Image Scale Estimation Using Surface Textures for Quantitative Visual Inspection

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UNIVERSITY OF WATERLOO
FACULTY OF ENGINEERING

Computer Vision for Smart Structure

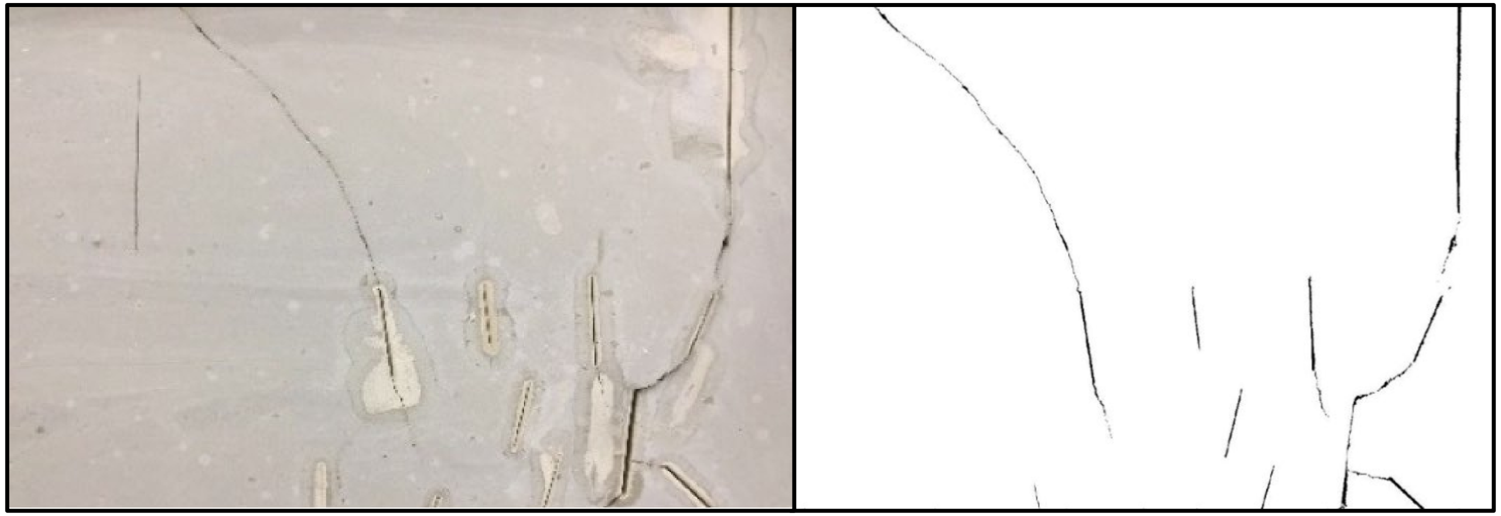
Background

Background (Continue)

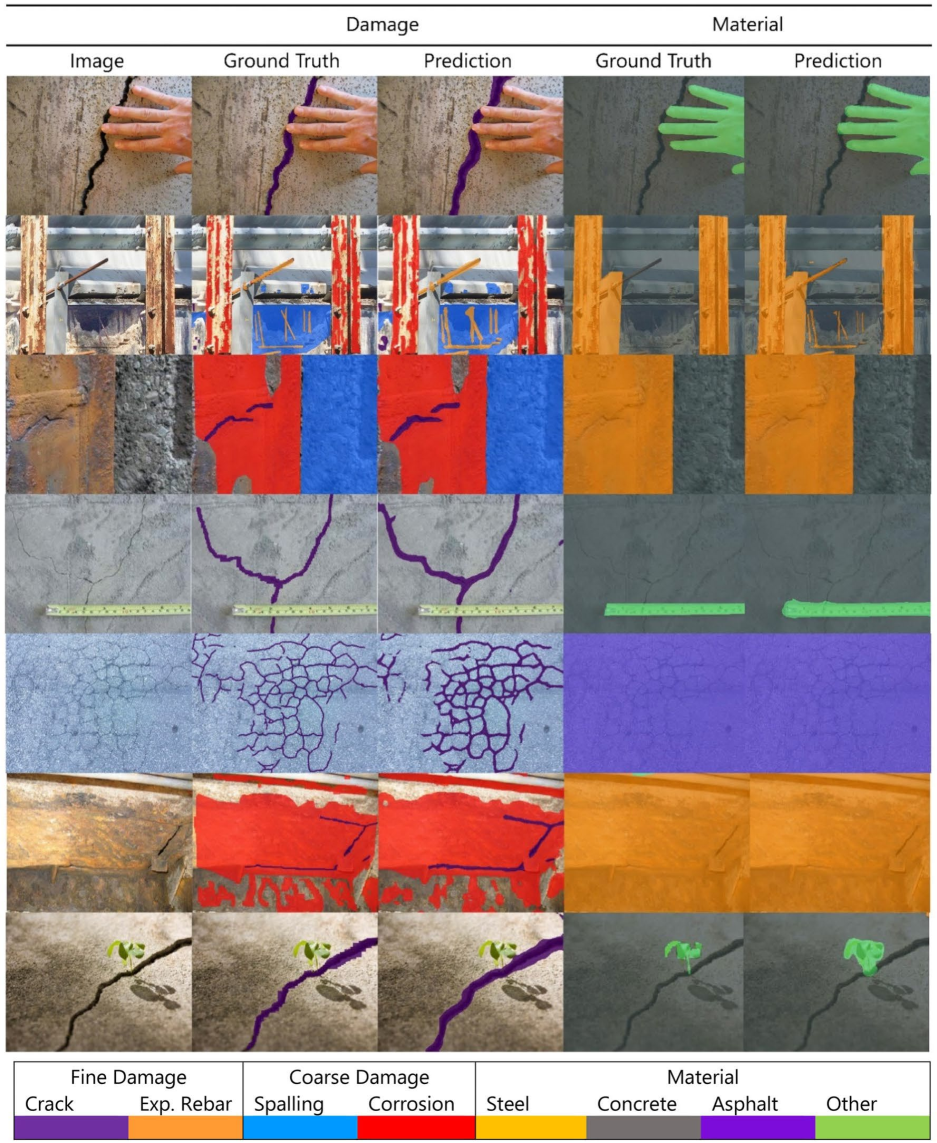
Routine visual inspection is mandated to identify and quantify structural defects.

Recent Developments

Several image processing and computer vision techniques have enabled automatic detection of regions-of-interest (**ROIs**)



An et al. 2018



Hoskere et al. 2020

Existing or Potential Approaches for Quantification

Ruler/marker-based measurement

Stereo camera

App-based measurement

Is There an Easier Way to Make Physical Measurements?

Scale?

Key Idea of the Proposed Technique

Proposed Approach

Objective

CNN-based image scale estimation framework which translate surface textures to an image scale (i.e. pixel/mm).

Advantages

- Only require a single camera
- Can be applied to historical images
- One-time training of a CNN model
- Can be added to existing feature detection processes to enable end-to-end inspection algorithm

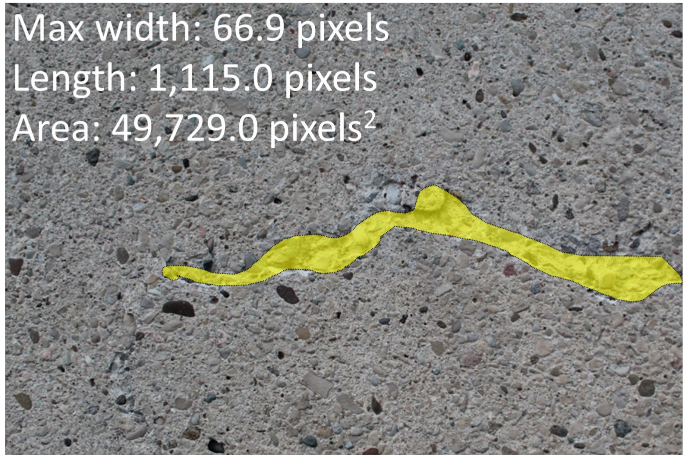
Limitations

- Assumes image is taken parallel to the scene (to estimate a single scale).

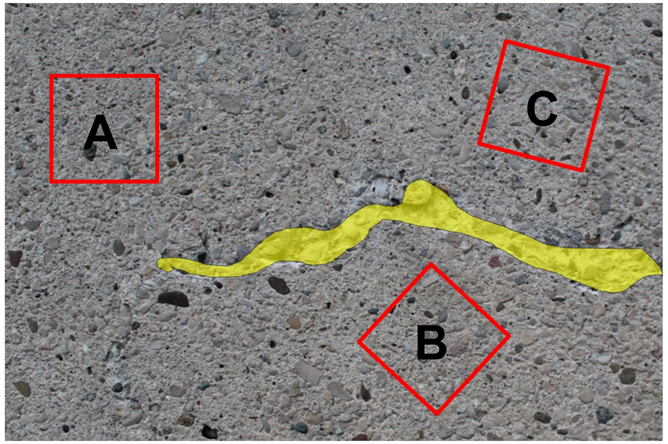
How to Use the Proposed System

Step 1. Image collection for target region

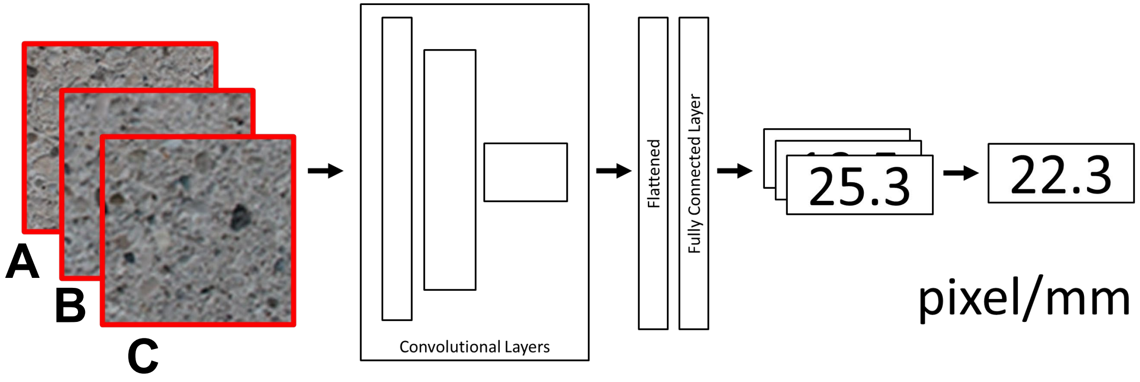
Step 2. Region-of-interest (ROI) detection



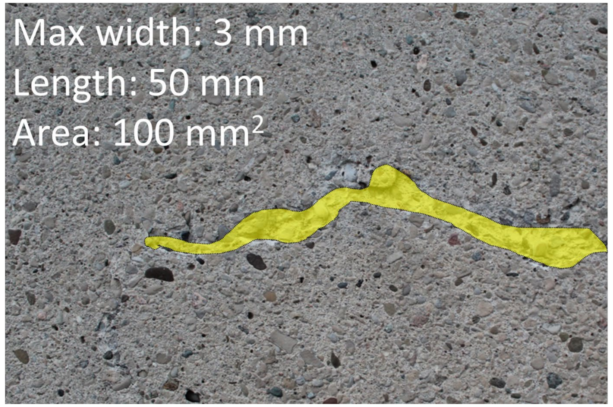
Step 3. Patch extraction of surface texture



Step 4. Image scale estimation using trained CNN model

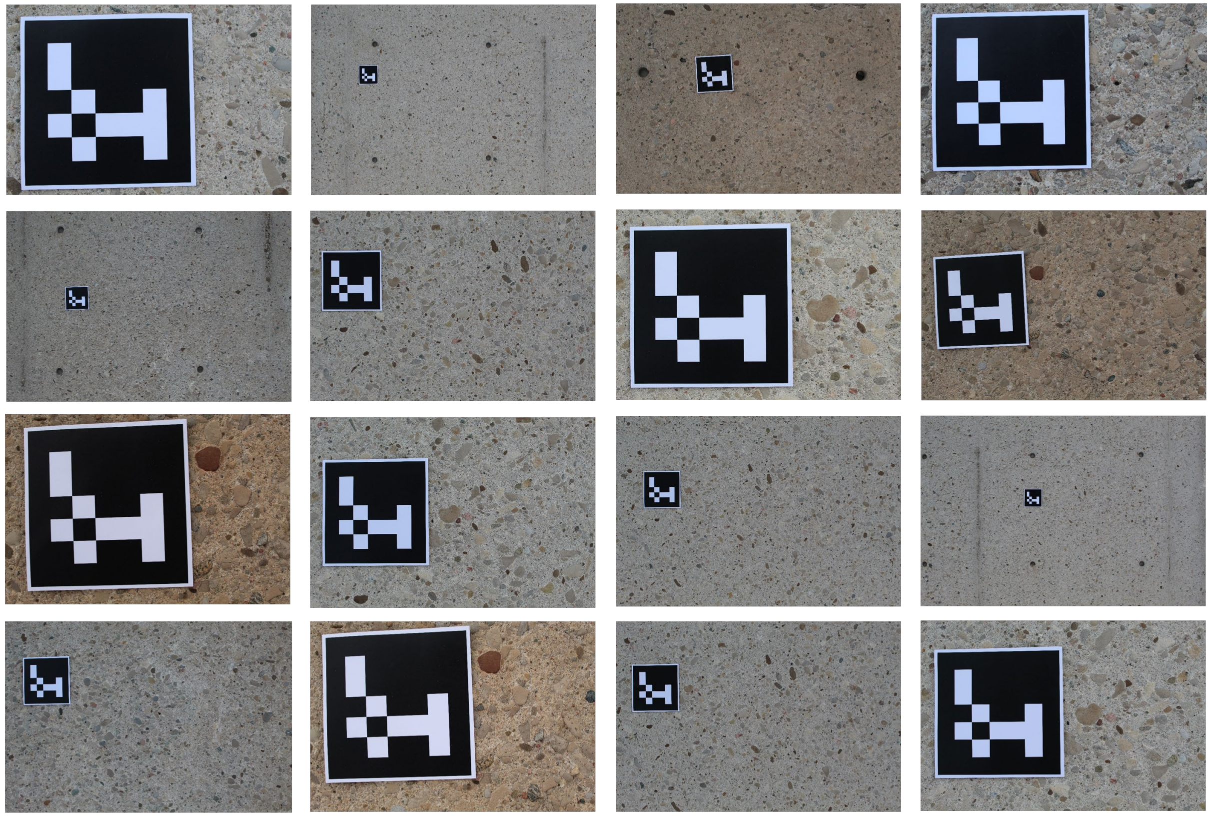


Step 5. Quantitative ROI evaluation

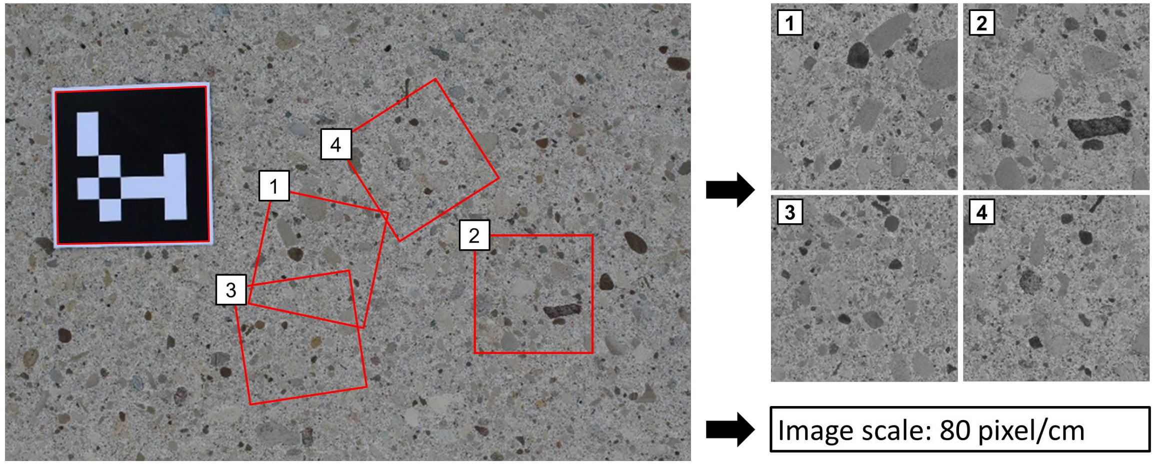


One-time Training Phase

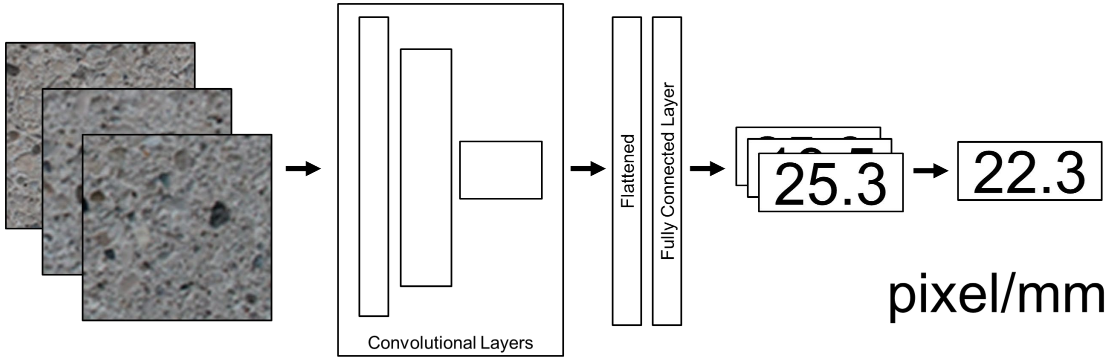
Step 1. Marker-included image collection for model training



Step 2. (For each image) Marker detection, scale calculation, and patch extraction



Step 3. CNN model training using patches and their corresponding image scales



Note that this is the process to make ground-truth database and train the network.

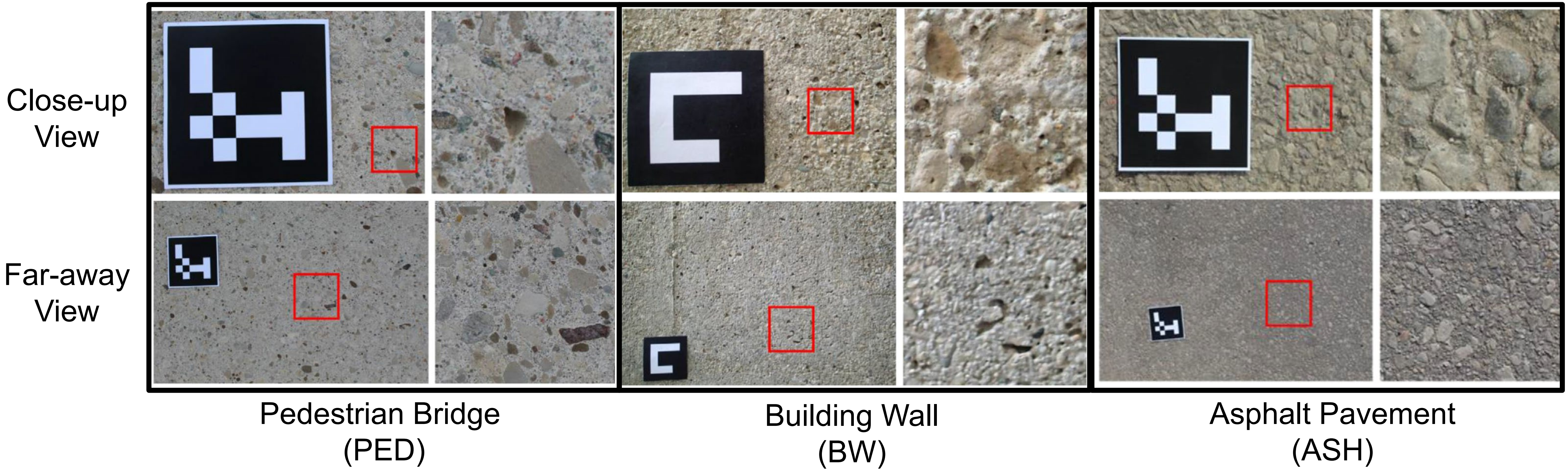
Experimental Validation: Test Structures

Pedestrian Bridge
(PED)

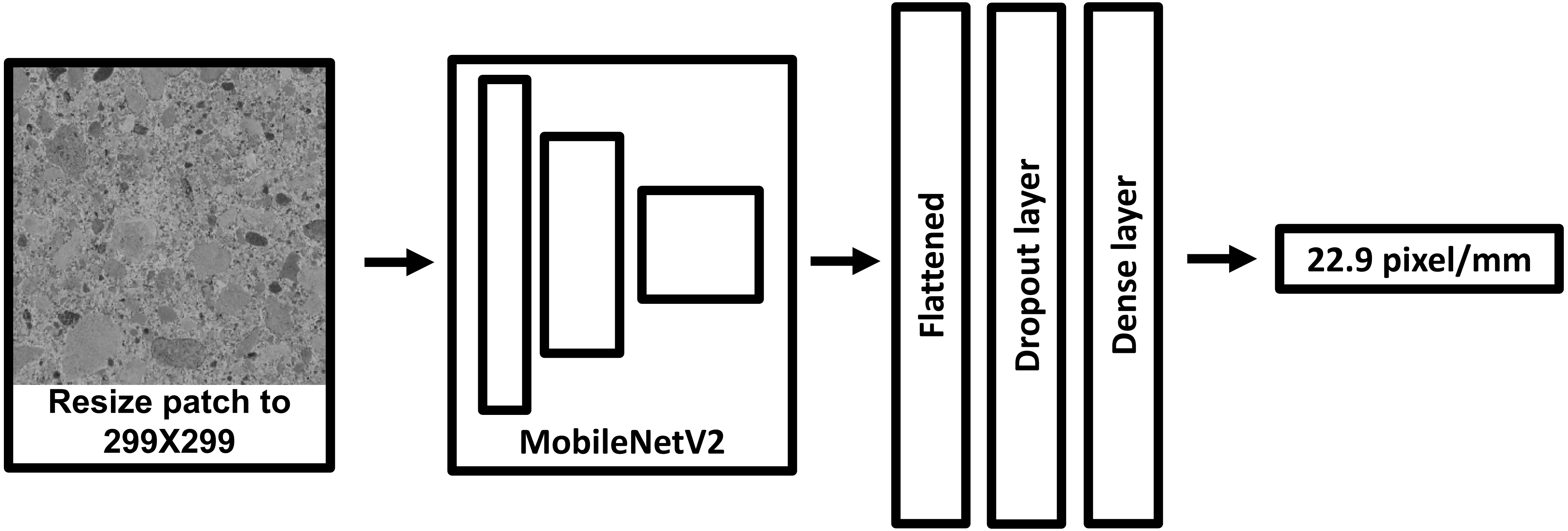
Building Wall
(BW)

Asphalt Pavement
(ASH)

Surface Textures from PED, BW, and ASH



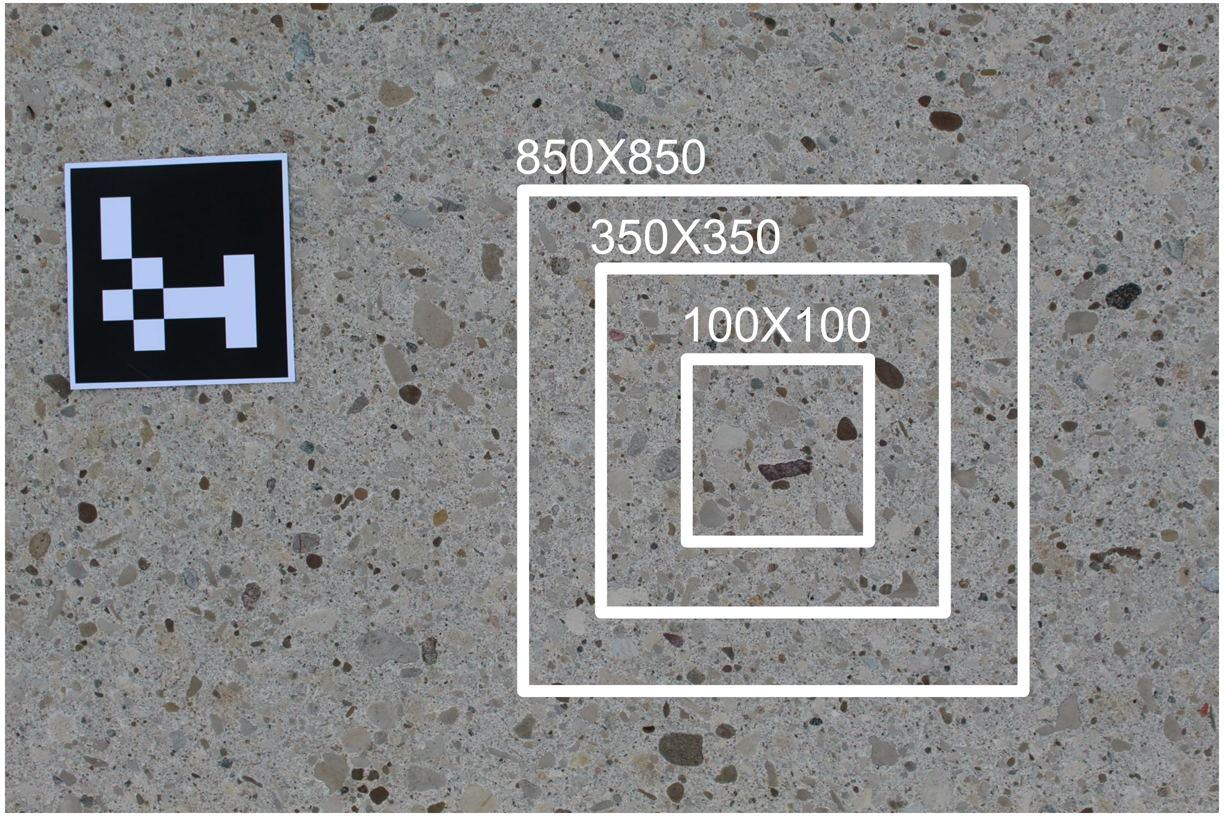
Network Architecture and Loss Function



$$MAPE = \frac{100\%}{n} \sum_{i=1}^{n} \frac{|y - \hat{y}|}{y}$$

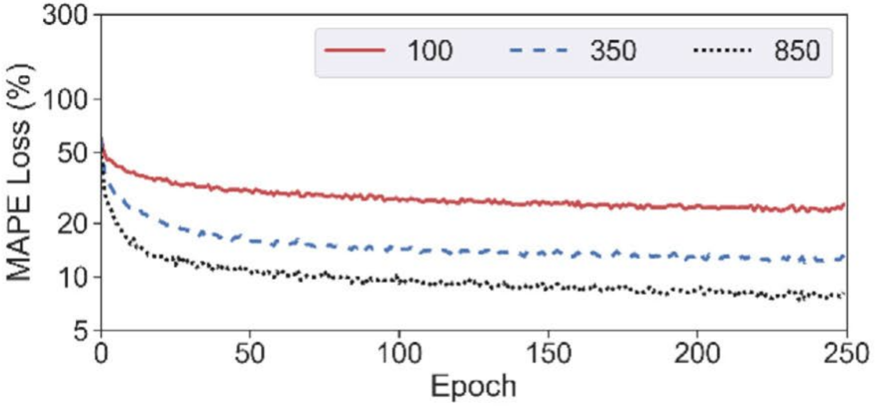
Training Details

- SGD optimizer:
  - learning rate: 10^{-4}
  - decay: 0.9
  - momentum: 0.01
- Texture patch augmentations:
  - Horizontal and vertical flips
  - Minor Rotations
  - Brightness changes ± 10%
- Patch sizes:
  - 100X100 pixels
  - 350X350 pixels
  - 850X850 pixels
- Extract ~50 patches per image

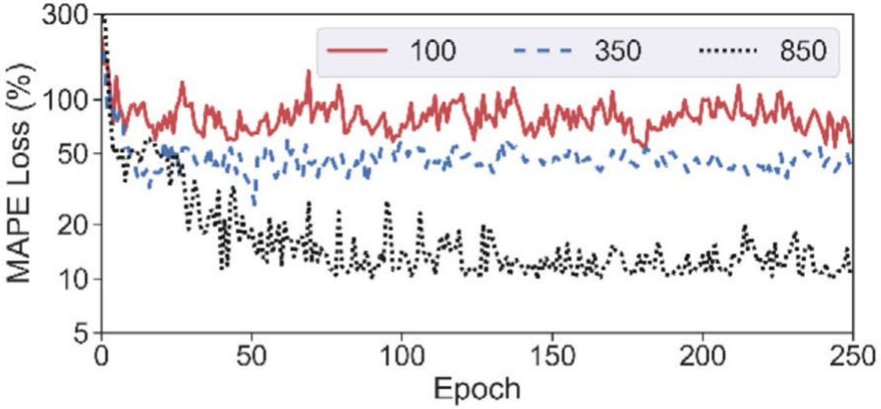


Training Details (Continue)

Patch size training results (PED):



Training

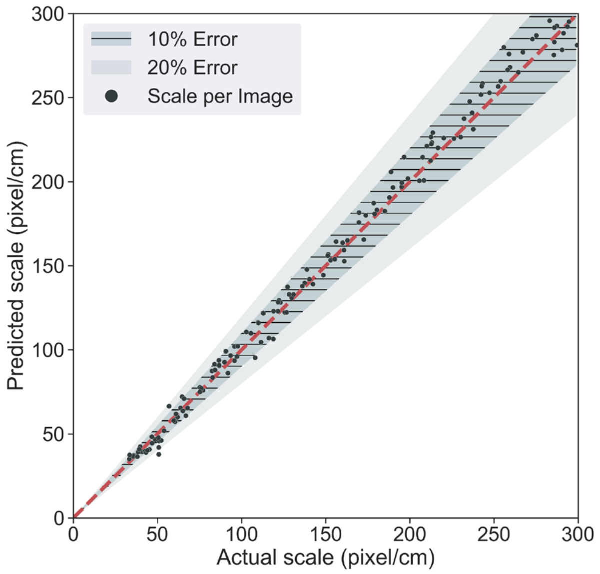


Testing

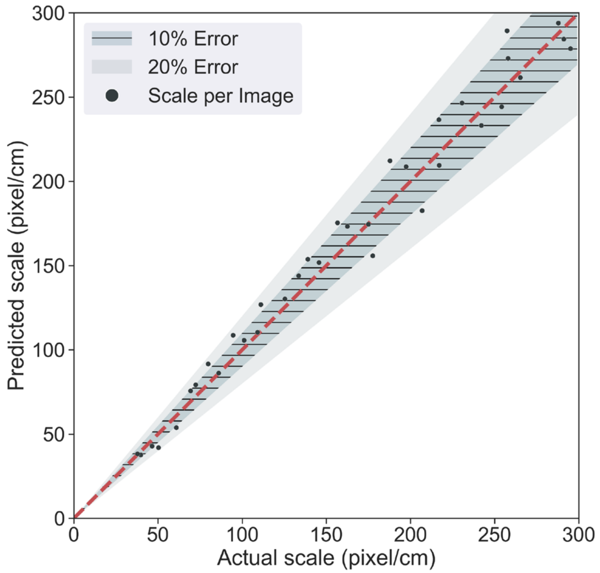
Final Training Dataset:
(Using patch size 850X850 pixels)

Dataset	Total Number of Scenes (training/testing)	Total Number of Images (training/testing)
PED	22 (18/4)	191 (154/37)
BW	14 (12/2)	434 (352/82)
ASH	21 (17/4)	182 (149/33)

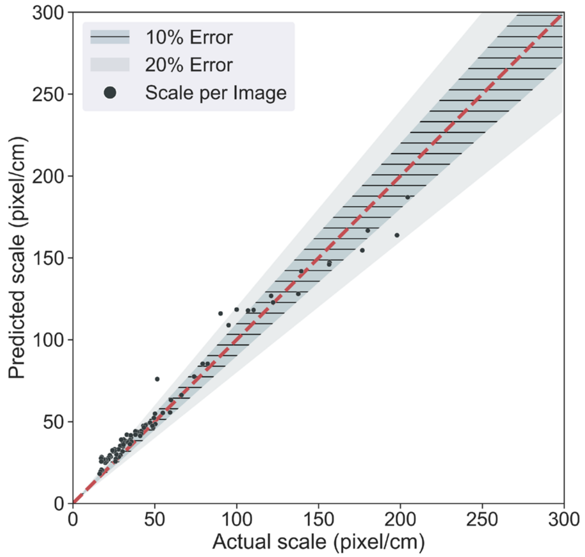
Experiment Results (Scale Estimation)



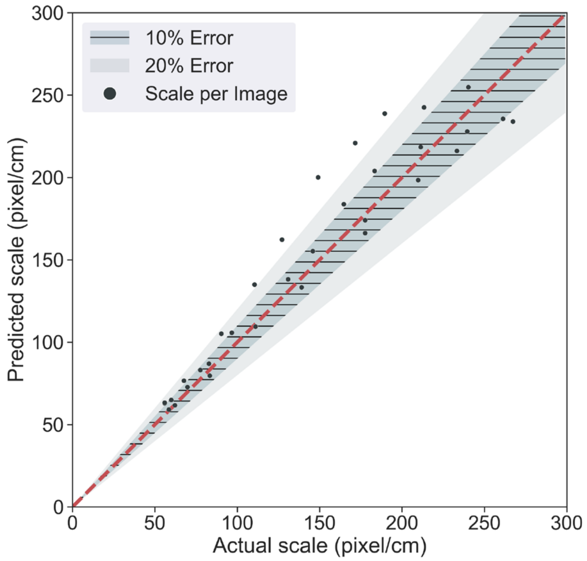
PED – Training



PED – Testing



BW – Testing



ASH – Testing

Validation Results:
(avg. error ± std. dev.)

Aggregation	PED	BW	ASH
Mean	6.7% ± 4.0%	15.8% ± 13.6%	10.5% ± 8.4%
Median	7.3% ± 4.5%	14.1% ± 11.9%	9.9% ± 8.3%

Thank you!

Any questions?

References

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