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SYDNEY

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Deep Learning Computer Vision for Crack Quantification in Concrete Pipelines

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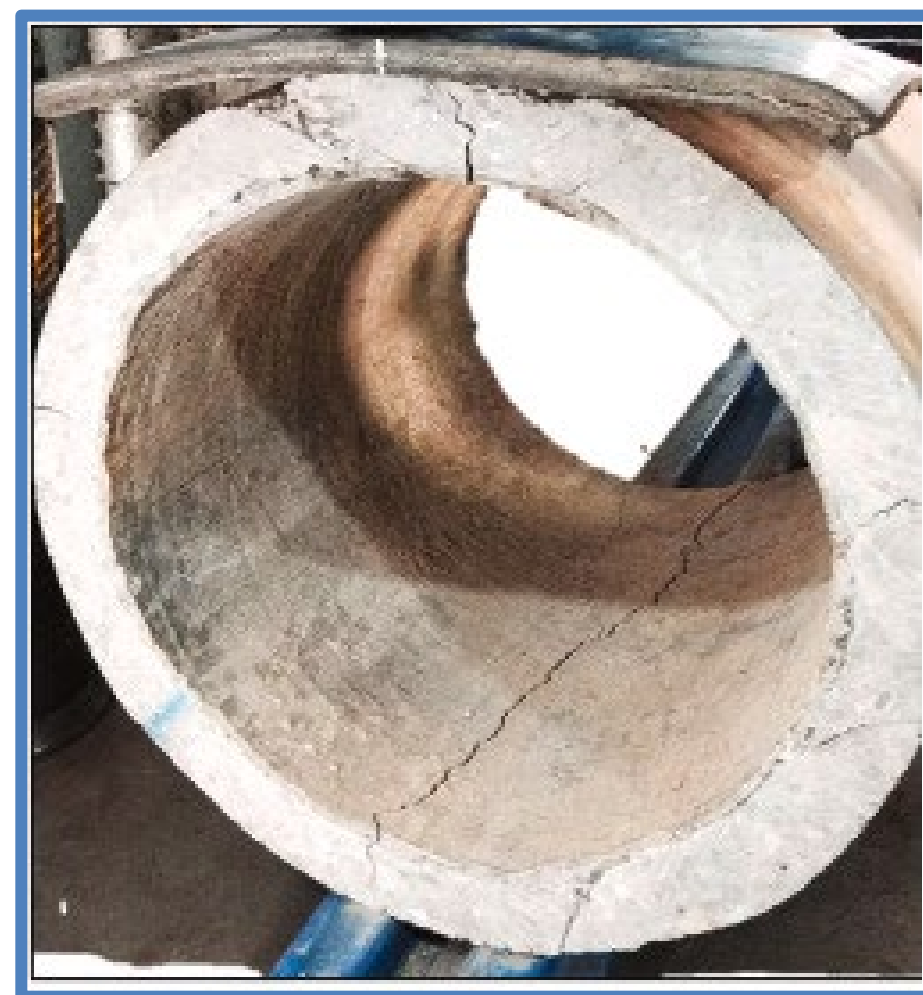
Faculty of Engineering and Information Technology Scholarship



***Concrete Pipe Association of Australasia,
SmartCrete CRC project***

“Crack Detection in Concrete Pipes Using Deep Learning Assisted Computer Vision”.

Cracks in Concrete: Why They Matter



Circumferential crack



Axial crack

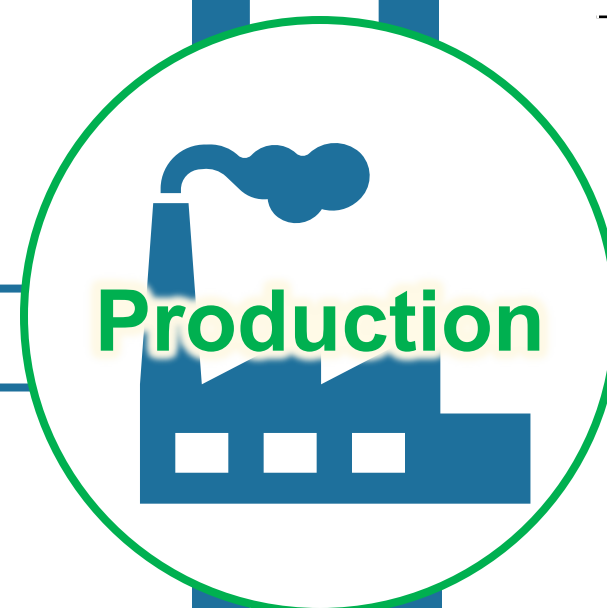
Figure 1. Concrete Pipe Cracks

Accelerate **water ingress** and reinforcement **corrosion**

Reduce structural **capacity** and **durability**

Increase maintenance **cost** and shorten **service life**

Cracks in Concrete: Standards



1

AUSTRALIA - AS 3600:2018

Component Type	Crack Width Limit (mm)
Reinforced concrete (general)	≤ 0.3 (typical) ≤ 0.2 for severe environments ≤ 0.4 for less critical

2

USA - ACI 318

Component Type	Crack Width Limit (mm)
Reinforced concrete (general)	≤ 0.3 (wet exposure) ≤ 0.4 (dry/indoor)

3

EU - EN 1992-1-1

Component Type	Crack Width Limit (mm)
Reinforced concrete (general)	$\leq 0.2-0.3$ (typical) up to 0.4 for non-critical appearance

4

CHINA - GB/T 51231-2016

Component Type	Crack Width Limit (mm)
Reinforced concrete (general)	≤ 0.30 (indoor) ≤ 0.20 (outdoor/humid)

Cracks in Concrete: Standards



1

AUSTRALIA - AS 3600

Exposure Class	Crack Width Limit (mm)
Moderate exposure	≤ 0.3
Severe exposure	≤ 0.2

2

USA - ACI 318

Exposure Class	Crack Width Limit (mm)
Moderate exposure	≤ 0.4
Severe exposure	≤ 0.25

3

EU - EN 1992-1-1

Exposure Class	Crack Width Limit (mm)
Carbonation corrosion	≤ 0.2
Chloride corrosion	$\leq 0.2 - 0.3$
Chemical attack	≤ 0.2

4

CHINA - GB 50010-2010

Exposure Class	Crack Width Limit (mm)
Non-corrosive exposure	≤ 0.3
Mild corrosivity	$\leq 0.2 - 0.25$
Severe corrosivity	≤ 0.2

Current Solutions & Challenges

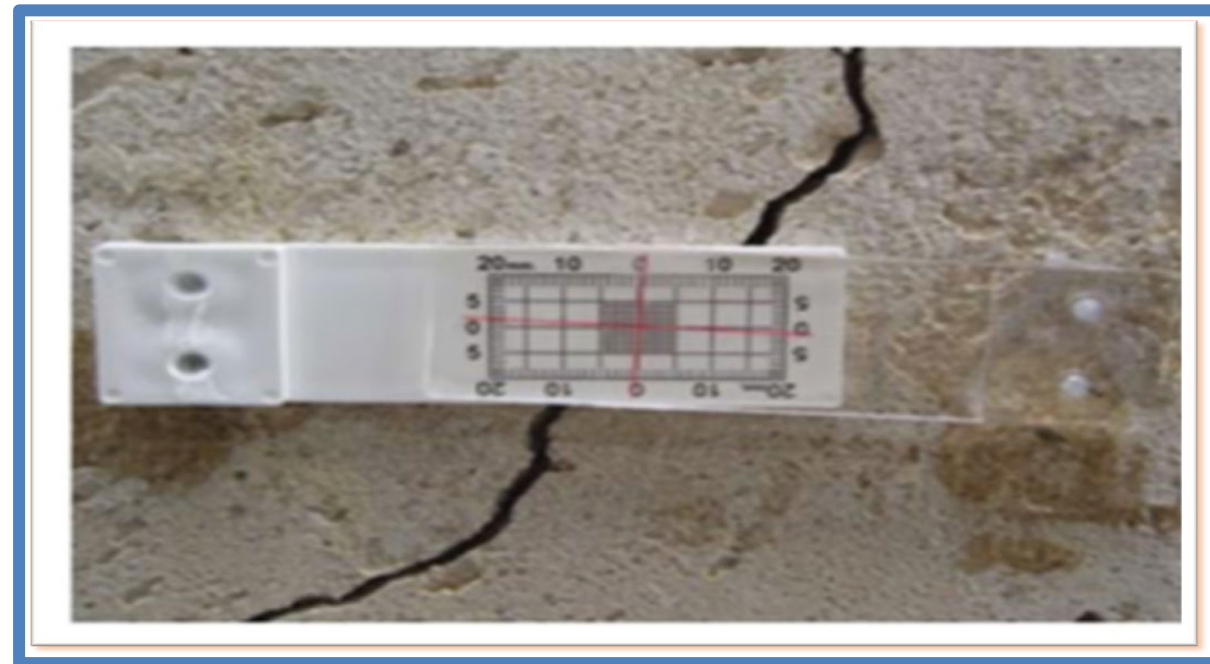
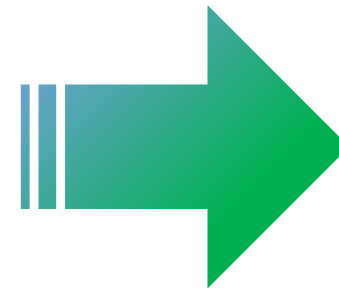


Figure 2. Manual inspection

- High subjectivity and variability
- Low efficiency and limited coverage
- Safety risks and inaccessibility



- Higher efficiency
- Improved consistency
- Enhanced safety

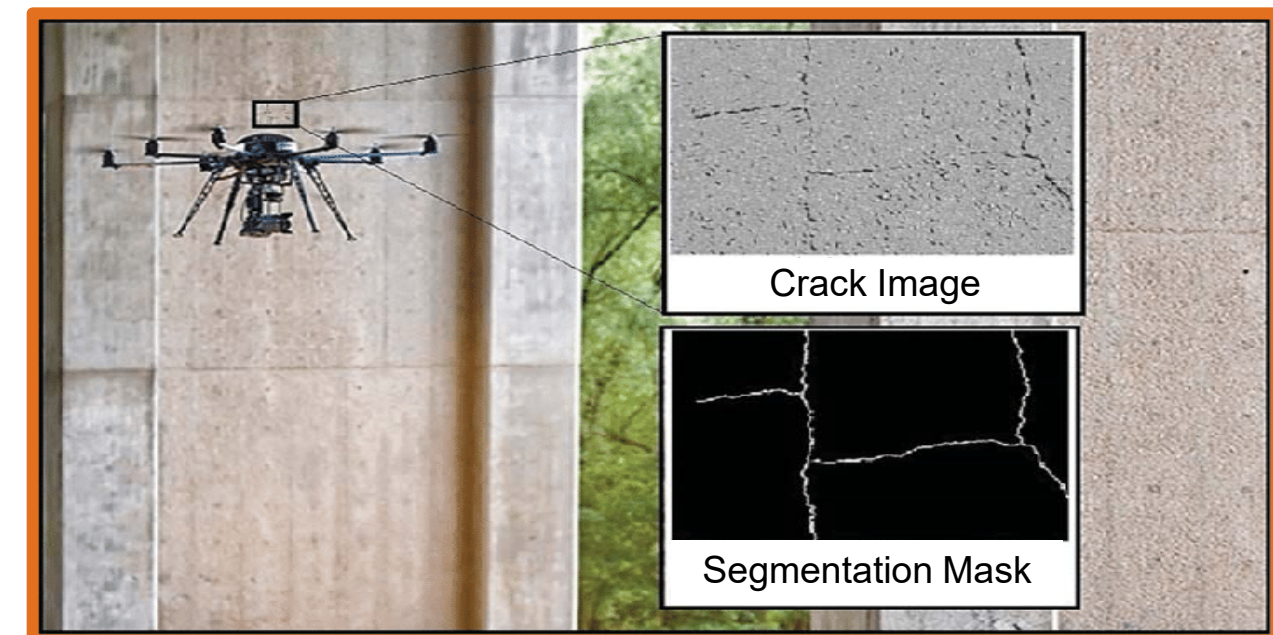
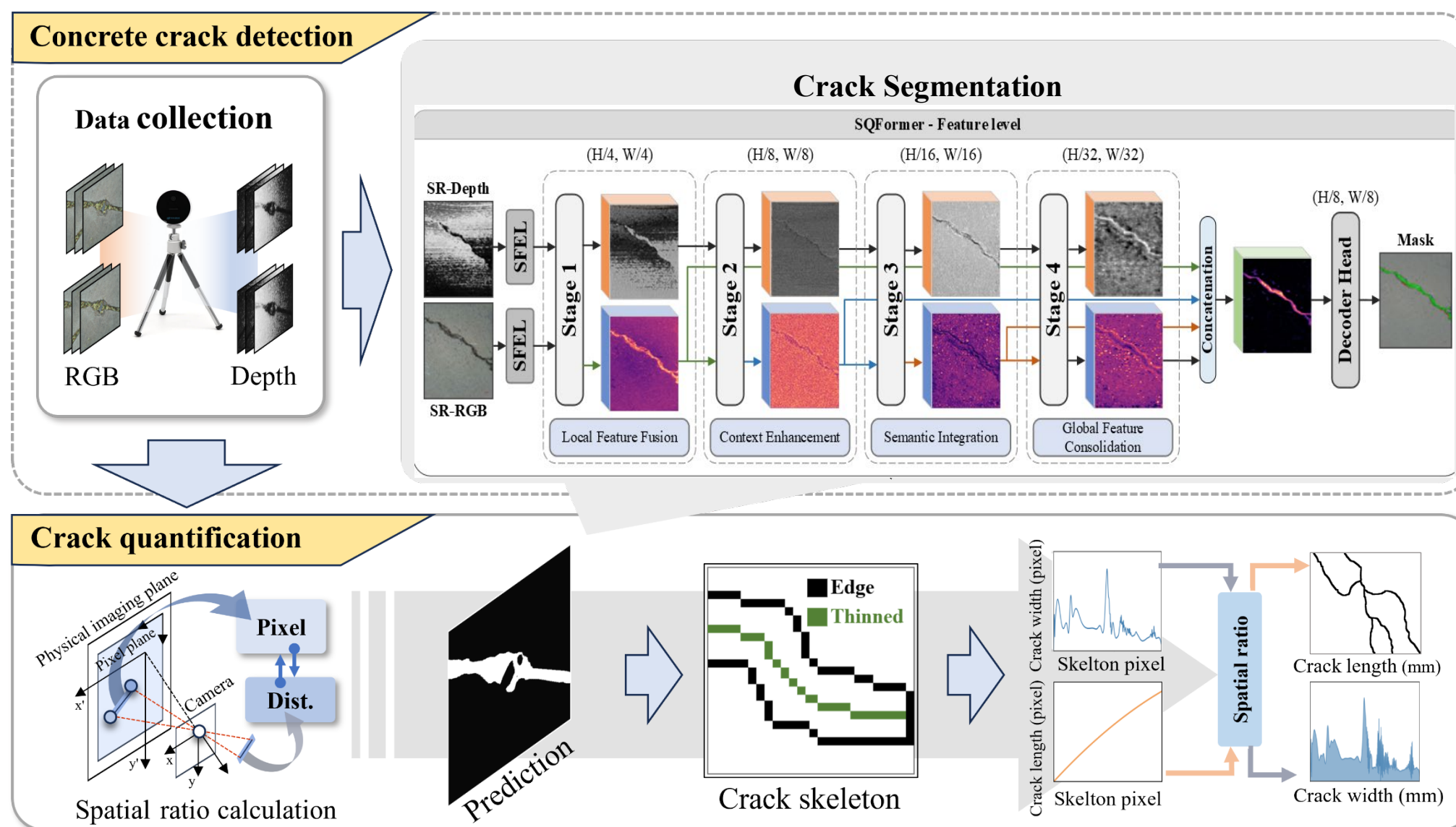


Figure 3. Deep learning methods

Crack Detection

Crack Quantification



Integrated framework for high-precision and robust concrete pipe crack detection and quantification

- Capable of identifying cracks as narrow as **0.1 mm**
- Automated and consistent results
- Robust performance in challenging backgrounds

Figure 4. Overall architecture of proposed crack quantification algorithm

Data Collection



Figure 5. Intel® RealSense™ LiDAR Camera L515



Figure 6. SunFounder GalaxyRVR RC Rover



Figure 7. The assembled Crack Capture Equipment

Table 1. Camera Parameters

Parameter	Specification
RGB	
Frame resolution (pixels)	1920 × 1080
Sensor FOV (H × V)	70° × 43°(±3°)
Frame rate (FPS)	30
Depth	
Frame resolution (pixels)	1024 × 768
Sensor FOV (H × V)	70° × 55°(±3°)
Frame rate (FPS)	30
Mechanical	Ø 61 mm × 26 mm; 95g; USB-C interface
Depth range	0.15~6.5m

High-precision depth sensing

Compact and portable

Cost-effective

Crack Segmentation

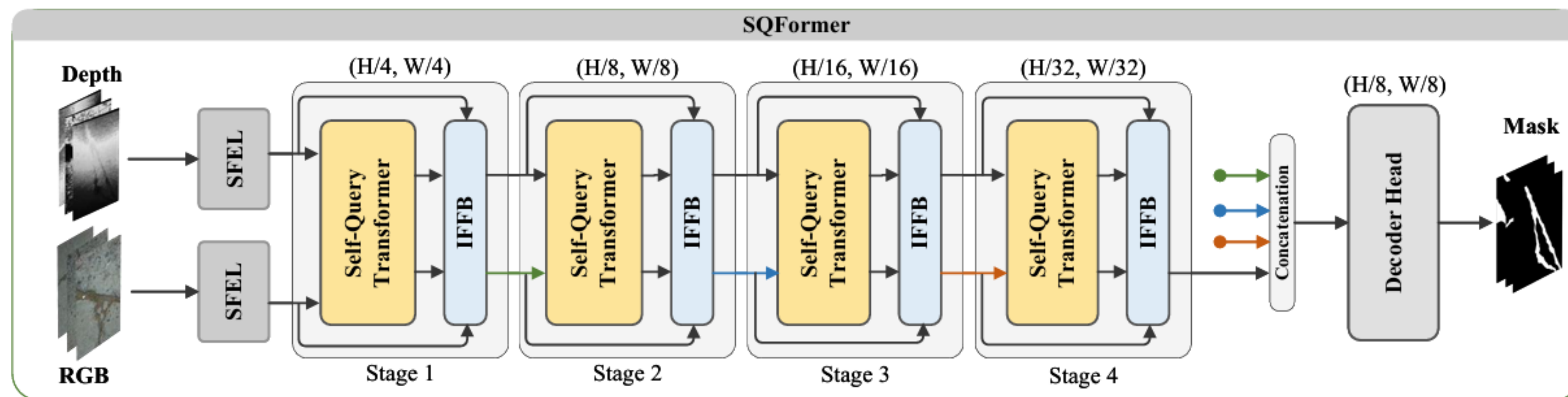


Figure 8. RGBD Fusion-based Crack Segmentation Deep Learning Network

Crack Quantification

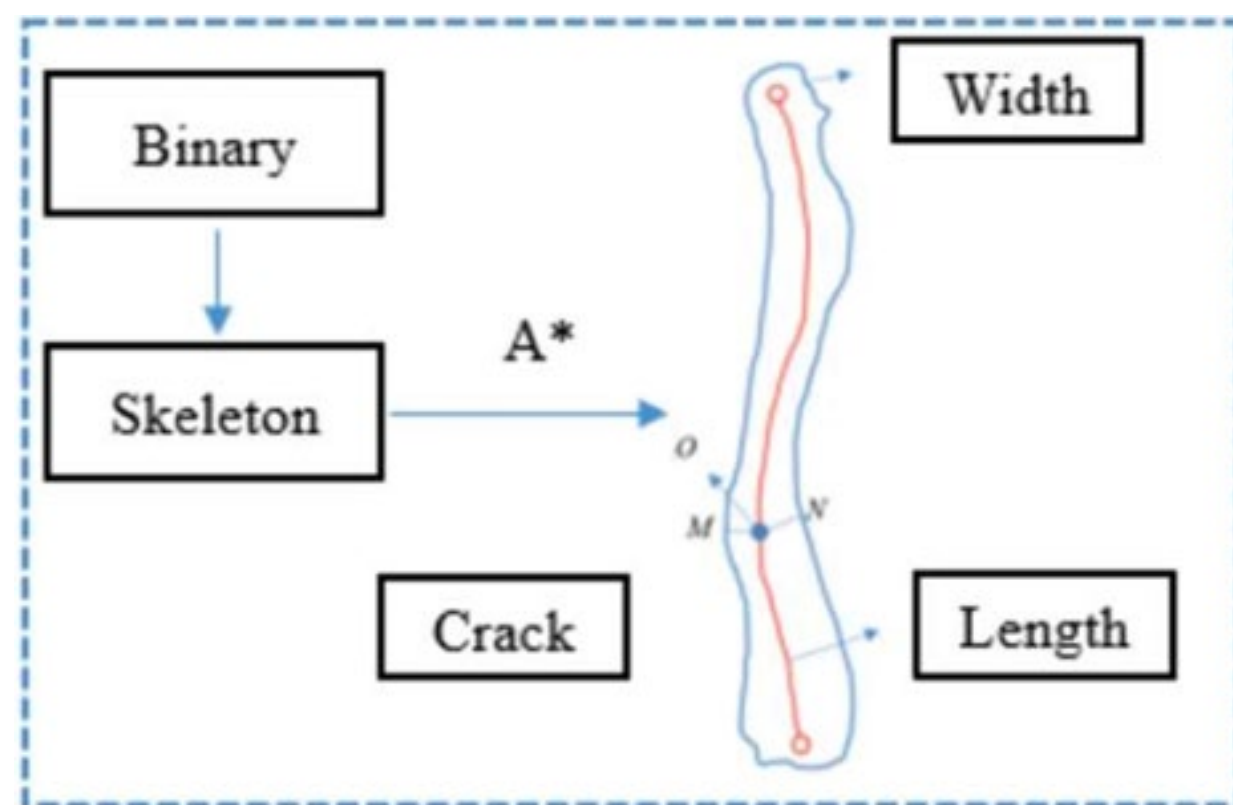


Figure 9. Crack Skeletonization



Crack Length Calculation

$$L_p = \sum_{i=1}^{n-1} \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$

Crack Width Calculation - maximum inscribed circle method



Example 1

Example 2

Figure 10. Crack Width Calculation

Crack Quantification

intrinsic matrix of the RGB-D camera

$$\mathbf{K} = \begin{bmatrix} f_x & 0 & u_x \\ 0 & f_y & v_y \\ 0 & 0 & 1 \end{bmatrix}$$



Real-world coordinates

$$x_i = \frac{u_i - u_x}{f_x} \times d, y_i = \frac{v_i - v_y}{f_y} \times d \quad (i = 1, 2)$$



Spatial ratio (R)

$$R = \frac{D}{d} = \frac{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}}{\sqrt{(u_2 - u_1)^2 + (v_2 - v_1)^2}}$$

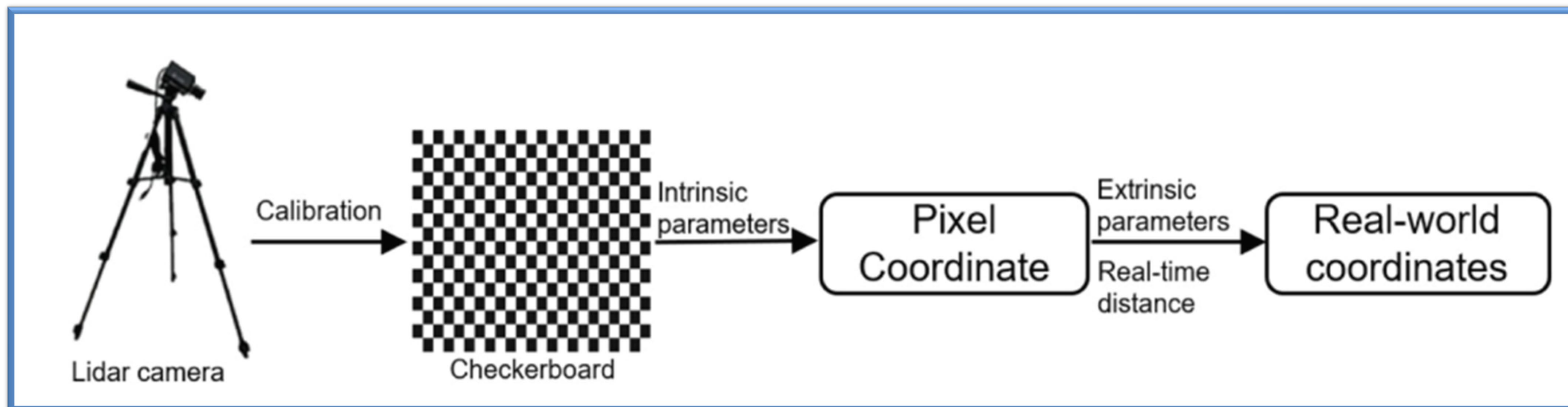


Figure 11. LiDAR-based depth scaling and camera calibration for crack quantification

Experimental Settings



Figure 12. On-Site Experiment

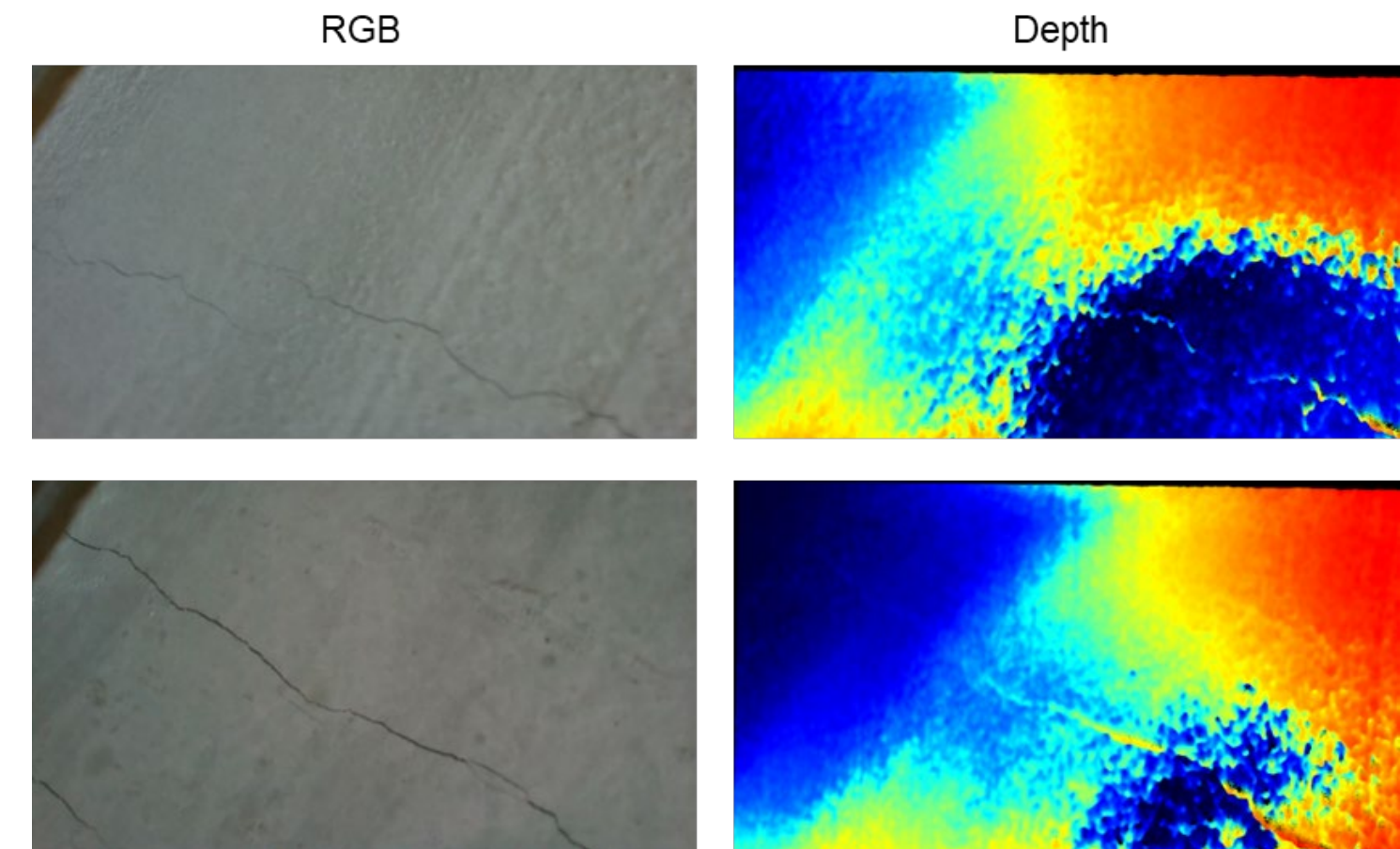


Figure 13. Data Samples

Zero-Shot Crack Segmentation Results

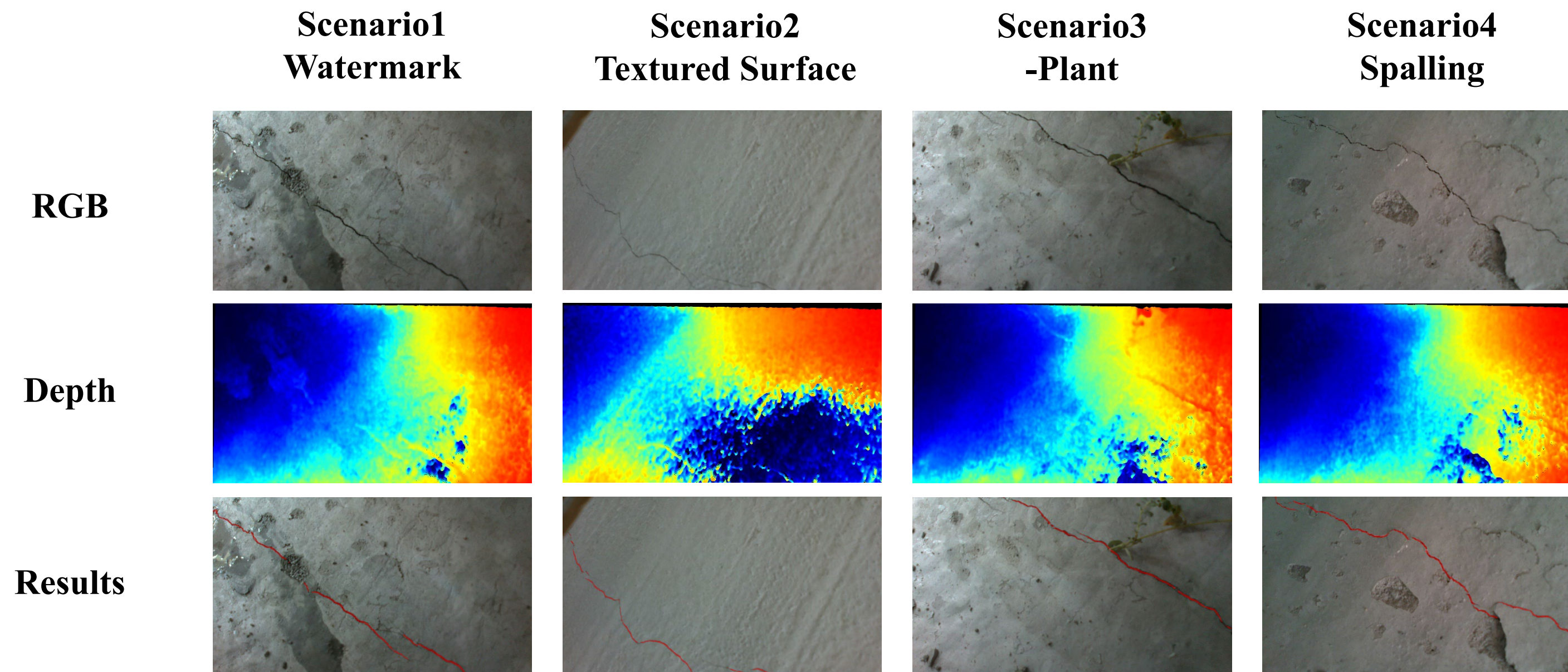


Figure 14. Crack Segmentation Results

Crack Quantification Results - Width

Table 2. Quantification Results of the Minimum Crack Width

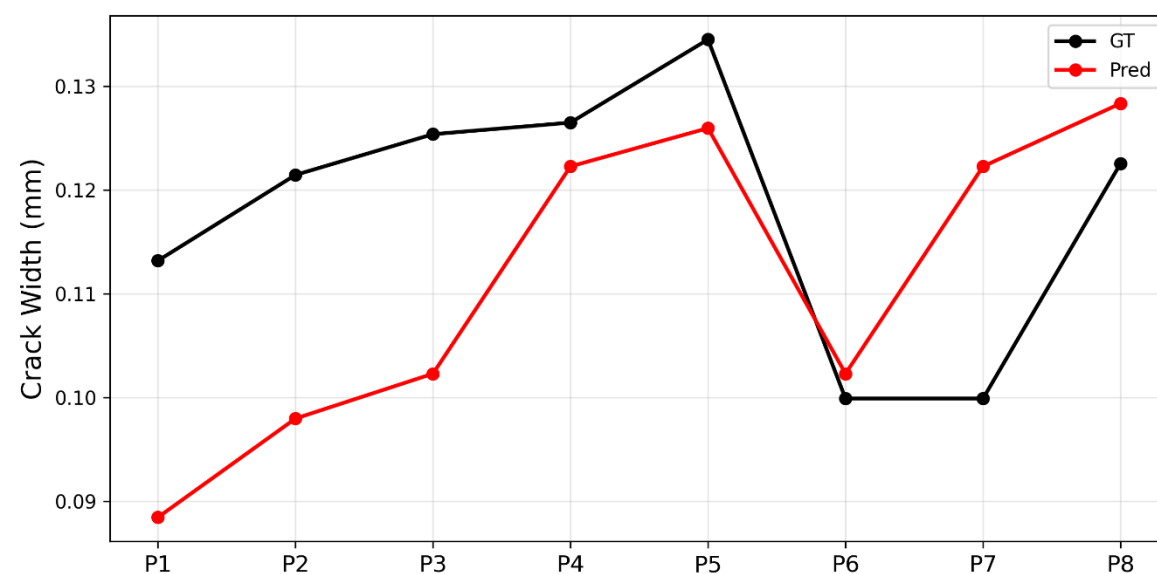
	Min crack width (mm)		Absolute error (mm)	Relative error (%)
	GT	Pred		
S1	0.087	0.085	0.002	2.3
S2	0.044	0.053	0.009	20.45
S3	0.113	0.1	0.013	11.5
S4	0.091	0.069	0.022	24.18

Tabel 3. Quantification Results of the Maximum Crack Width

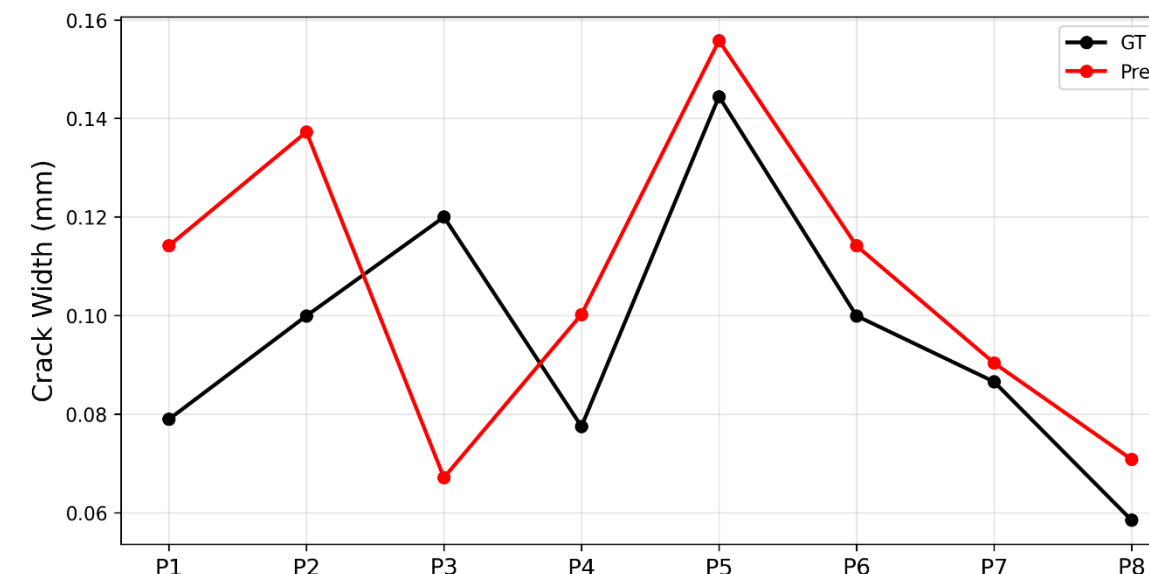
	Max crack width (mm)		Absolute error (mm)	Relative error (%)
	GT	Pred		
S1	0.135	0.101	0.034	33.66
S2	0.2	0.203	0.003	1.5
S3	0.16	0.153	0.007	4.38
S4	0.15	0.163	0.013	8.67

Crack Quantification Results - Width

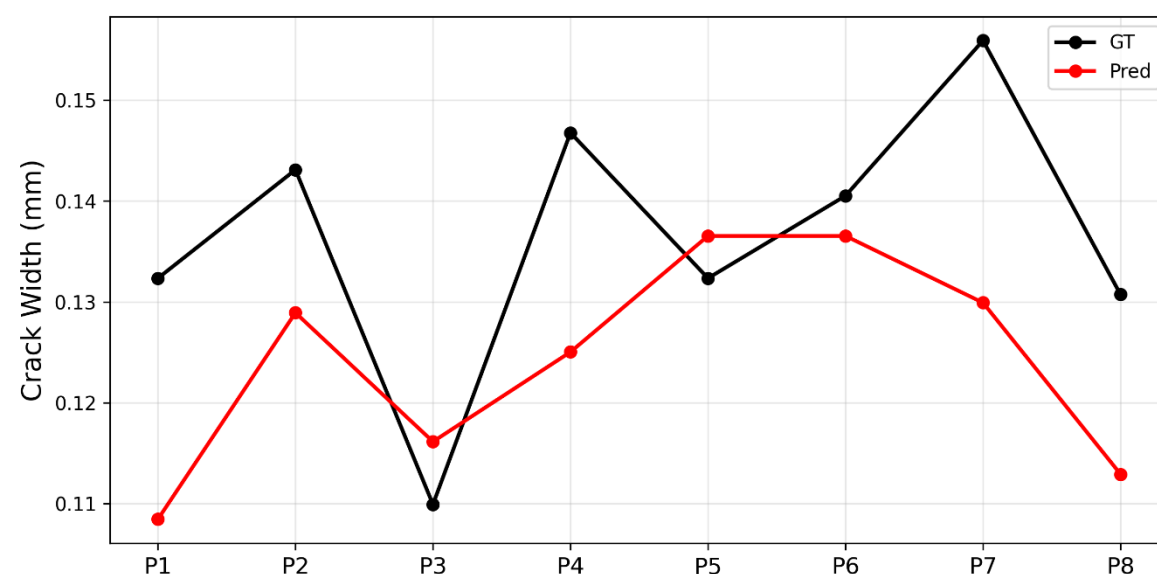
Scenario 1



Scenario 2



Scenario 3



Scenario 4

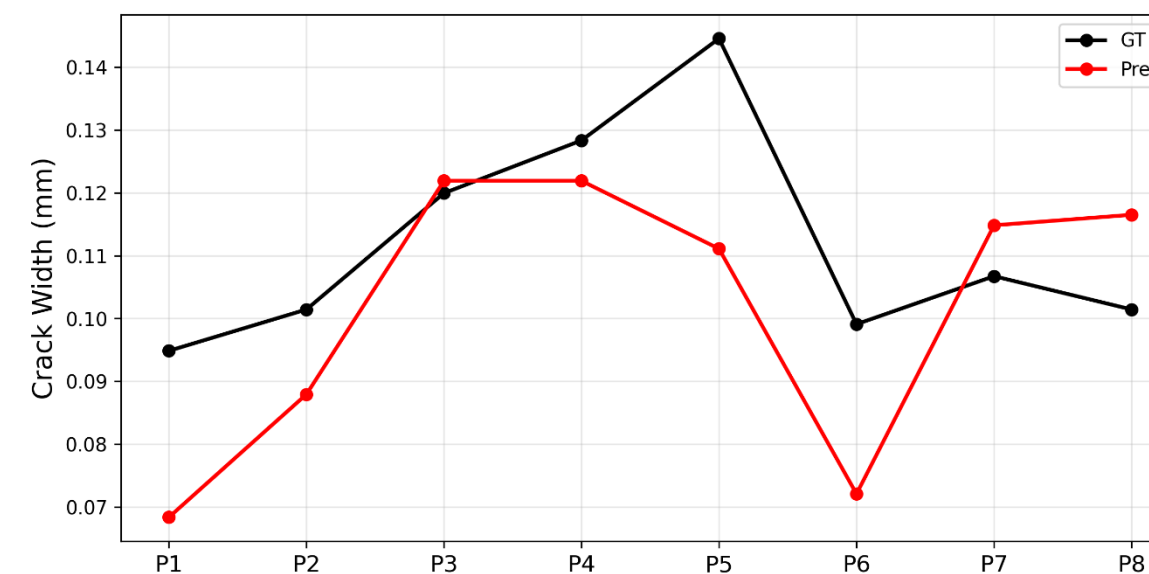


Figure 15. Crack Width at Selected Points Along the Skeleton

Crack Quantification Results - Length

Table 4. Quantification Results of the Crack Length

	Crack length (mm)		Absolute error (mm)	Relative error (%)
	GT	Pred		
S1	15.71	14.98	0.73	4.65
S2	28.24	22.98	5.26	18.63
S3	11.22	9.69	1.53	13.63
S4	14.56	13.41	1.15	7.9

Crack Segmentation- Failure Cases

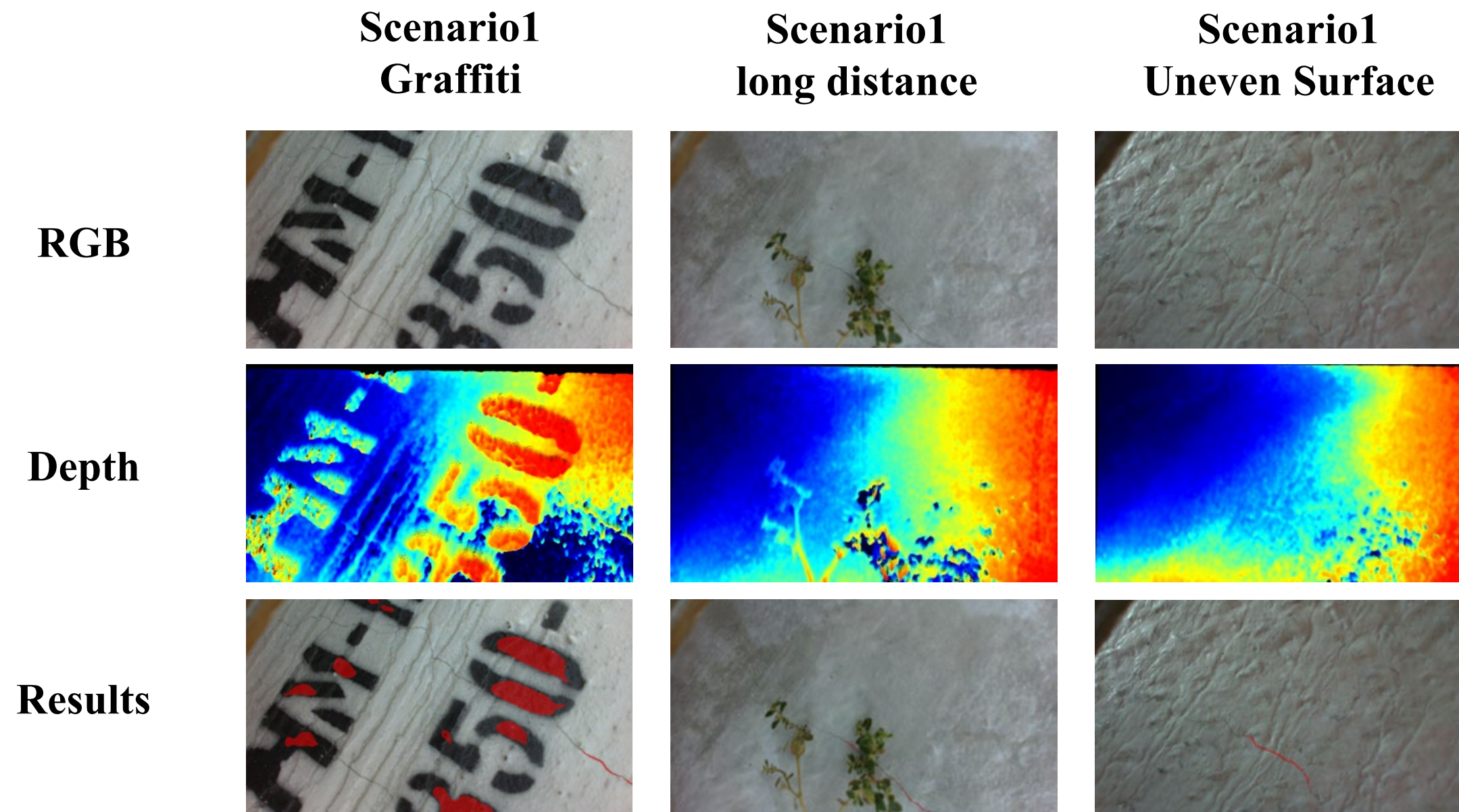


Figure 16. Crack Segmentation Results – Failure Cases



THANK YOU