Image Localization for Computer-Enhanced Visual Inspection of Civil Infrastructure

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Problems of Current Visual Inspection

Dangerous works

Low accessibility

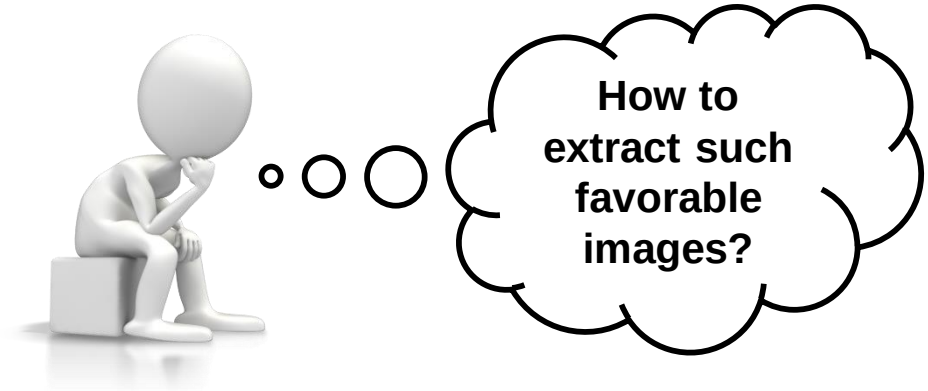
Traffic block

- Large scale
- Subjective interpretation
- Accessibility
- Periodic inspection
- Time consuming

A Major Gap between Current Research and Practice

Autonomous visual Inspection using aerial vehicles

A large volume of images collected from drones



Identification of region of interest (ROI) "useful" for visual inspection

Development of an Image Localization and Classification Technique

Objective

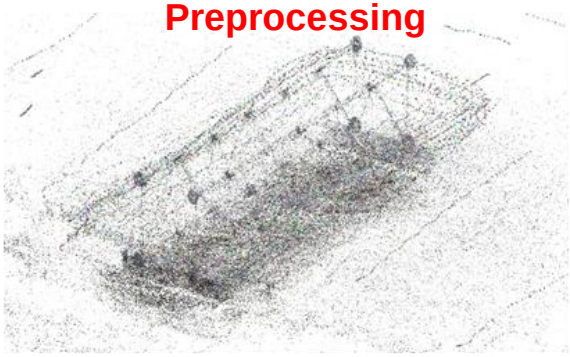
Develop an **image localization and classification** technique that can automatically extract the **regions-of-interest** (ROI) on each of the collected images so as to process and analyze only highly relevant and localized image areas for visual inspection or damage detection.

Contribution

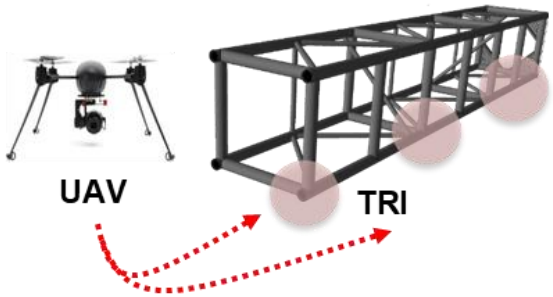
Develop an enabling technique to facilitate successful application of **existing damage detection techniques** on large volumes of actual images in an efficient and reliable way. The key is to avoid unnecessary processing of the large portion that are irrelevant and complex.

Overview of the Technical Steps

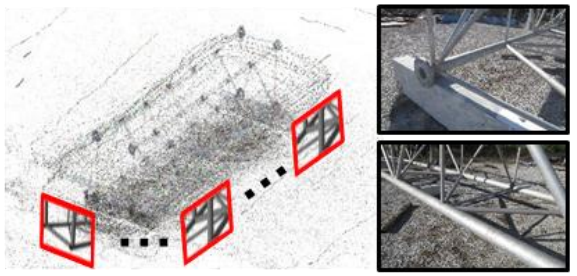
Preprocessing



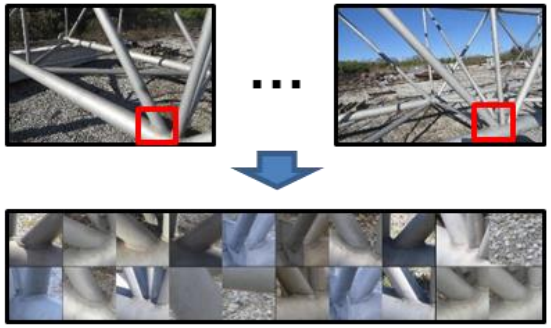
(a) Baseline model construction



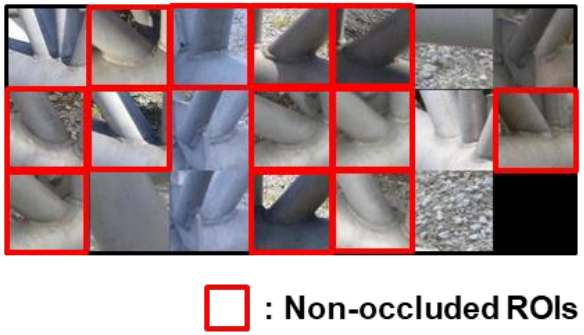
(b) Step 1: Image collection



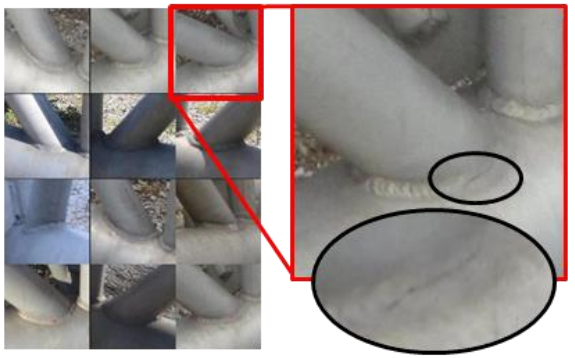
(c) Step 2: Image registration



(d) Step 3: ROI localization



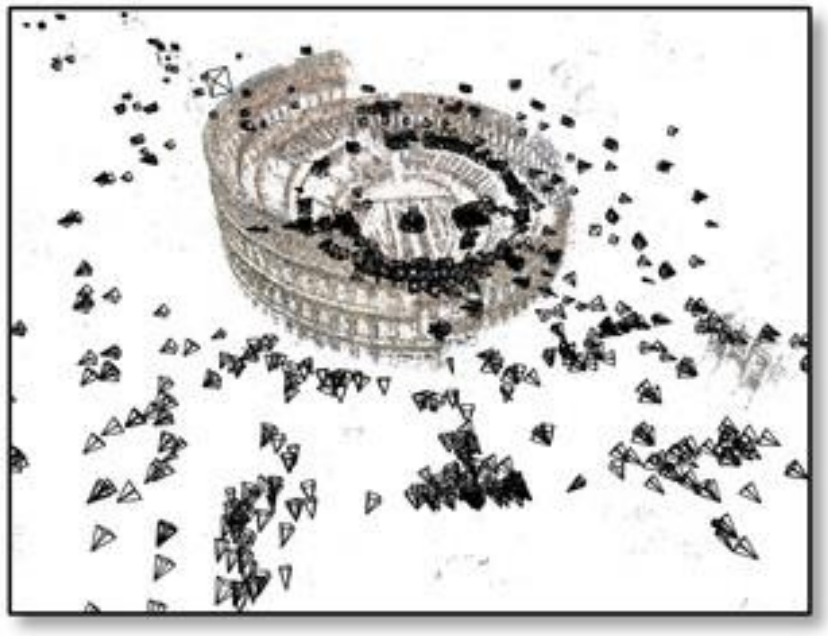
(e) Step 4: ROI classification



(f) Step 5: Damage detection

What is Structure from Motion (SfM)?

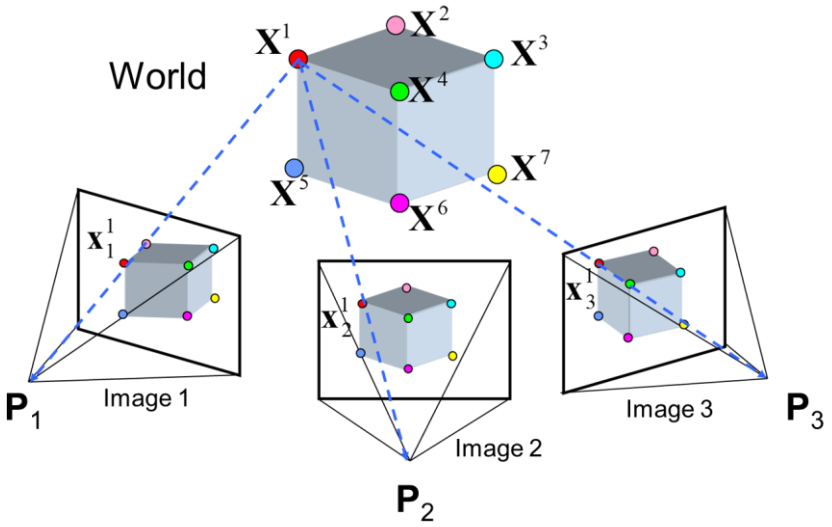
Pictures



Scene structure & Camera locations and parameters (BigSfM, 2009)

- No need for prior camera calibration
- No need for prior selection of image locations
- No need to capture images using a single camera

Projection Matrix from Structure from Motion (SfM)

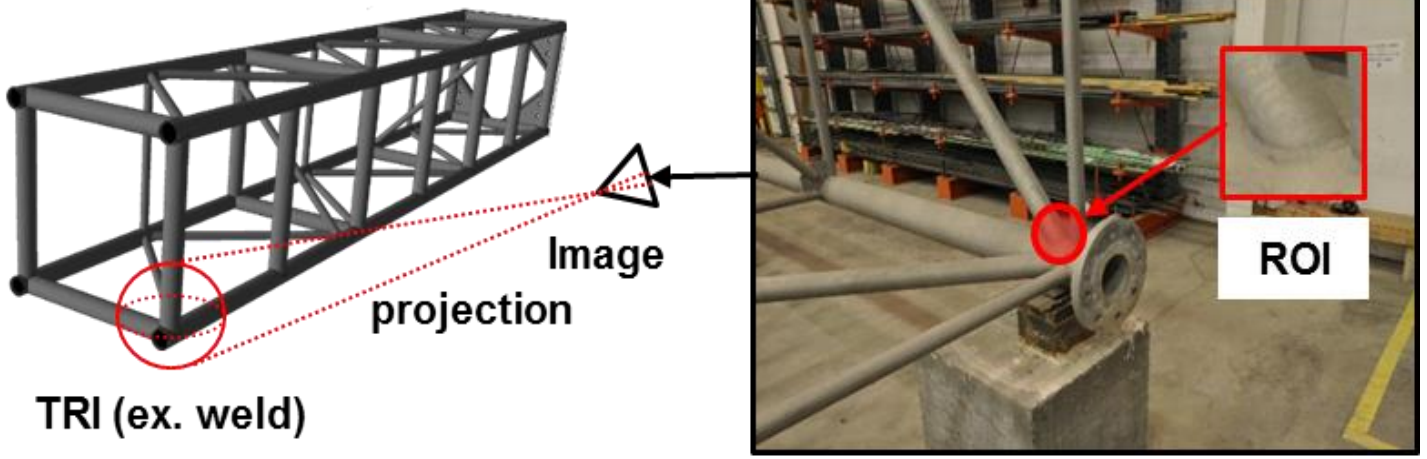


Projection matrix

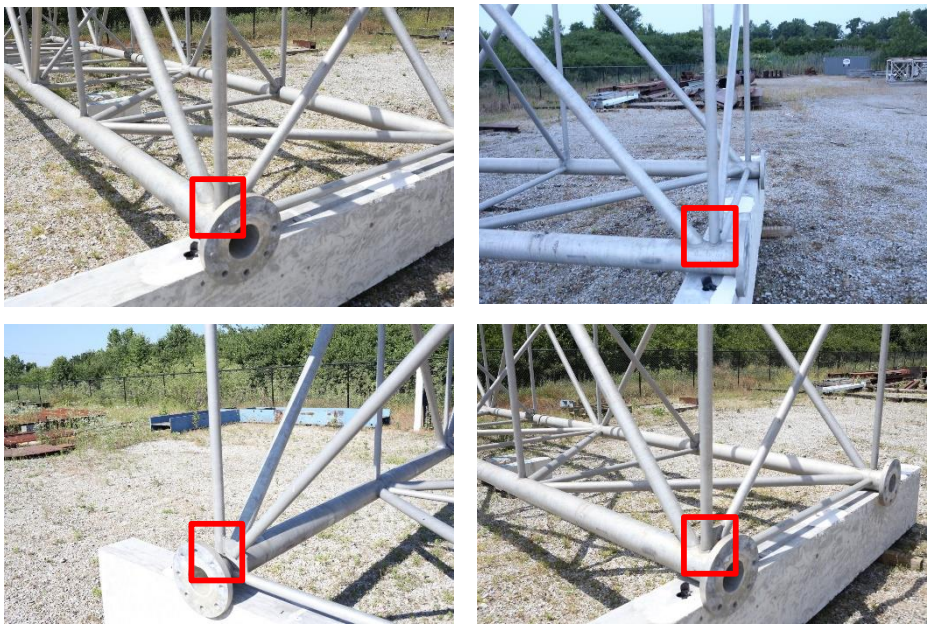
$$\mathbf{x}_i = \mathbf{P}_i \mathbf{X}$$

2D point on image i **3D point**

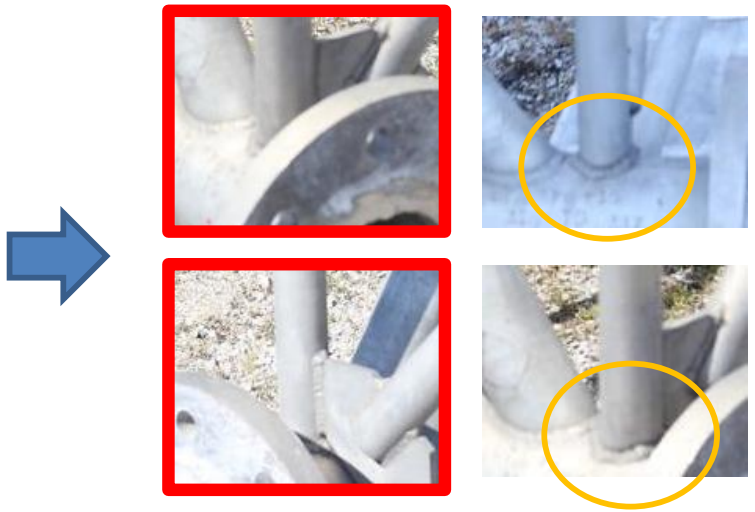
i : Image number



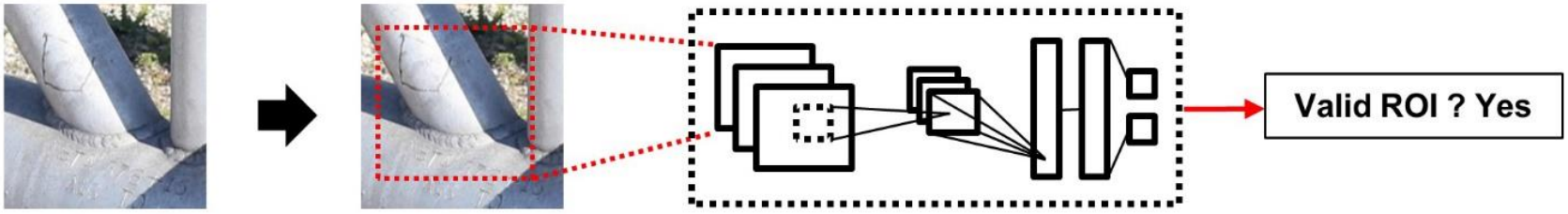
ROI Classification using a Binary Occlusion Classifier (BOC)



Collection of test images

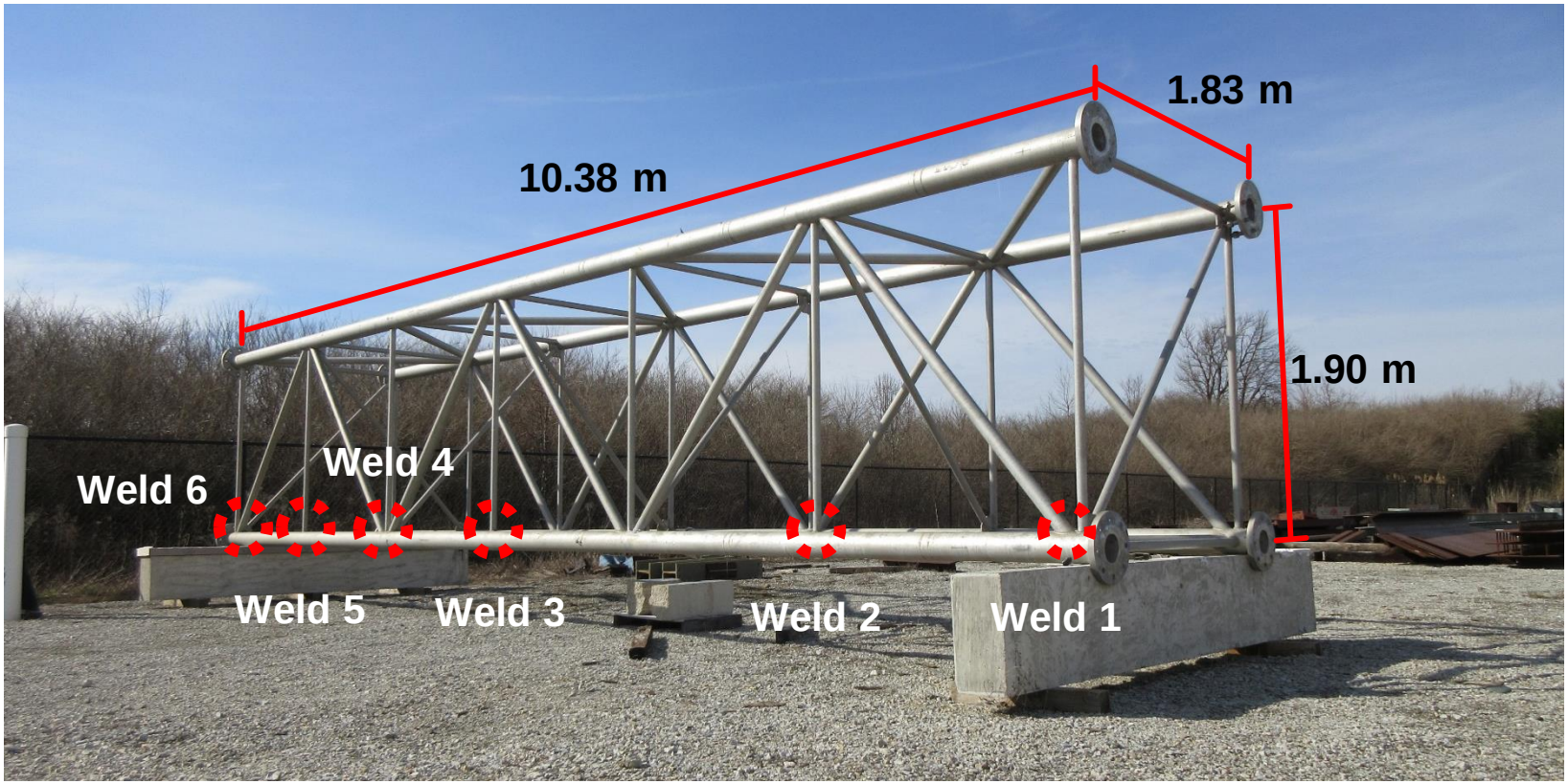


: Not useful for visual inspection



Training of binary occlusion classifier using convolutional neural network

Experimental Validation: Description of the Test Truss Structure




Weld 1


Weld 2

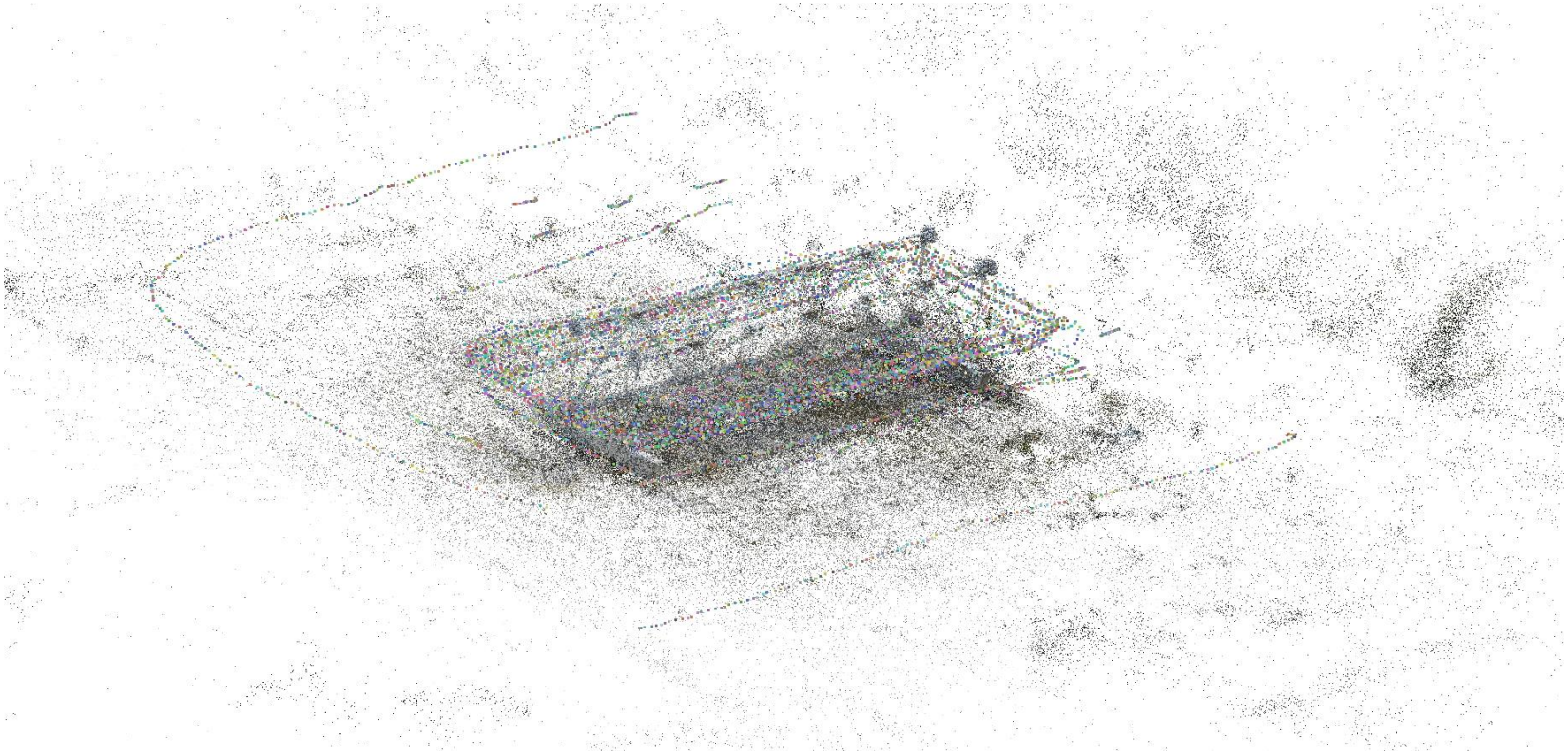

Weld 3


Weld 4


Weld 5

Weld 6

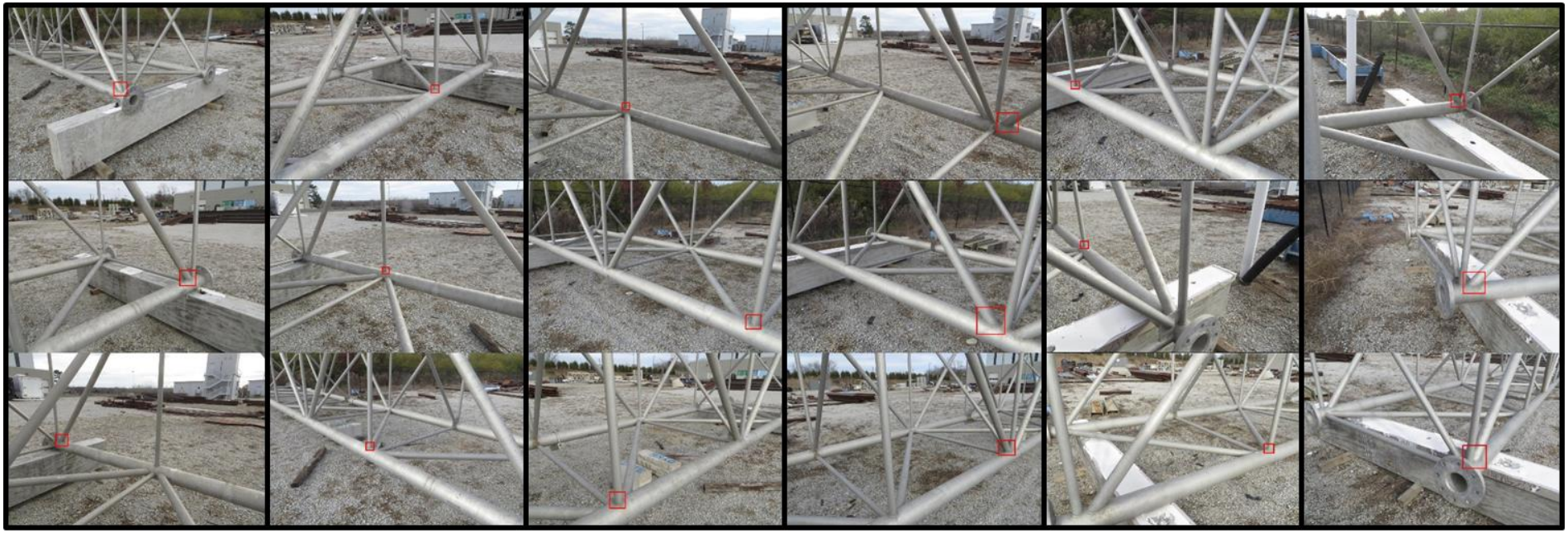
Construction of the Baseline Model using SfM (Preprocessing)



A total of **5,321** baseline images are collected from the test structure during **five** months and **11 different days** under different time window in a day and/or weather conditions.

Sample Baseline Images used for Constructing a Baseline Model

Bounding Box (ROI) on Each Sample Baseline Image



Weld 1 Weld 2 Weld 3 Weld 4 Weld 5 Weld 6

Sample ROIs used for Training a BOC

Positive

Negative

We manually annotate these images to construct a dataset for training the BOC. Non-occluded ROIs, denoted as positive, are defined as those in which the entire weld line on the ROI, that can be maximally viewed at the corresponding image location, is not interrupted by any object(s) in front.

Results of the ROI Localization and Classification using Test Images

	Weld 1	Weld 2	Weld 3	Weld 4	Weld 5	Weld 6
# of images	119	77	88	84	60	55
# of localized ROIs	104	51	54	70	45	47
# of classified ROIs (positive/negative)	69/35	49/2	48/6	47/23	44/1	33/14
Precision	92.75%	100%	97.92%	85.11%	100%	90.91%

Examples of ROIs that have been localized and classified from the set of test images (Each set of 30 localized ROIs from Welds 1 to 6)

Weld 1

Weld 2

Weld 3

Examples of ROIs that have been localized and classified from the set of test images (Each set of 30 localized ROIs from Welds 1 to 6)

Weld 4

Weld 5

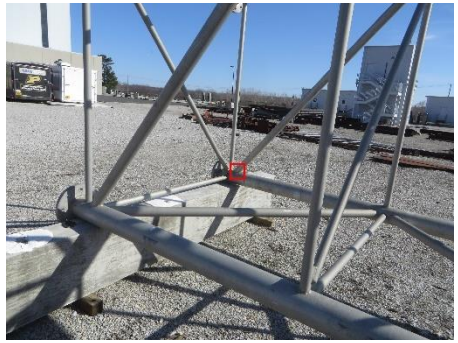
Weld 6

Localization and Classification of ROIs from Test Images Collected in Four Months Later











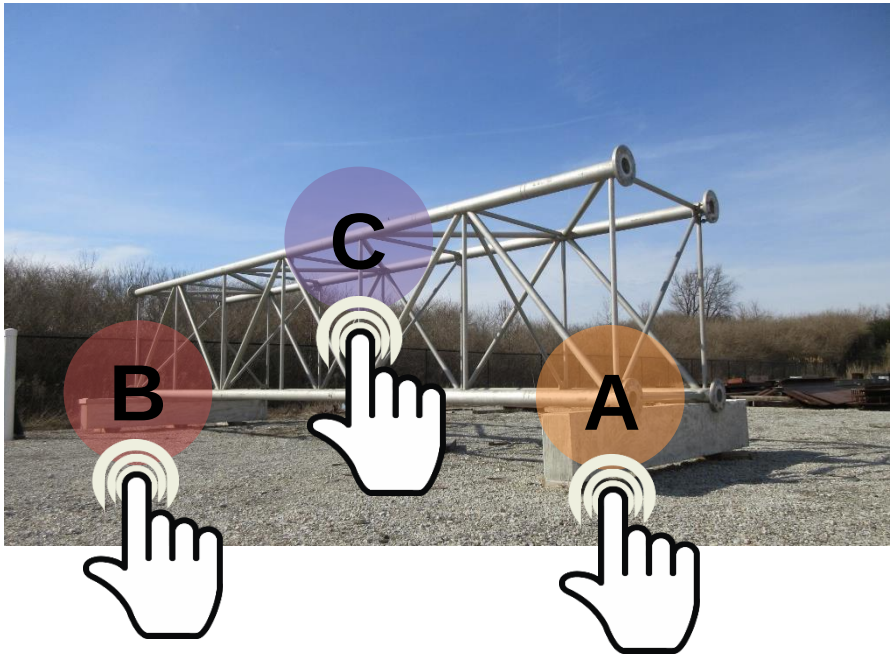


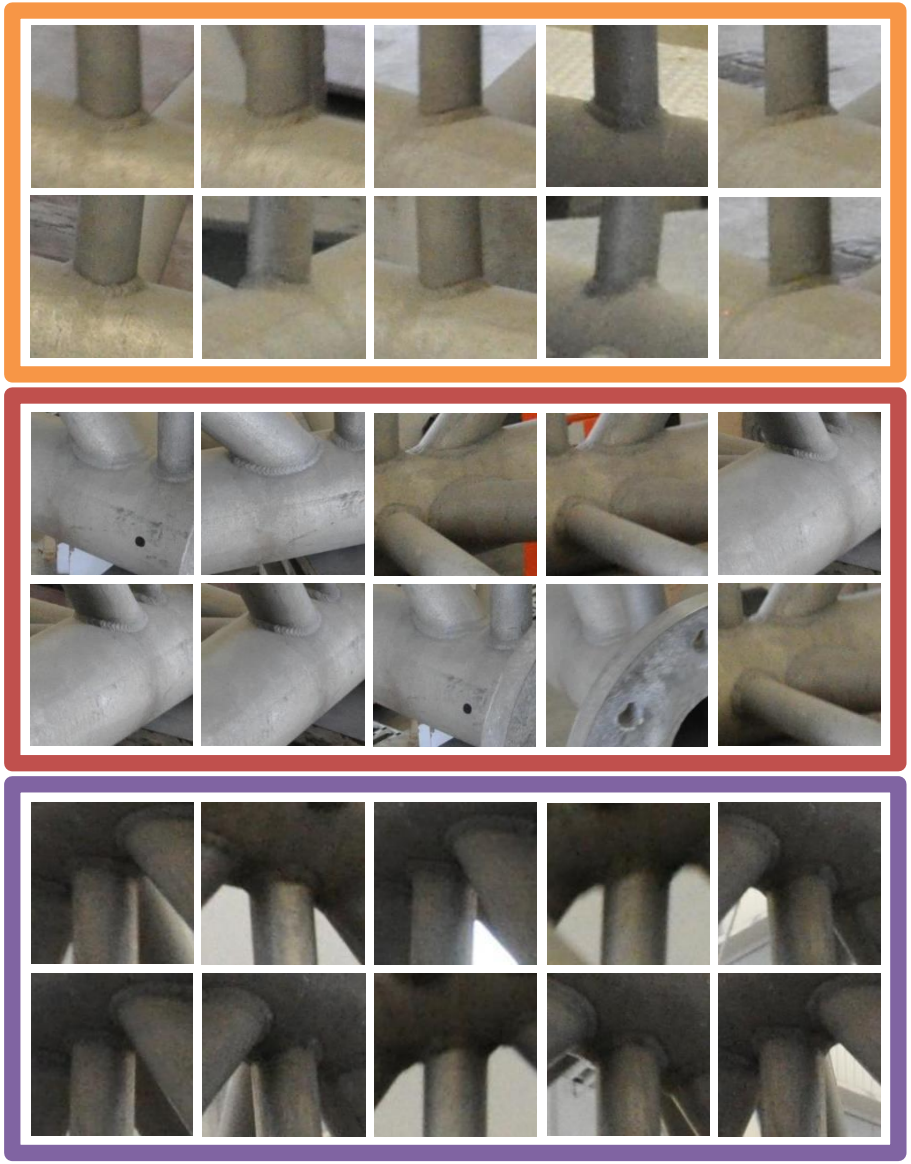




Detected as negative

Potential Application: Human-based Visual Inspection Scenario using the Developed Approach





Summary and Conclusions

- A novel automated image localization technique is developed to extract regions of interest on each of the images in a large set of images before applying vision-based inspection techniques.

- Analysis of such highly relevant and localized images will enable efficient and reliable visual inspection.

- The capability of the technique is successfully demonstrated to extract the ROIs of weld connections using a full-scale highway sign structure.

Questions and Answers