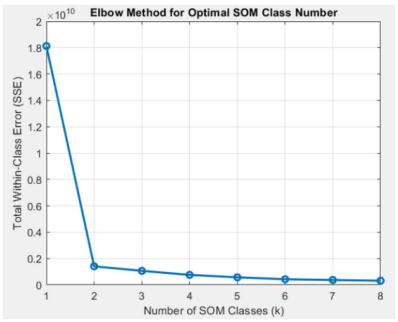
SOM-Based Class Discovery and Feature Attribution for Crack Region Interpretation

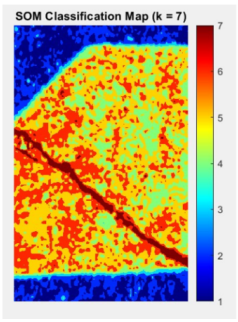
Shadow Crack

Detected Crack

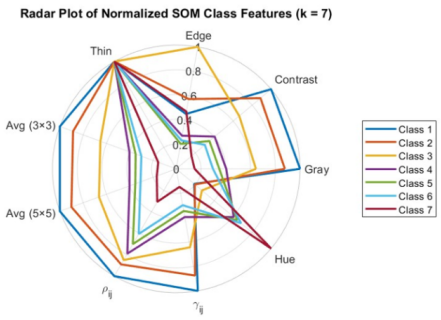
Input image under shadow occlusion; SOM identifies multi-class structure without supervision.



Optimal Class Number (Elbow Method)
Class number (k) automatically selected by within-cluster error minimization



SOM-Based Crack Region Segmentation
Pixel-level clustering based on **9 visual-statistical features**, including grayscale, contrast, edge, hue, and structural indicators (e.g., thinness, colNorm, rowNorm, etc.)



Feature Attribution by Class
Radar plot showing class-wise feature dominance across 7 cluster types

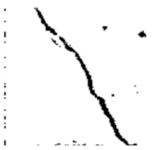
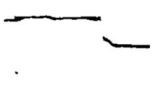
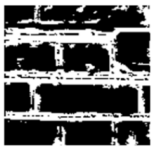
- **SOM auto-selects class number and clusters pixel regions with no labeled data**
- **Supports unsupervised damage interpretation and label-free classification pipelines**
- **Radar plot reveals feature attribution across crack, mortar, and background classes**

Xinxin Sun, Ph.D. | May 2025

Contact: xinxin68@umd.edu | Concept under refinement — module integration in progress

SOM-Generated Pseudo Labels Enable Efficient CNN Training for Multi-Crack Scenarios

Experiment	Clean SOM (All Types)		Raw SOM (All Types)		Clean SOM (Concrete Only)		Raw SOM (Concrete Only)	
Training Labels	Clean SOM: Concrete, Brick, Shadow		Raw SOM: Concrete, Brick, Shadow		Clean SOM: Concrete; Birck/Shadow as Background		Raw SOM: Concrete; Birck/Shadow as Background	
	Label	Output	Label	Output	Label	Output	Label	Output
Concret Crack								
Brick Crack								
Shadow Crack								
Time	42s		42s		30s		36s	

Crack Type	Input	SOM Output	CNN Output
Concrete Crack			
Brick Crack			
Shadow Crack			

- **SOM-generated pseudo-labels used to train CNN models with no manual annotation.**
- **Concrete + background labels yielded highest segmentation fidelity and training efficiency.**
- **CNN trained with Clean SOM cracks + background achieves complete crack structure detection in 30s.**

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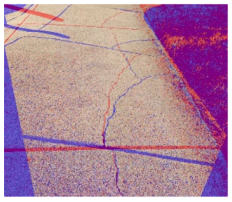
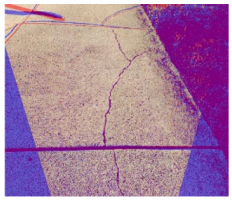
Unsupervised Alignment for Robust Crack Tracking in Field Conditions

Viewpoint A

Viewpoint B



SURF-RANSAC Matching (Failed)



KAZE-RANSAC Alignment (Success)

Crack Alignment Pipeline

KAZE-RANSAC achieves robust geometric alignment under field-induced distortion, outperforming classical SURF-based matching in consistency and accuracy.

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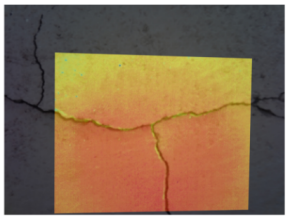
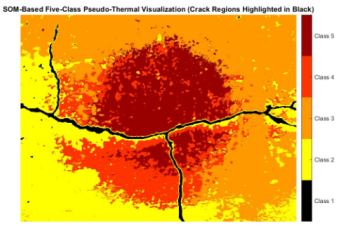
Crack Image



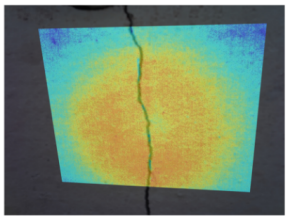
IR Captured



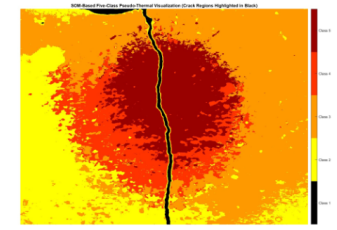
SOM-Based Pseudo-Thermal Field (No IR Sensor)

SOM-Based Five-Class Pseudo-Thermal Visualization
(Crack Regions Highlighted in Black)

Crack Image



IR Captured



SOM-Based Pseudo-Thermal Field (No IR Sensor)

SOM-Based Five-Class Pseudo-Thermal Visualization
(Crack Regions Highlighted in Black)

- Crack structure detected **without** thermal input
- Preserves heat-like gradients around defects
- Can support sensor-free damage localization

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Concept only—prototype results under refinement