-	0	9.1	0	296	7.5
2	0.49	153	1.7	-	-	0	-	0	502	8.3
3	0.08	55	-	18.7	-	0	7.2	0	122	-
4	1.80	794	4970.9	1671.1	0.7	0	-	0	2	4057.9
5	1.00	492	159.5	93.5	37.7	0	21.6	0	0	6156.2
6	1.43	692	84.3	301.2	0.2	0	17.7	14	2146	1327.6
7A	1.13	597	147.1	1156.3	0.3	0	26.8	10	1020	2314.7
7B	0.31	176	33.1	424.5	-	0	48.9	0	396	251.2
8A	2.46	411	135	3524.8	2.1	0	9.5	34	3546	20371
8B	2.44	110	39.6	839.1	-	2	-	14	3558	669.8
9A	0.57	153	-	495.7	1.4	0	212.6	4	458	153.7

Thank you!

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