MATLAB EXPO

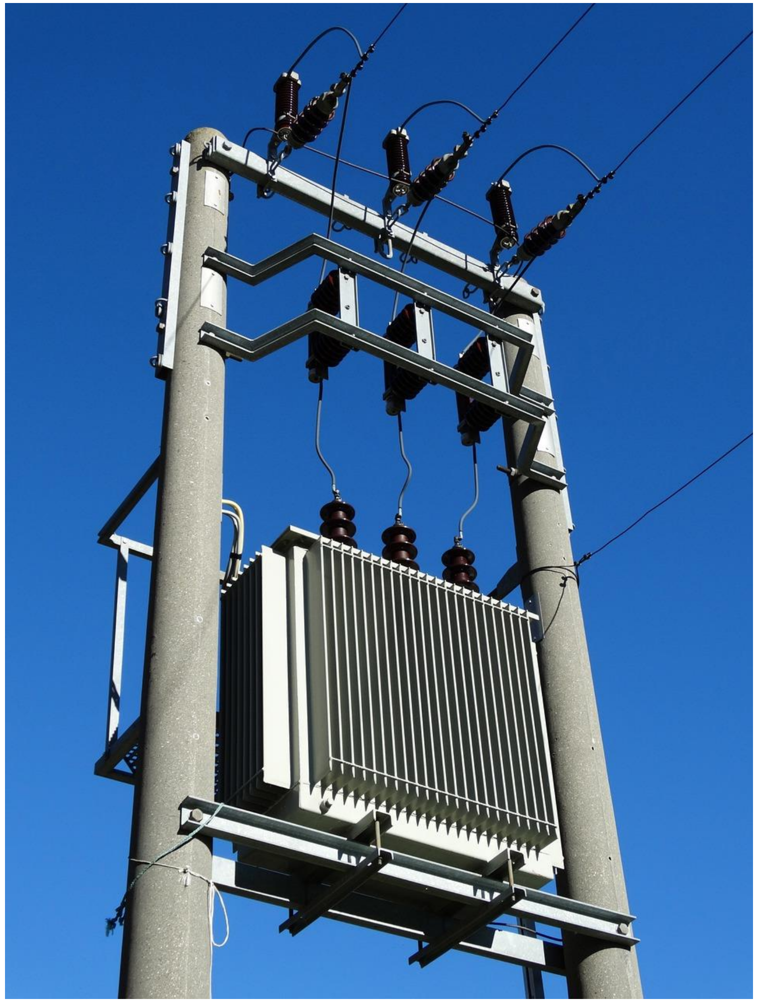
UNITED KINGDOM

Automating Fault Detection Using Visual Inspection

Elre Oldewage, MathWorks

MathWorks

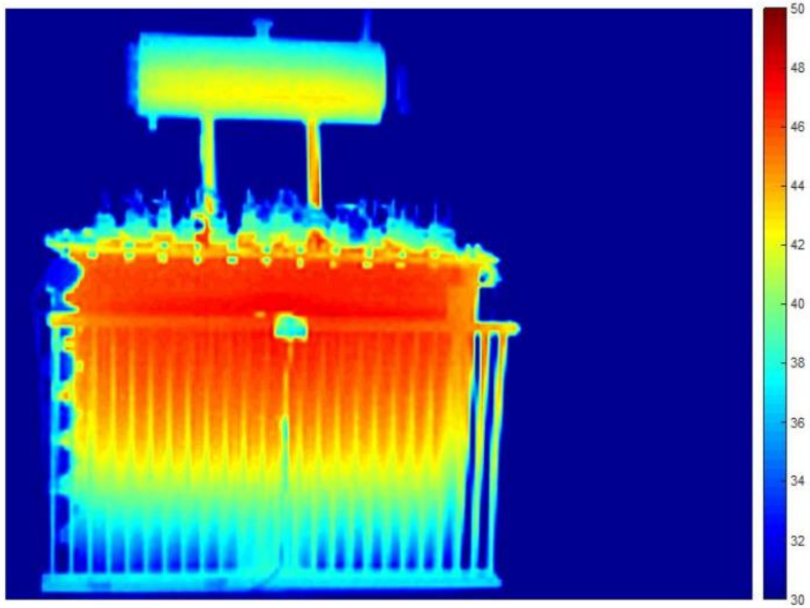
Siemens Develops Health Monitoring System for Distribution Transformers



[User Story](#)

Results

- Retrofittable solution with non-invasive temperature sensors
- User-friendly commissioning
- Online learning for algorithm



Korea Institute of Energy Research Develops AI-Based Predictive Maintenance Models for Offshore Wind Power

Results

- Development time cut in half
- 90%+ prediction accuracy achieved
- Aggressive deadline met

User Story

Mondi Implements Statistics-Based Health Monitoring and Predictive Maintenance for Manufacturing Processes with Machine Learning

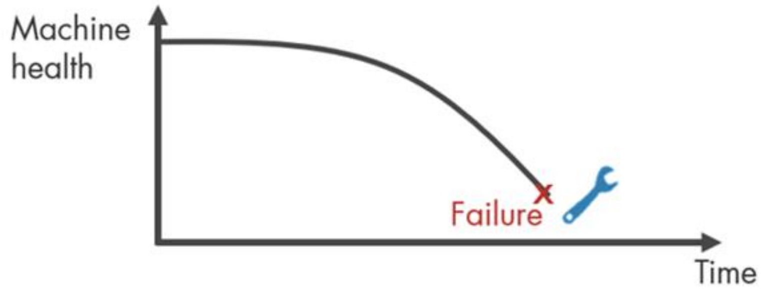
User Story

Results

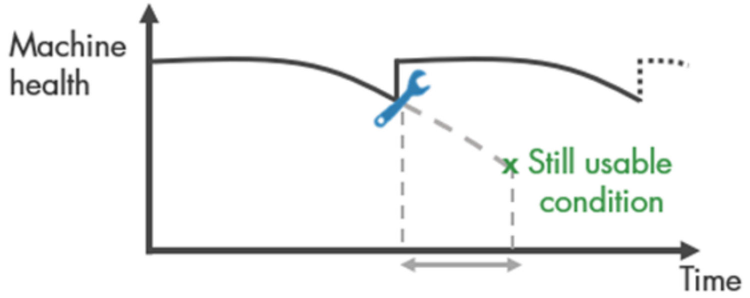
- More than 50,000 euros saved per year
- Prototype completed in six months
- Production software run 24/7

How best to do maintenance?

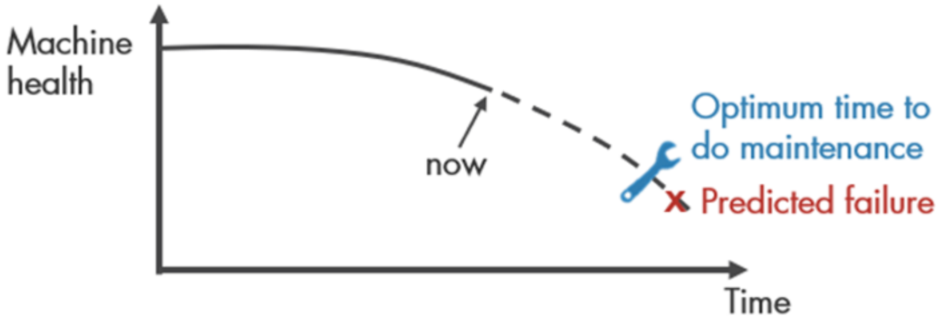
- **Reactive** – Do maintenance once there’s a problem
  - Problem: unexpected failures can be expensive and potentially dangerous



- **Scheduled** – Do maintenance at a regular rate
  - Problem: unnecessary maintenance can be wasteful; may not eliminate all failures



- **Predictive** – Forecast when problems will arise
  - Problem: difficult to make accurate forecasts for complex equipment



Why perform predictive maintenance?

- Prevent loss or damage of expensive equipment
- Failures can be dangerous
- Maintenance also costly and possibly dangerous
- Reduced downtime
- Improved operating efficiency

What is visual inspection?

*“Automated visual inspection is the **image-based inspection** of parts or equipment where a camera scans the device under test for both **failures** and **quality defects**"*

Automated Defect Detection

Computer Vision

Optical Inspection

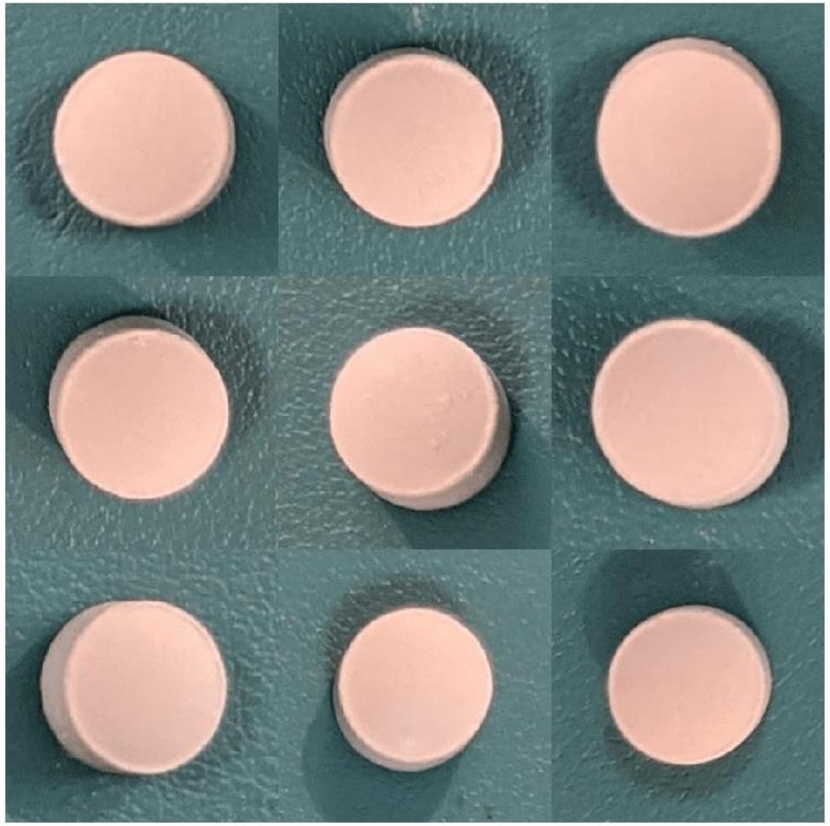
Automated Inspection

Image Processing

Machine Learning

Classical image processing

Detecting defective pills for quality control

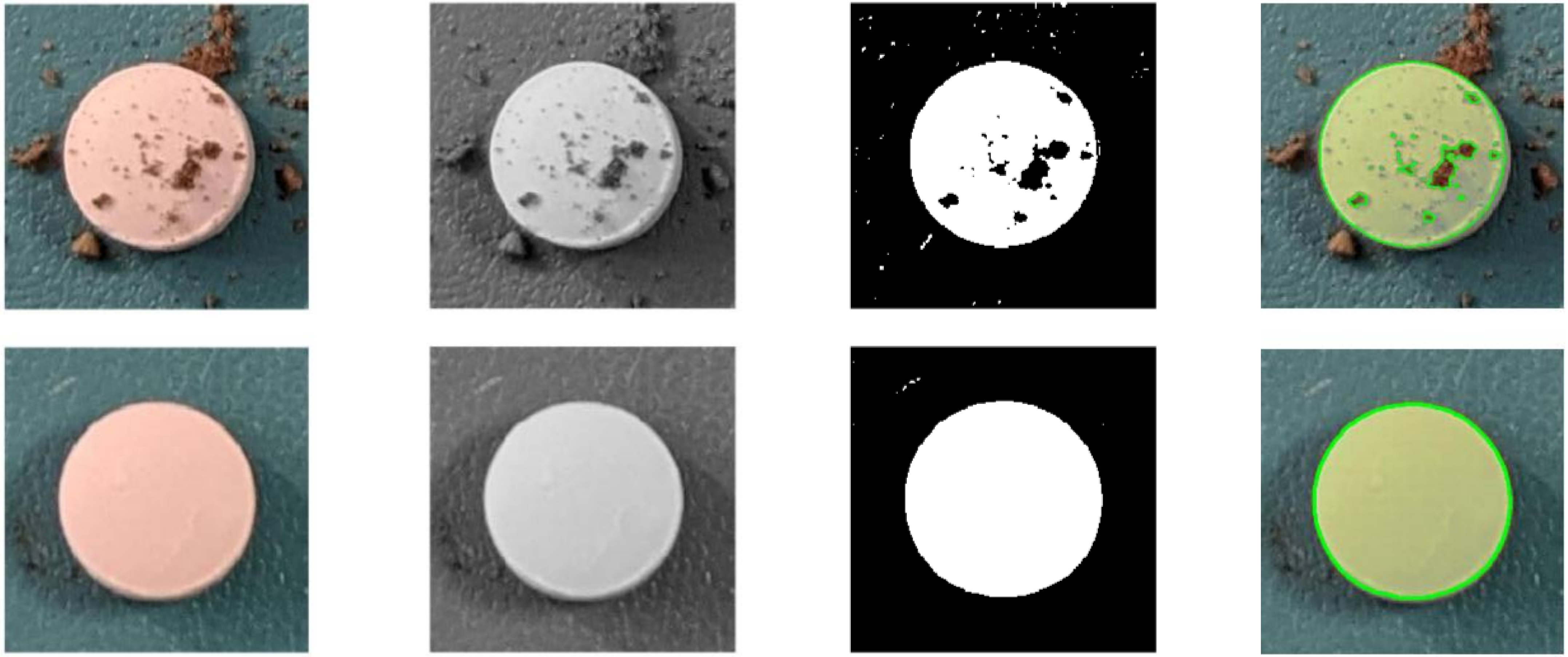


Normal Dirty Chipped

Documentation example

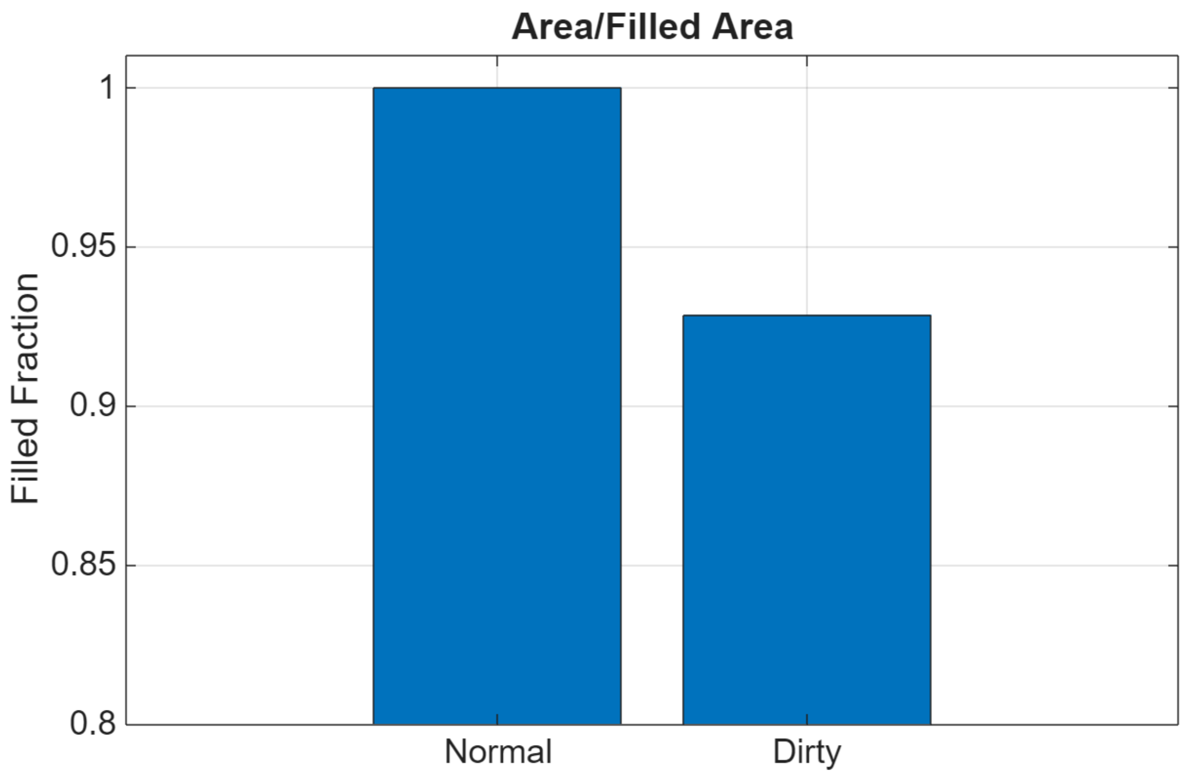
Classical image processing

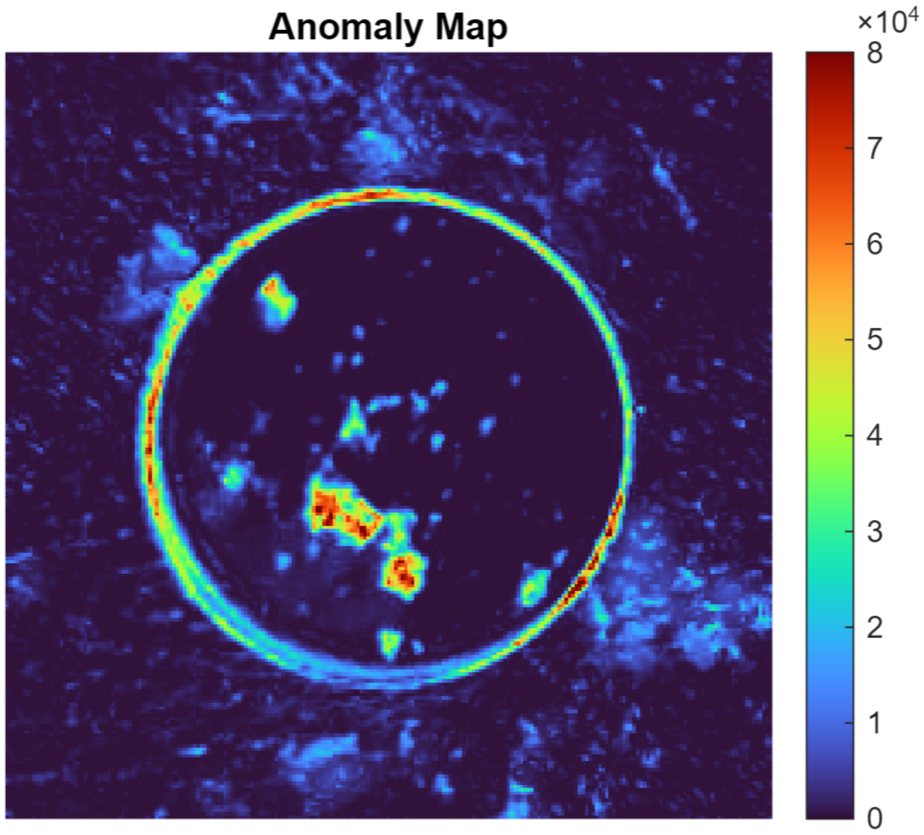
Detecting defective pills for quality control



Classical image processing

Detecting defective pills for quality control

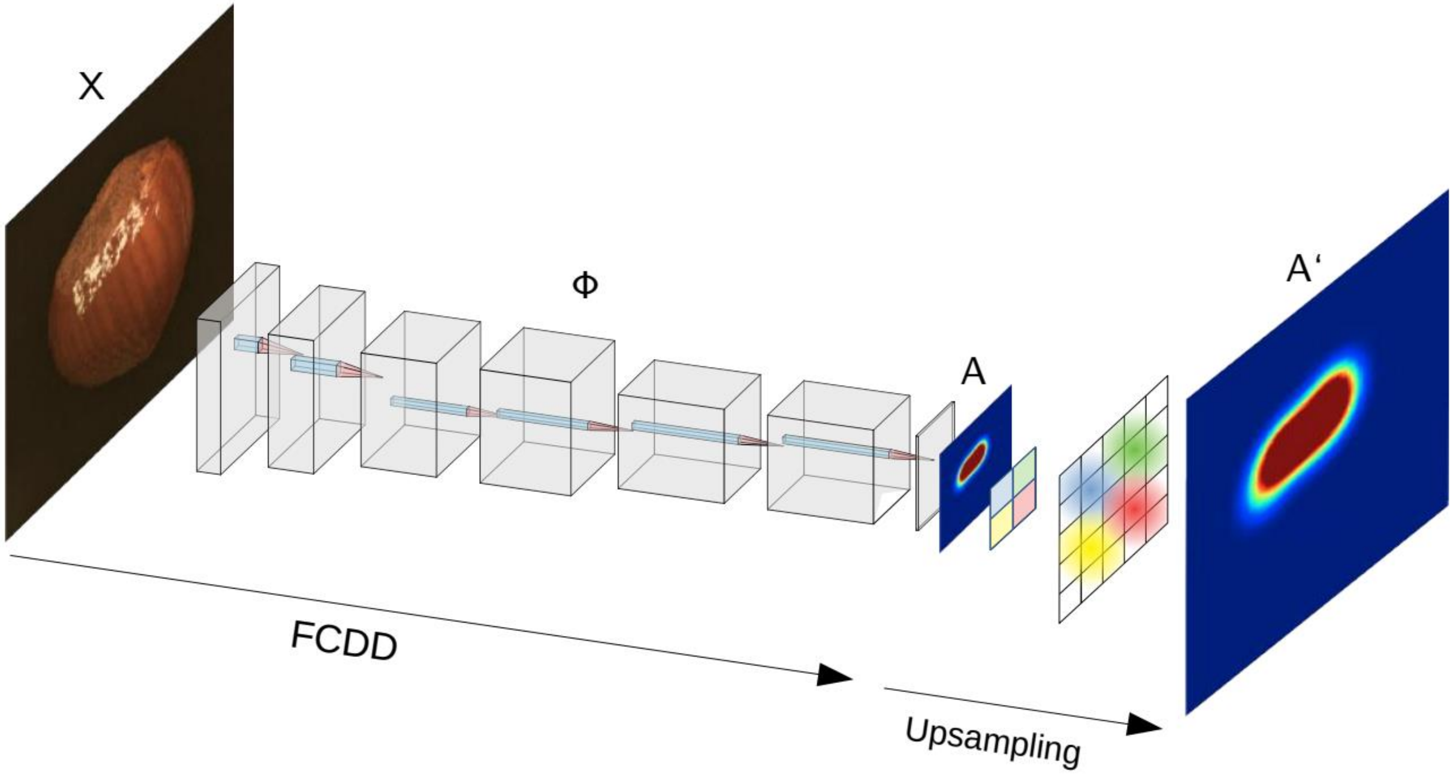


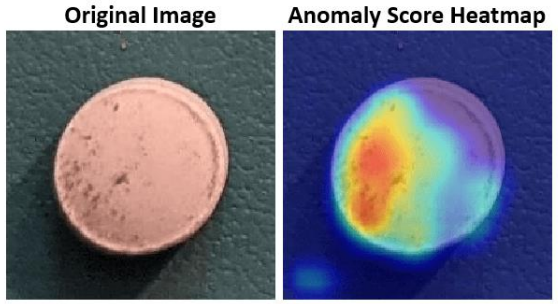



```
normDiff =  sum( (double(normal) - double(dirty)).^2 , 3 );
```

Deep learning

Detecting defective pills for quality control

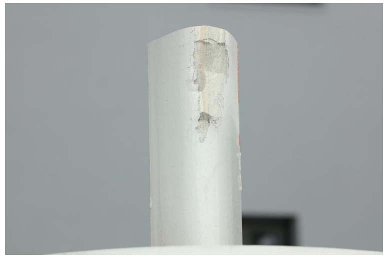
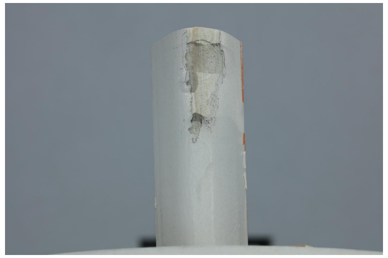




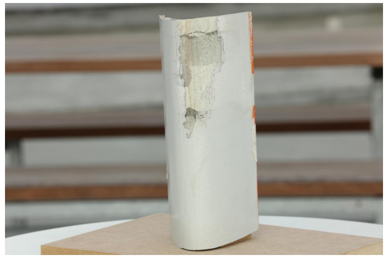
Explainable Deep One-Class Classification, Liznerski et. al (2021)

https://arxiv.org/pdf/2007.01760

Challenge: Poor quality input data

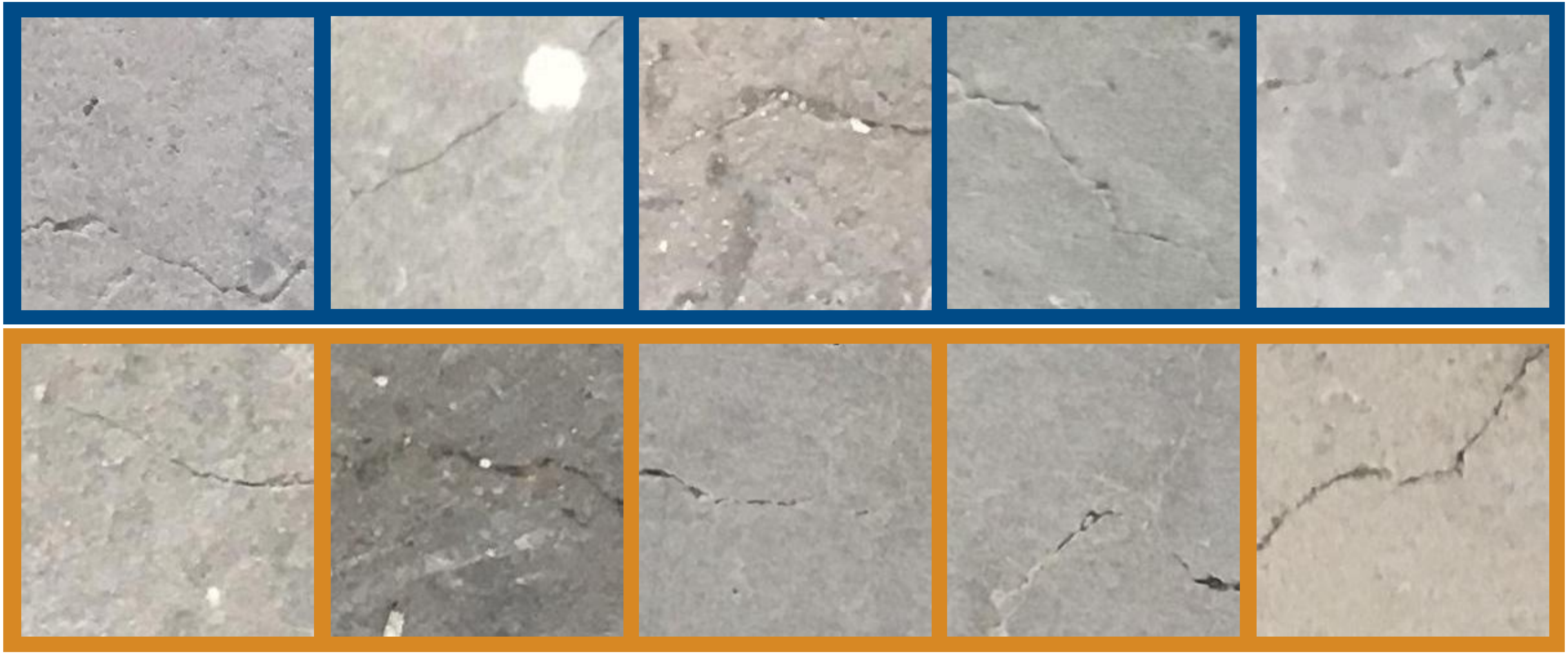








Are conditions under which the data is gathered controlled?

Challenge: Difficulty identifying anomalous inputs

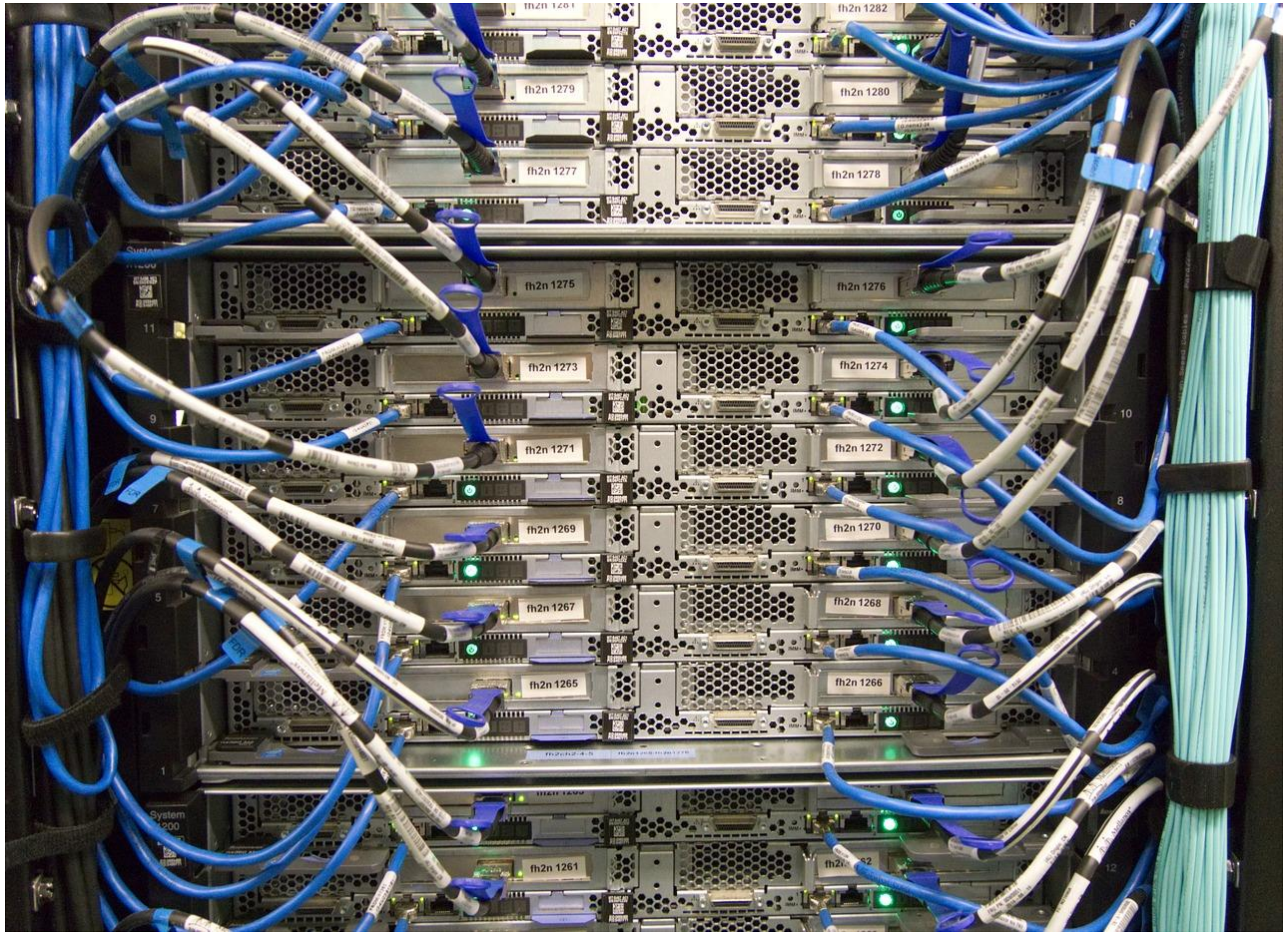


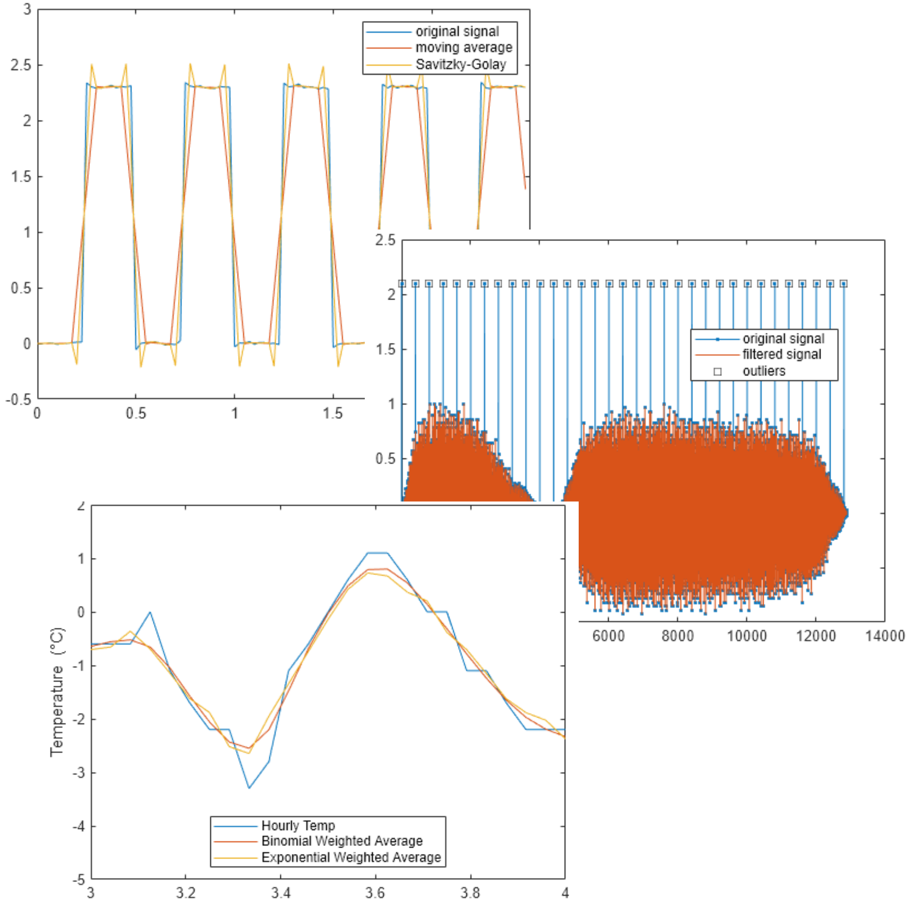
Concrete Crack Images for Classification

DOI:10.17632/5y9wdsg2zt.2

Challenge: Automation

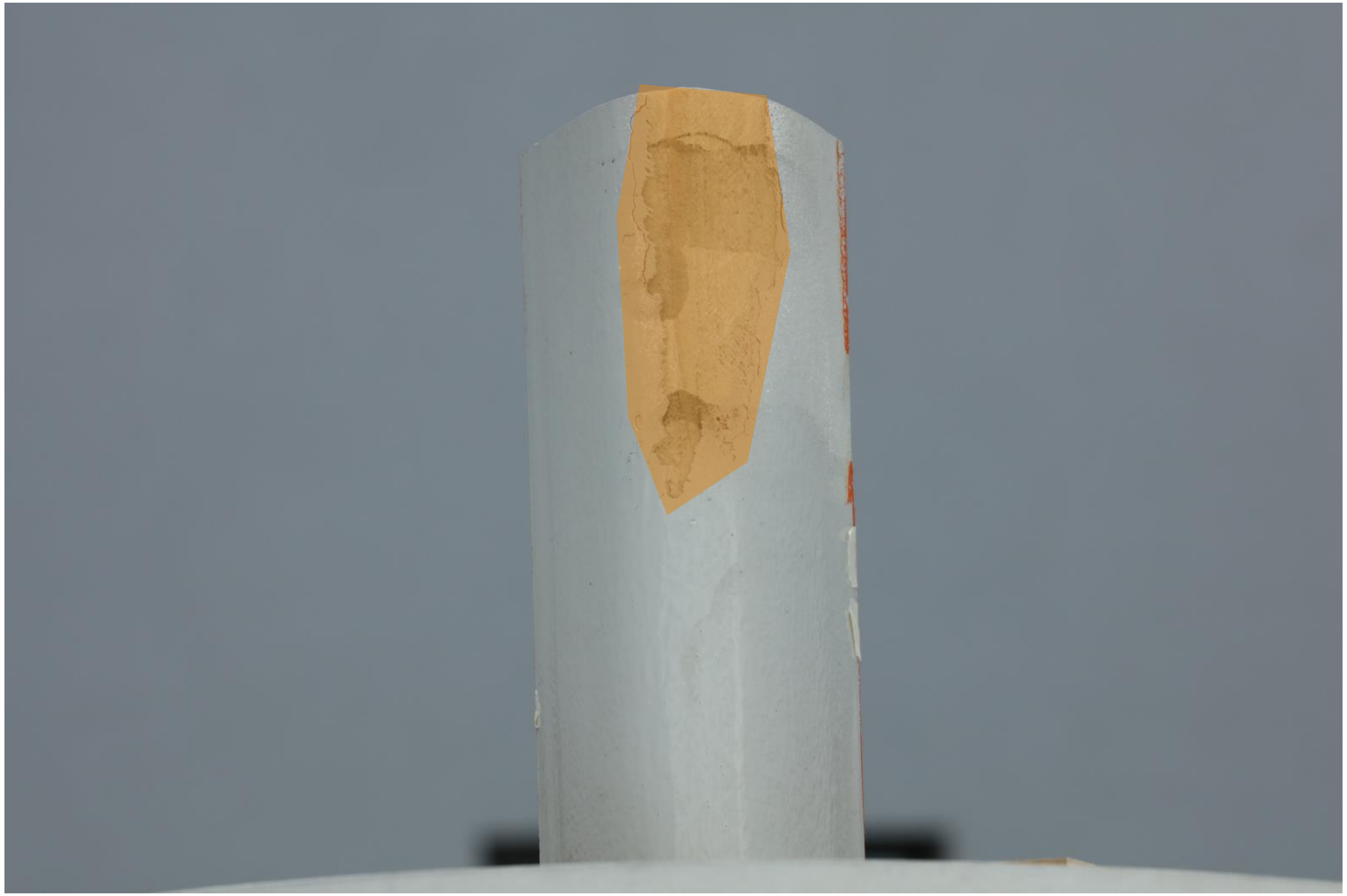
Challenge: Scale





Case study – Visual inspection for wind turbines

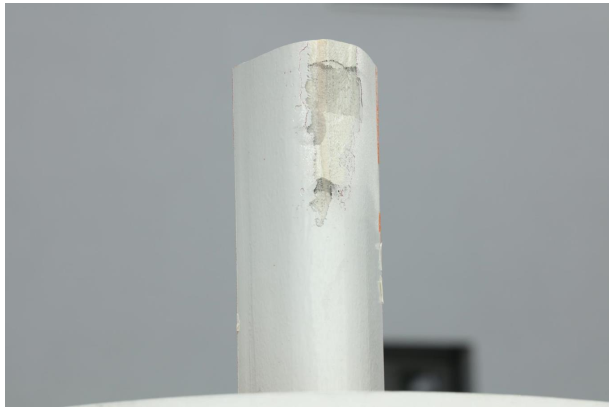
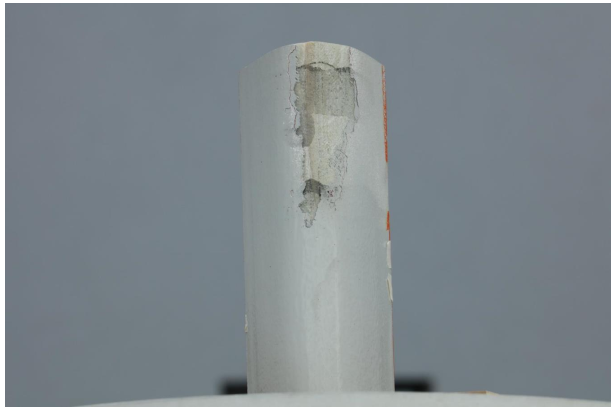
Can we identify damaged areas on wind turbine blades?

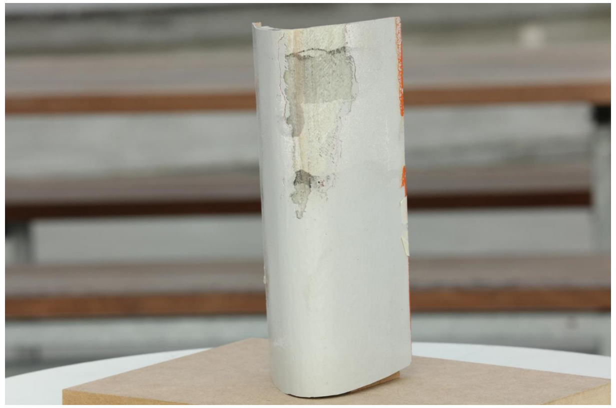
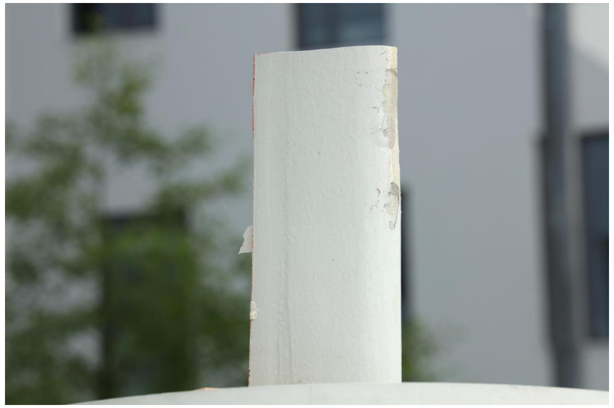


Damaged Turbine Blade

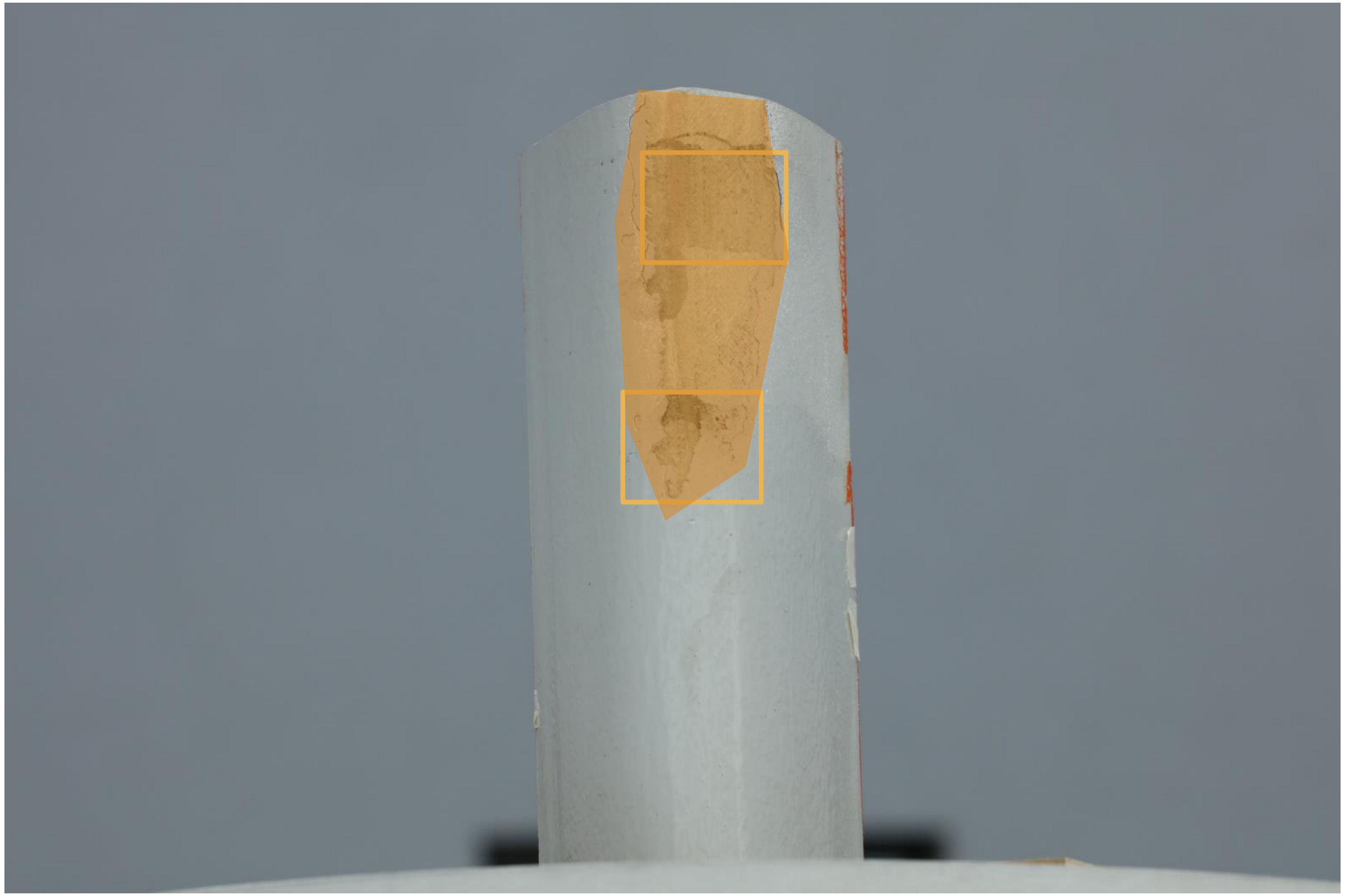
Visual inspection of wind turbine blades

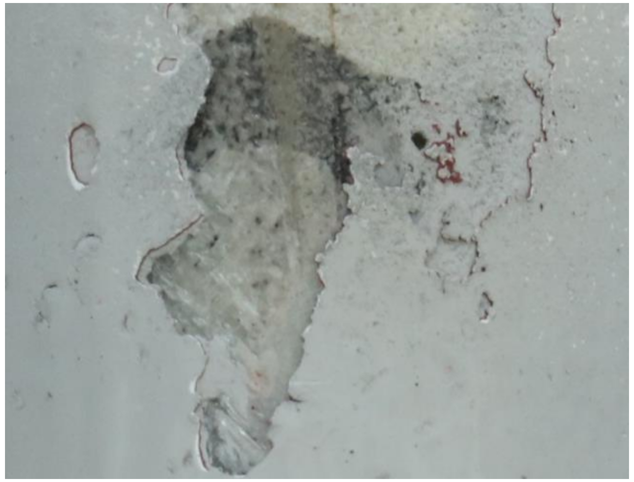
Our dataset

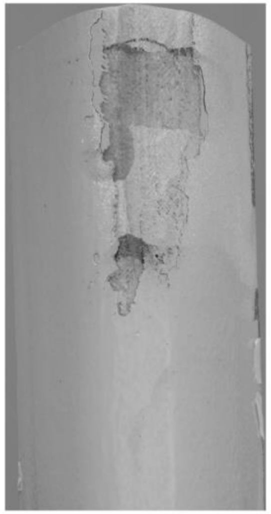
Identifying blade damage



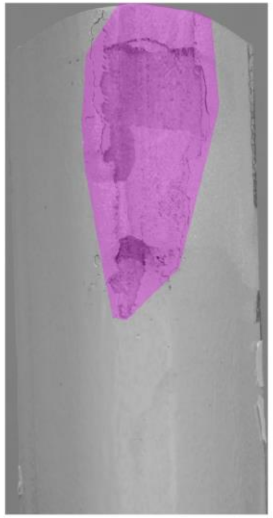


Problem Outline

Importing Data

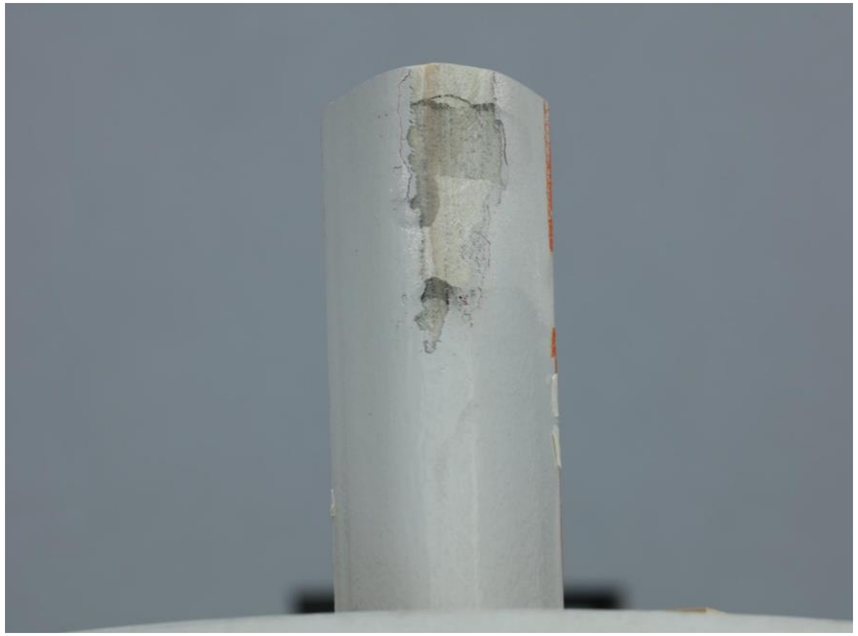


Crop to Blade



Detect Damaged Area

Importing the data



```
img = imread("2C8A0207.JPG");
imshow(img)
```

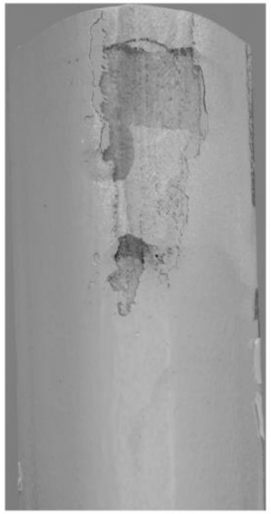
Image read

?

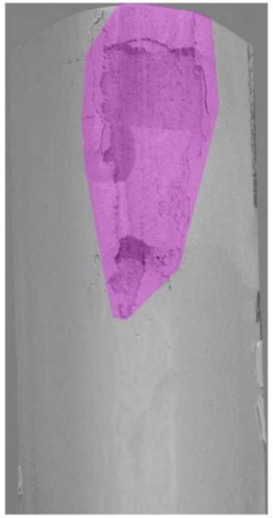
Scaling this up?

Problem Outline

Importing Data



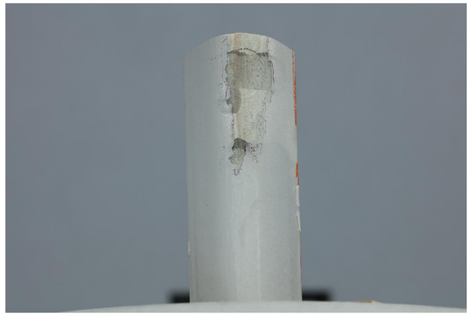
Crop to Blade

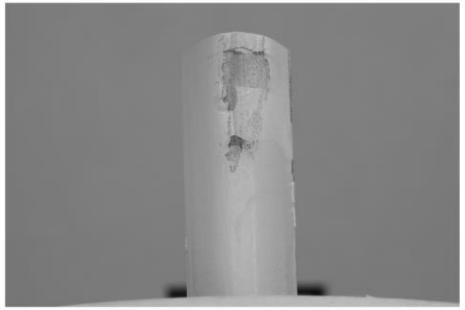


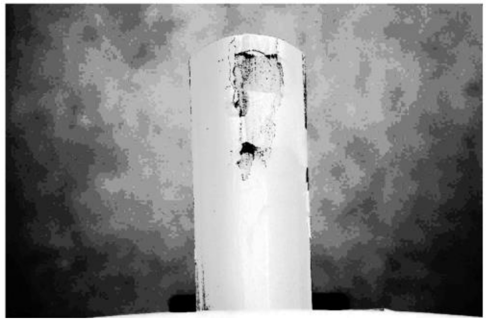
Detect Damaged Area

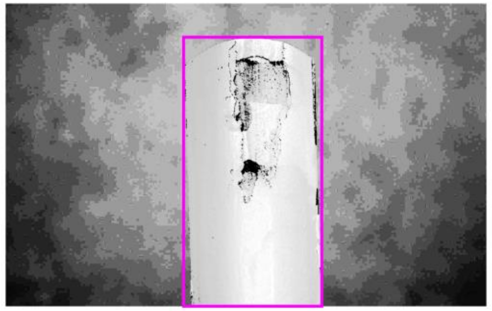
Cropping out the background

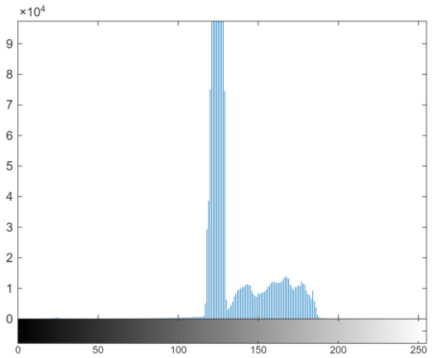
`histeq`

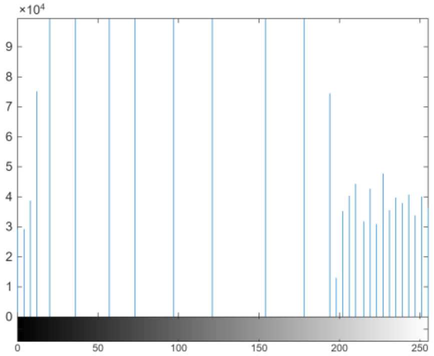










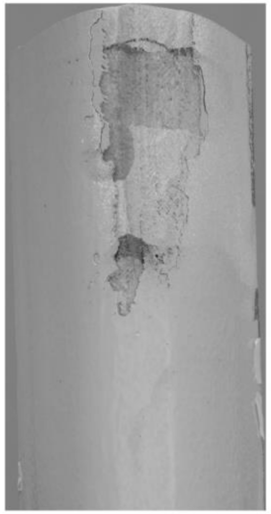


`im2gray`

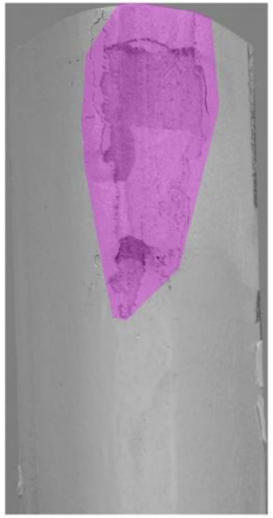
`bwareafilt`
`regionprops`

Problem Outline

Importing Data

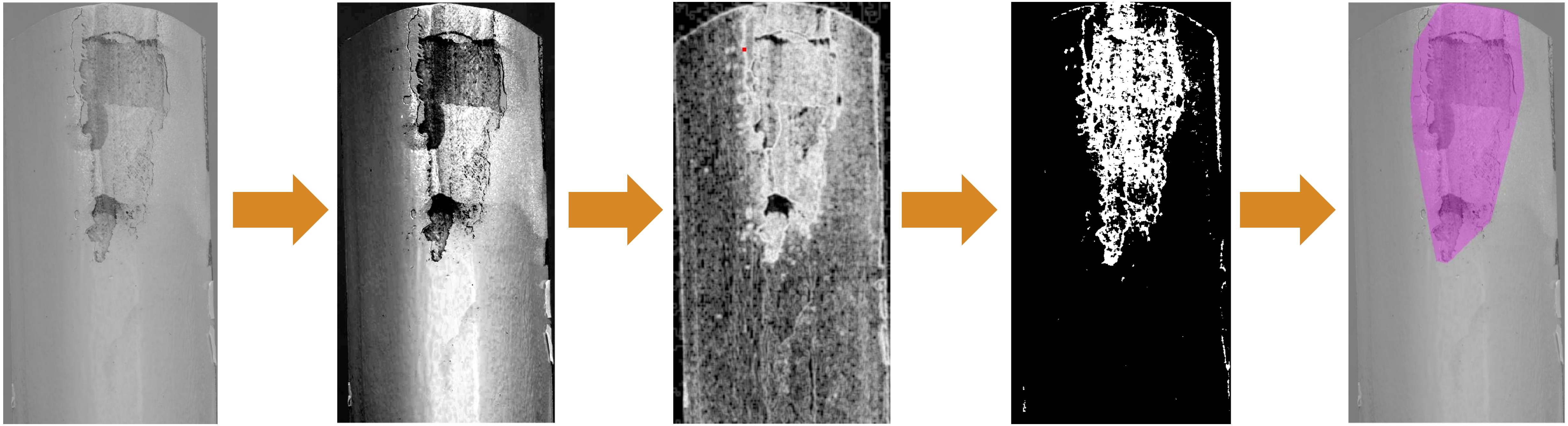


Crop to Blade



Detect Damaged Area

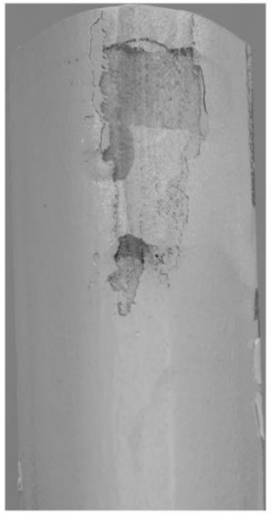
Detecting damage



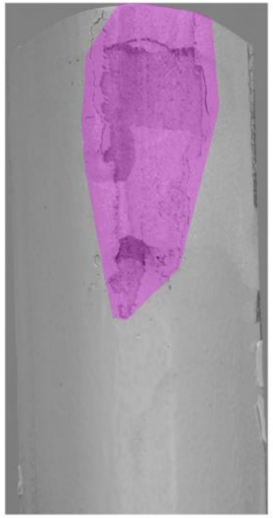
histeq entropyfilt prctile bwconvhull

Problem Outline

Importing Data



Crop to Blade

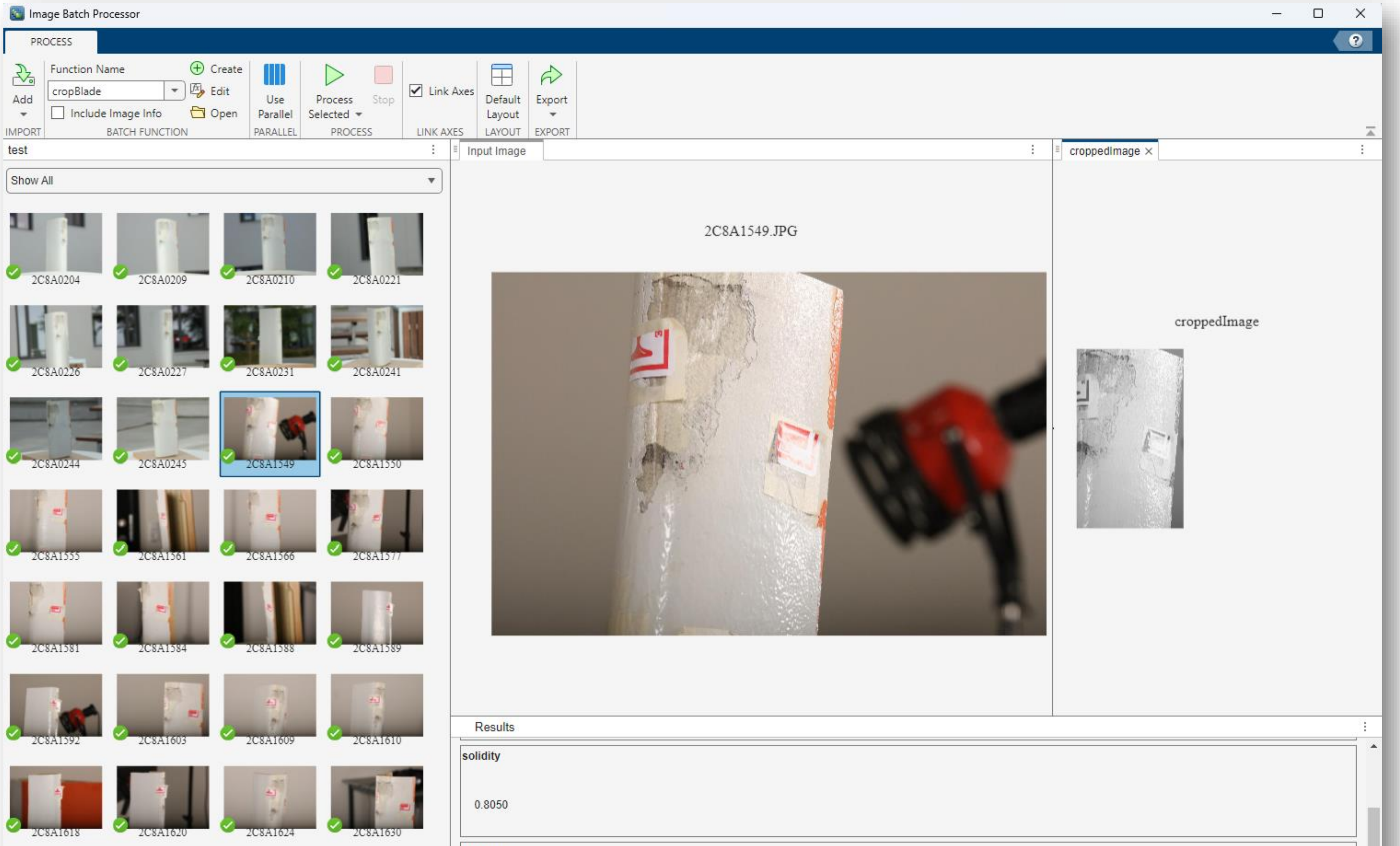


Detect Damaged Area

Validation?

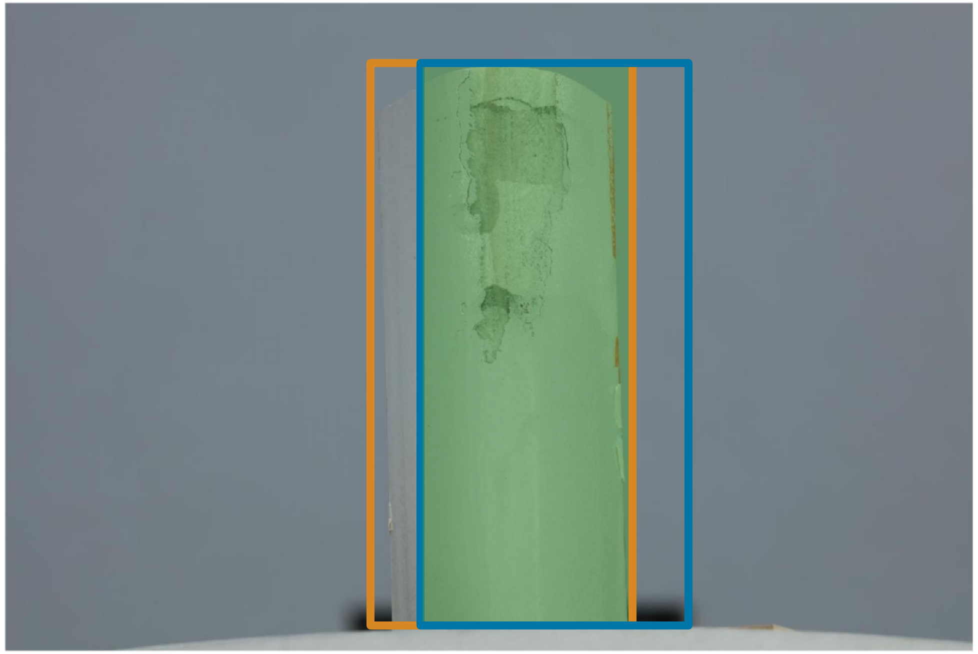
Image Batch Processor

More about the image batch processor



Validation

- Compute overlap between computed bounding box and ground truth
- Map detected damage convex hull back to original image co-ordinates and compute overlap with ground truth
- **This requires labeling to obtain a ground truth**



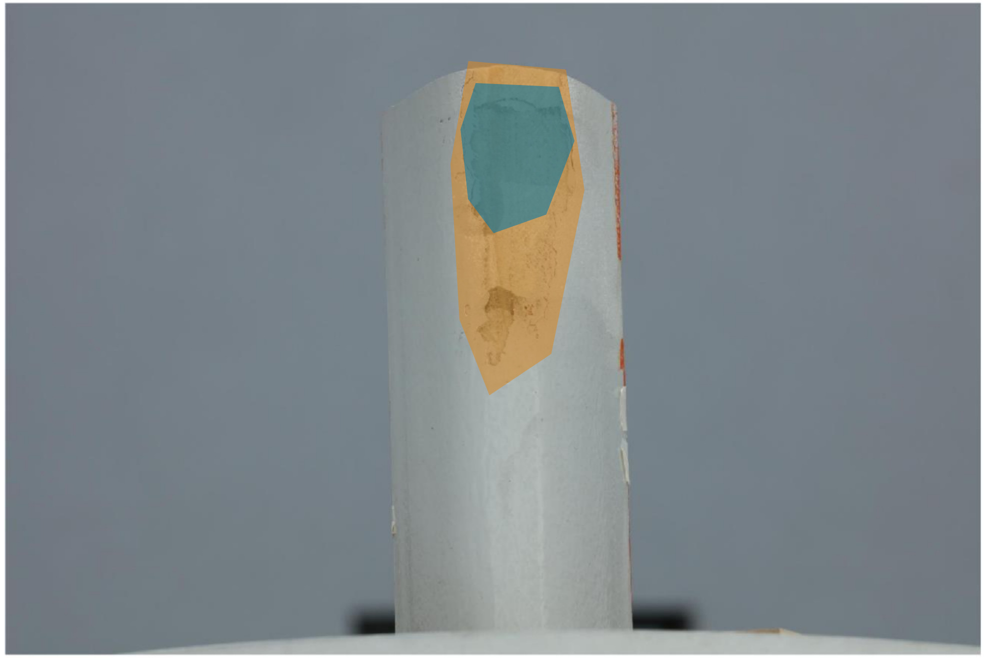
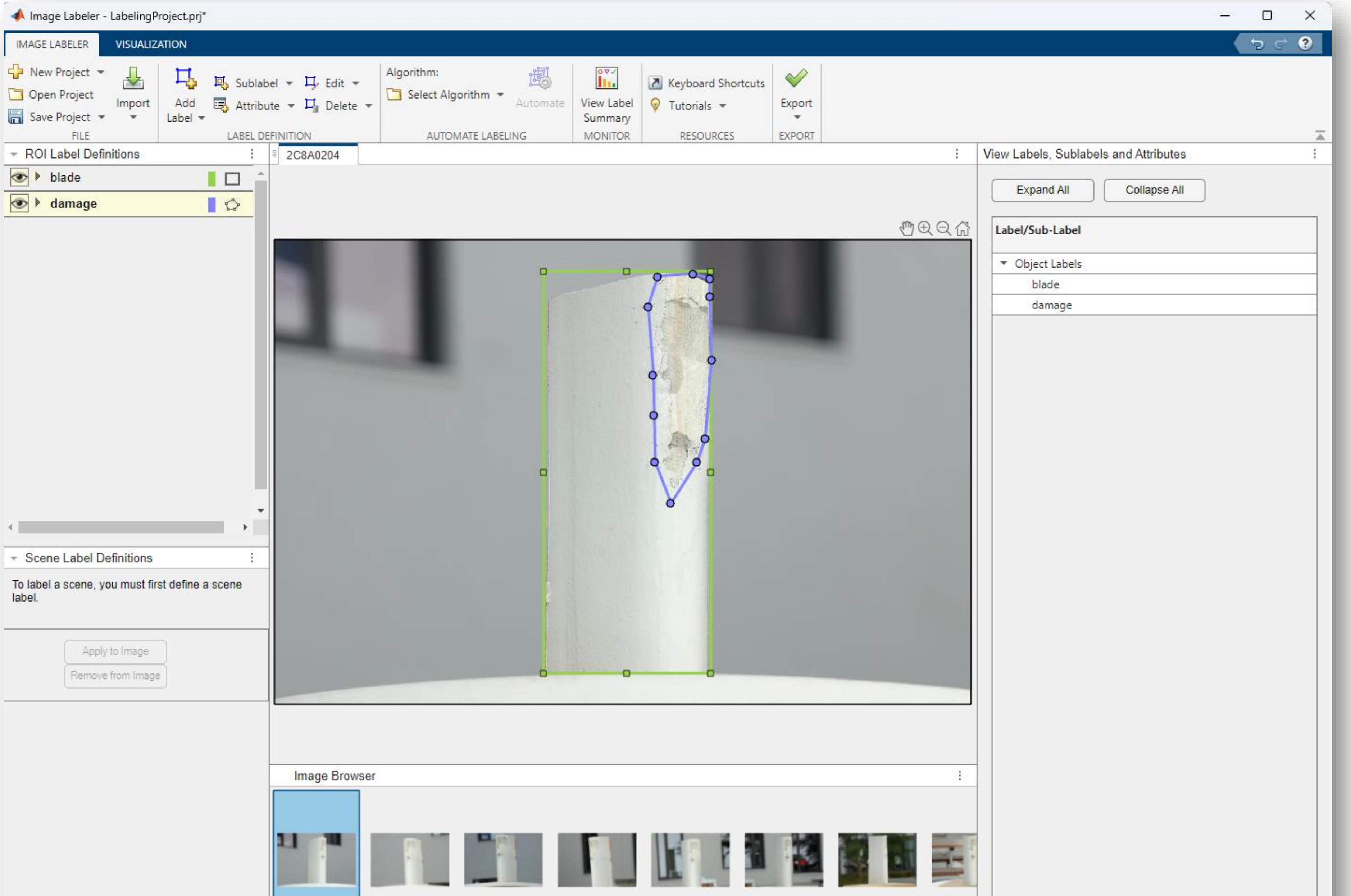


Image Labeler

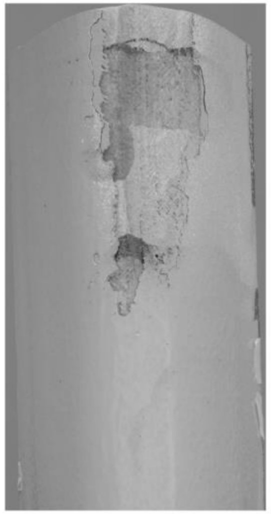
[More about the image labeler]



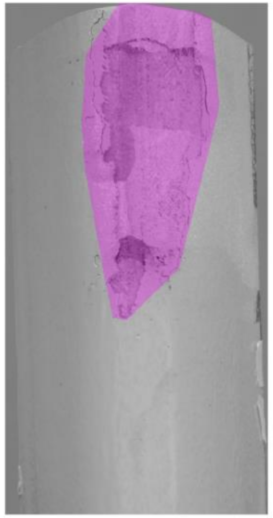
Problem Outline

Can we do better using deep learning?

Read Data



Crop to Blade



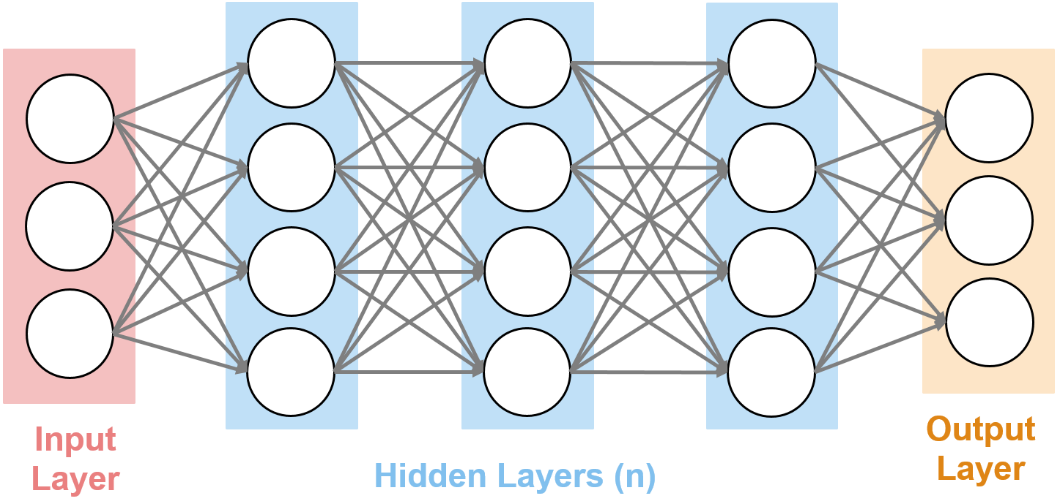
Detect Damaged Area

Deep learning workflow

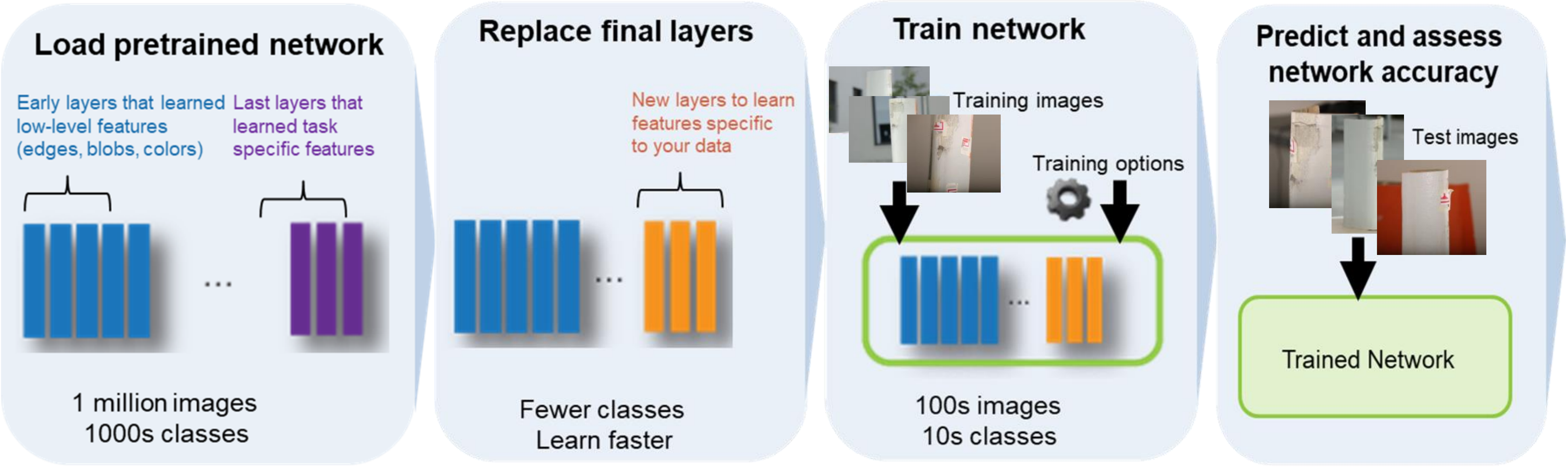
ACCESS AND EXPLORE DATA → LABEL AND PREPROCESS DATA → DEVELOP AND VALIDATE MODEL → DEPLOY

Neural Network = Model

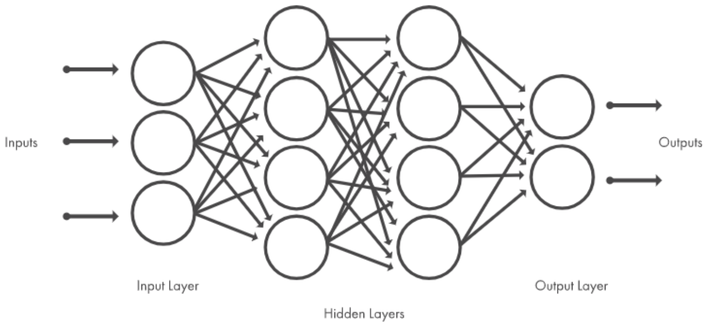
- Designing the architecture
- Training and validating the model
- Tuning training options



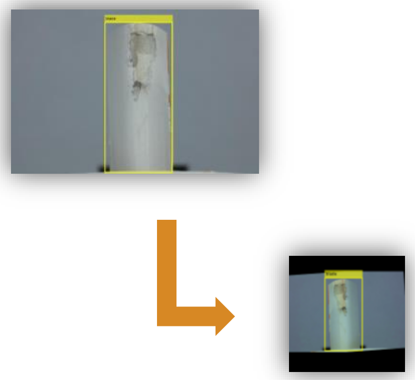
Transfer learning



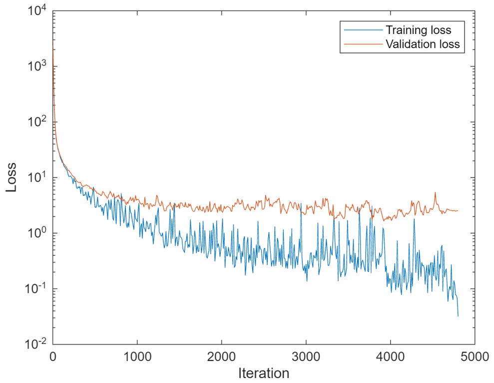
Solving the cropping sub-problem



Architecture



Data Augmentation

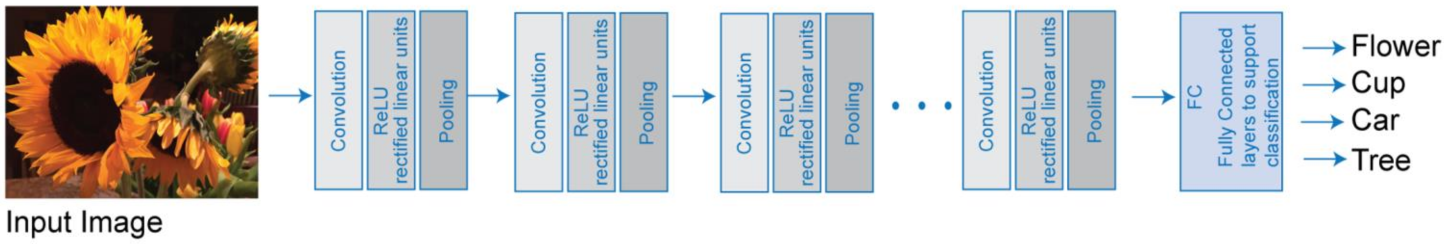


Train & Evaluate

Architecture

Classification

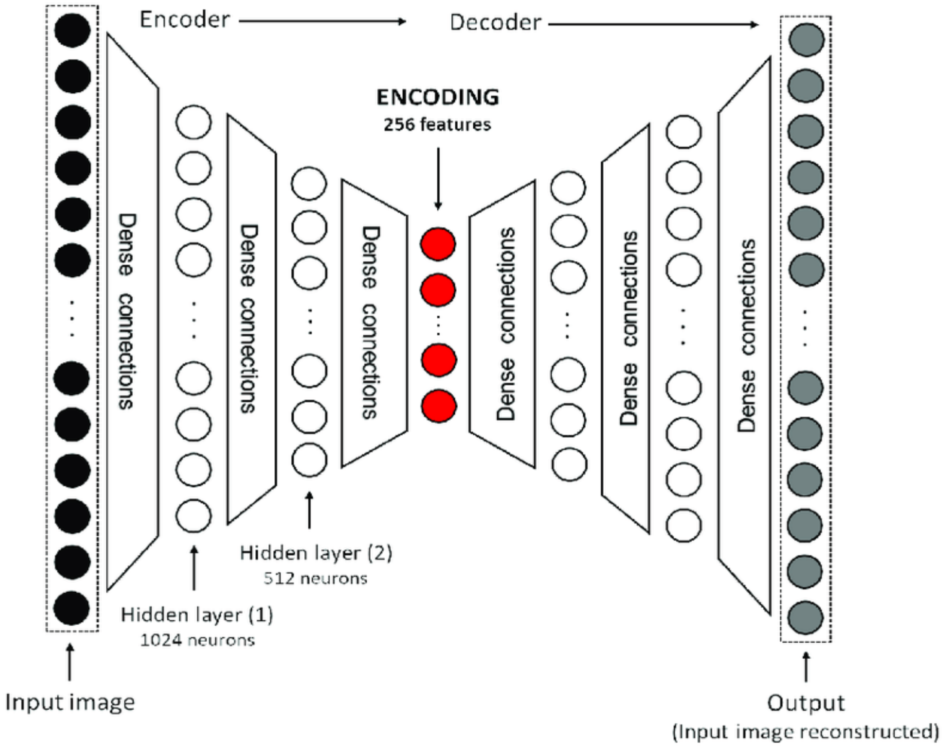
Convolutional Neural Networks



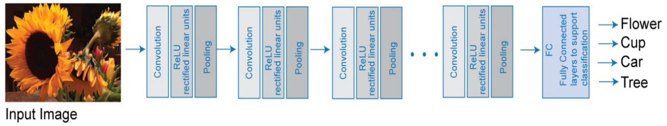
Architecture

Anomaly Detection

Deep Autoencoder



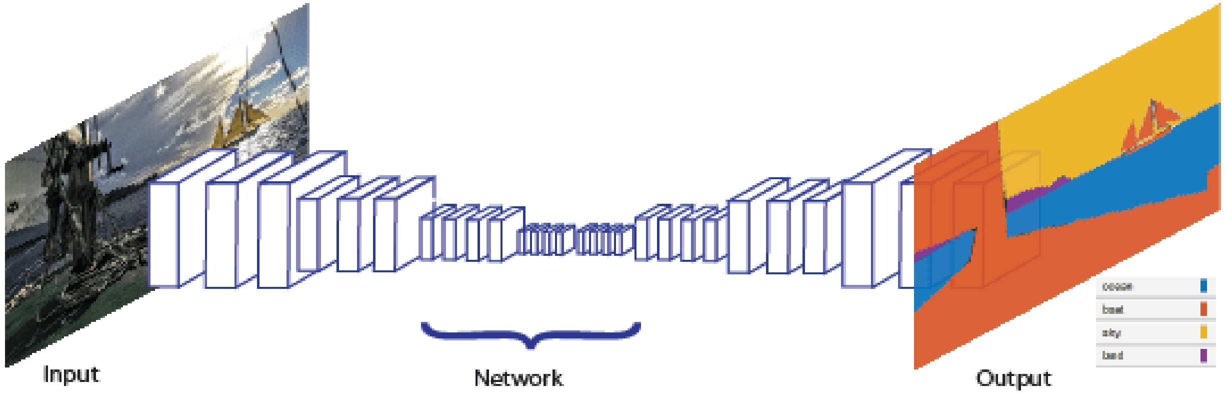
Convolutional Neural Networks



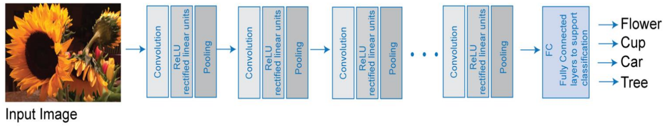
Architecture

Image Segmentation

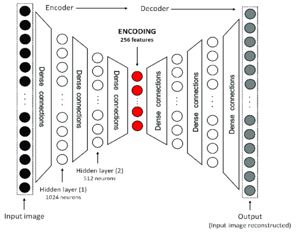
Semantic Segmentation Network



Convolutional Neural Networks



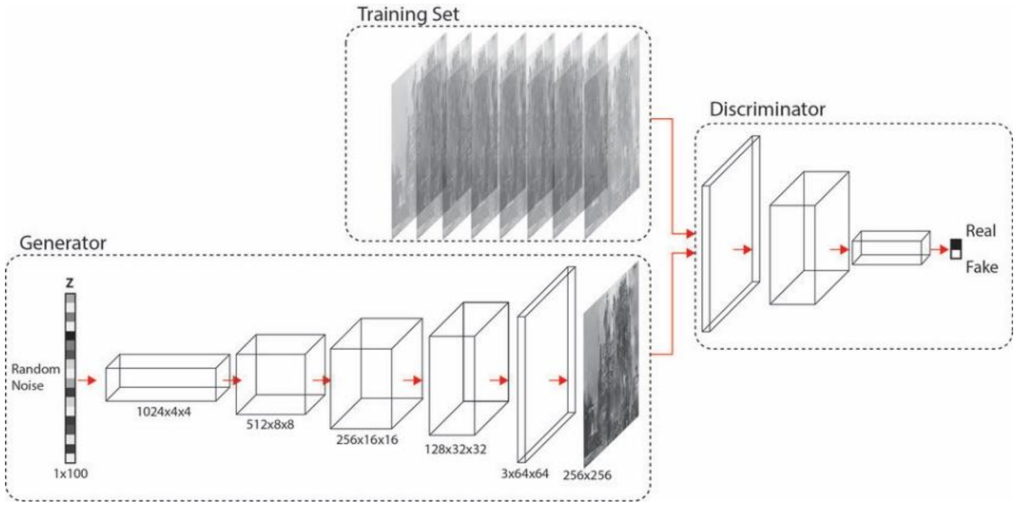
Deep Autoencoder



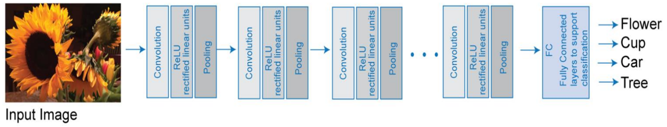
Architecture

Denoising, Synthetic data generation

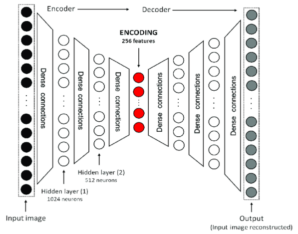
Generative Adversarial Network (GAN)



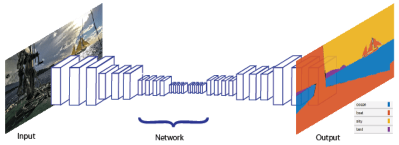
Convolutional Neural Networks



Deep Autoencoder



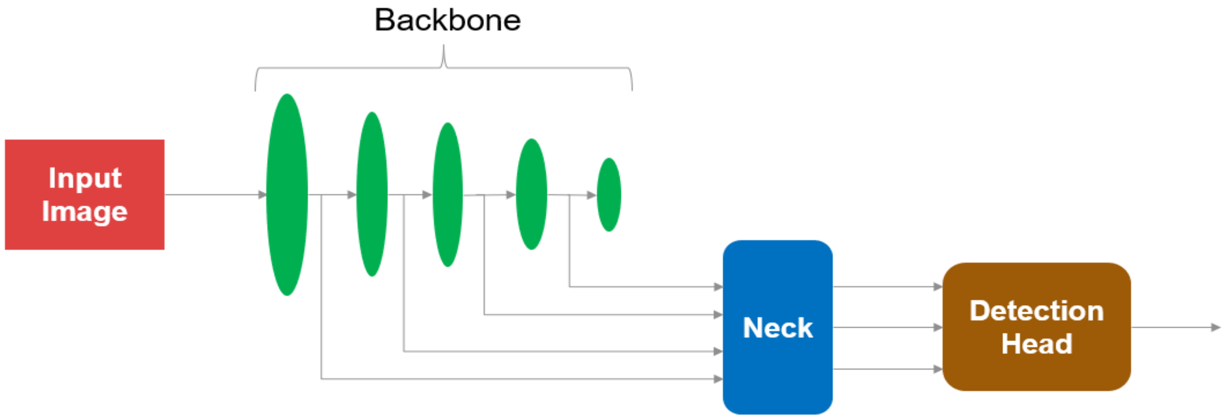
Semantic Segmentation Network

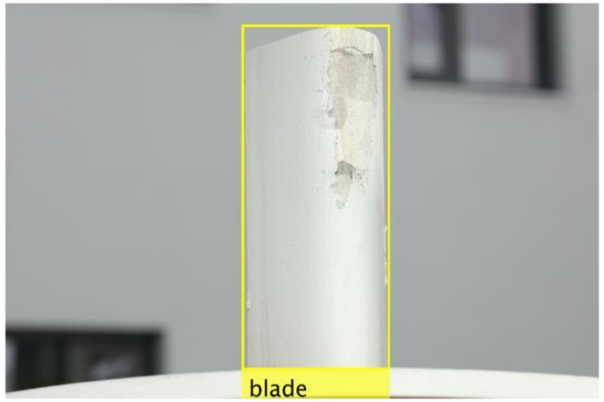


Architecture

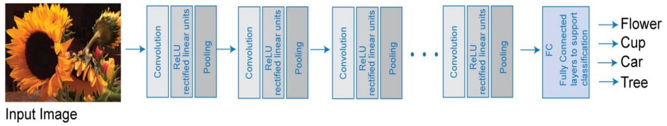
Object Detection

YOLO – You Only Look Once

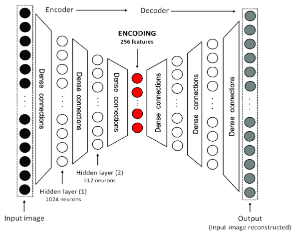




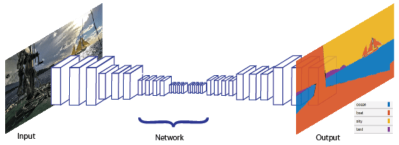
Convolutional Neural Networks



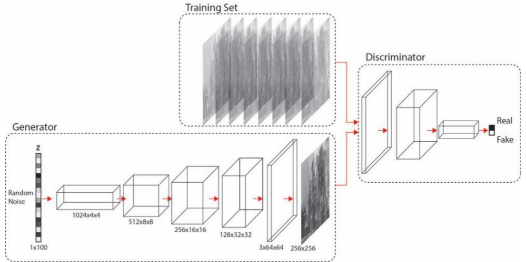
Deep Autoencoder



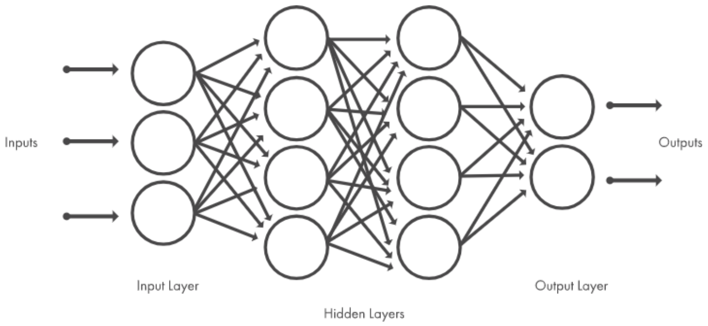
Semantic Segmentation Network



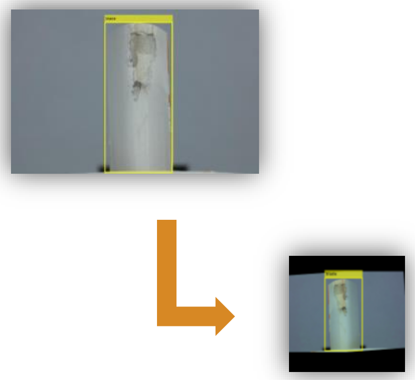
Generative Adversarial Network (GAN)



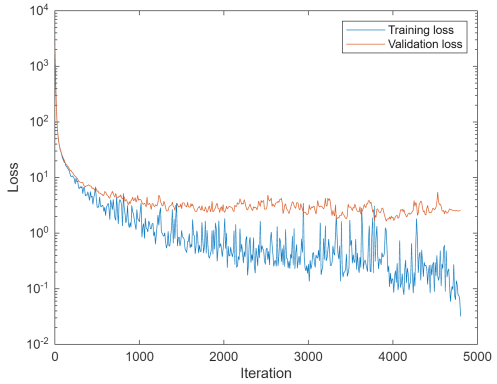
Solving the cropping sub-problem



Architecture

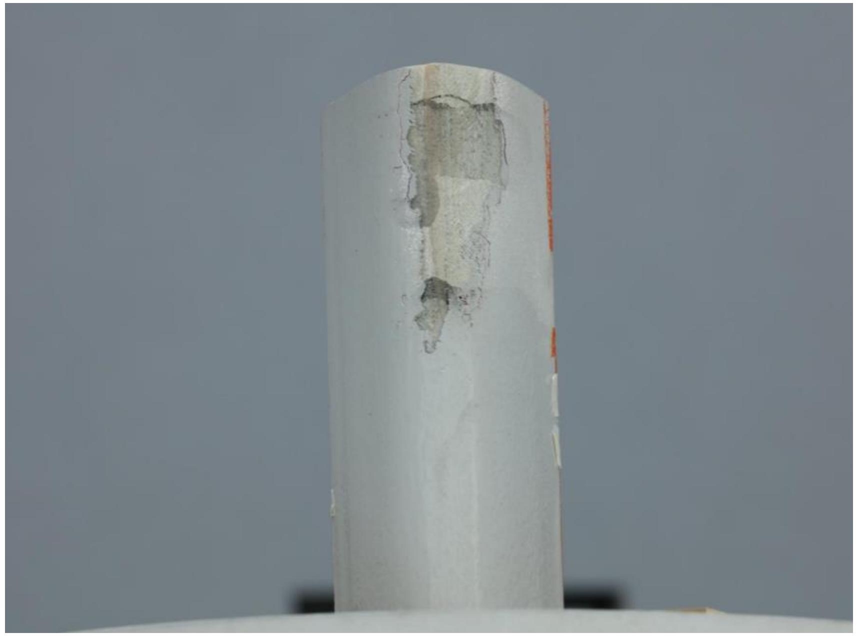


Data Augmentation



Train & Evaluate

Importing the data



```
img = imread("2C8A0207.JPG");
imshow(img)
```

Image read

?

Scaling this up?

Importing the data and data augmentation

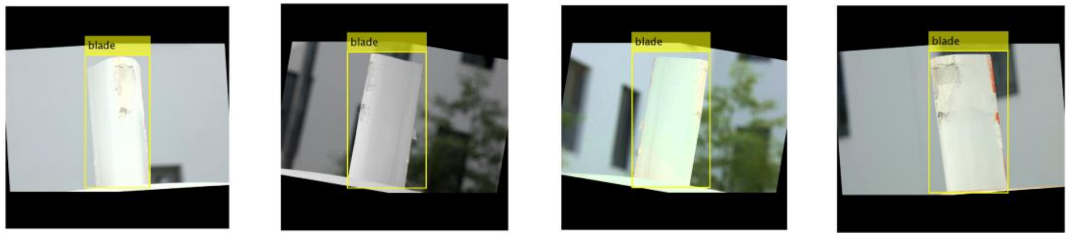
```
f = figure();
img = imread("2C8A0207.JPG");
imshow(img)
```

Image read

Datastore

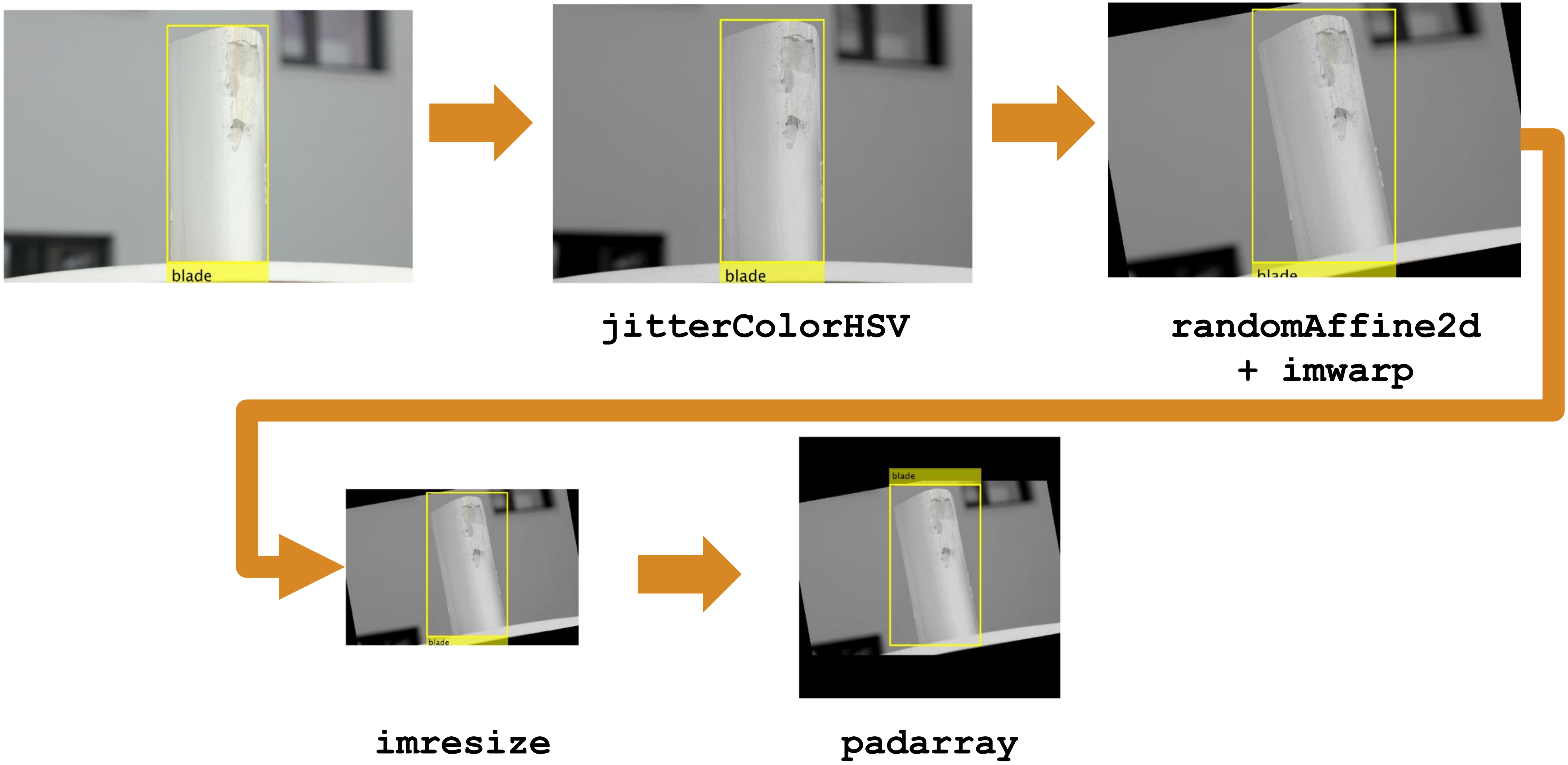
Hard Drive

```
data = trainDS.read();
```

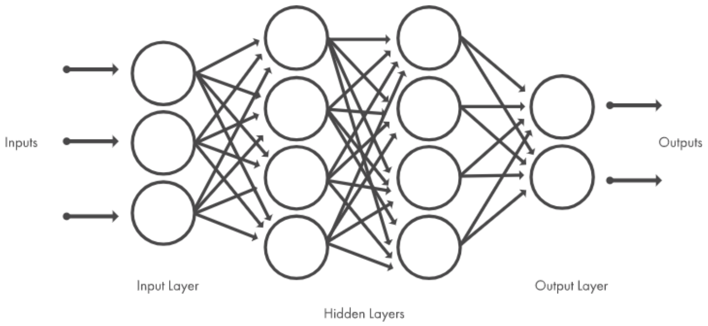


Datastores

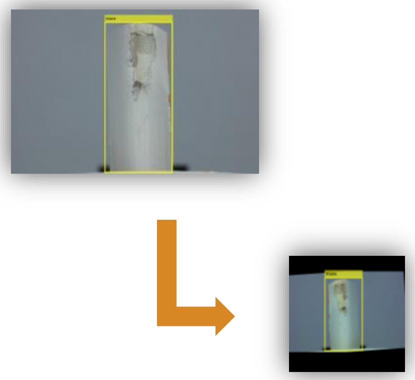
Data Augmentation



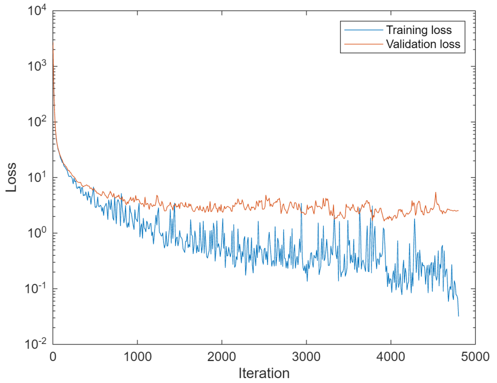
Solving the cropping sub-problem



Architecture



Data Augmentation



Train & Evaluate

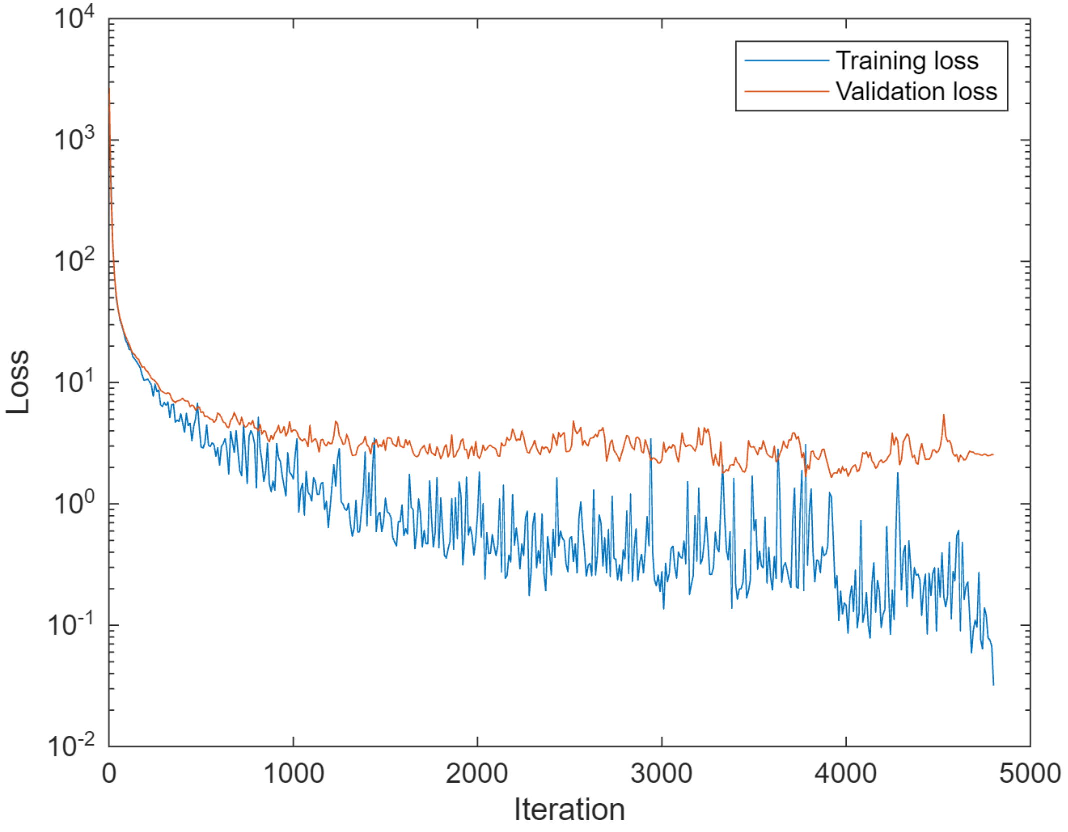
Training and evaluation

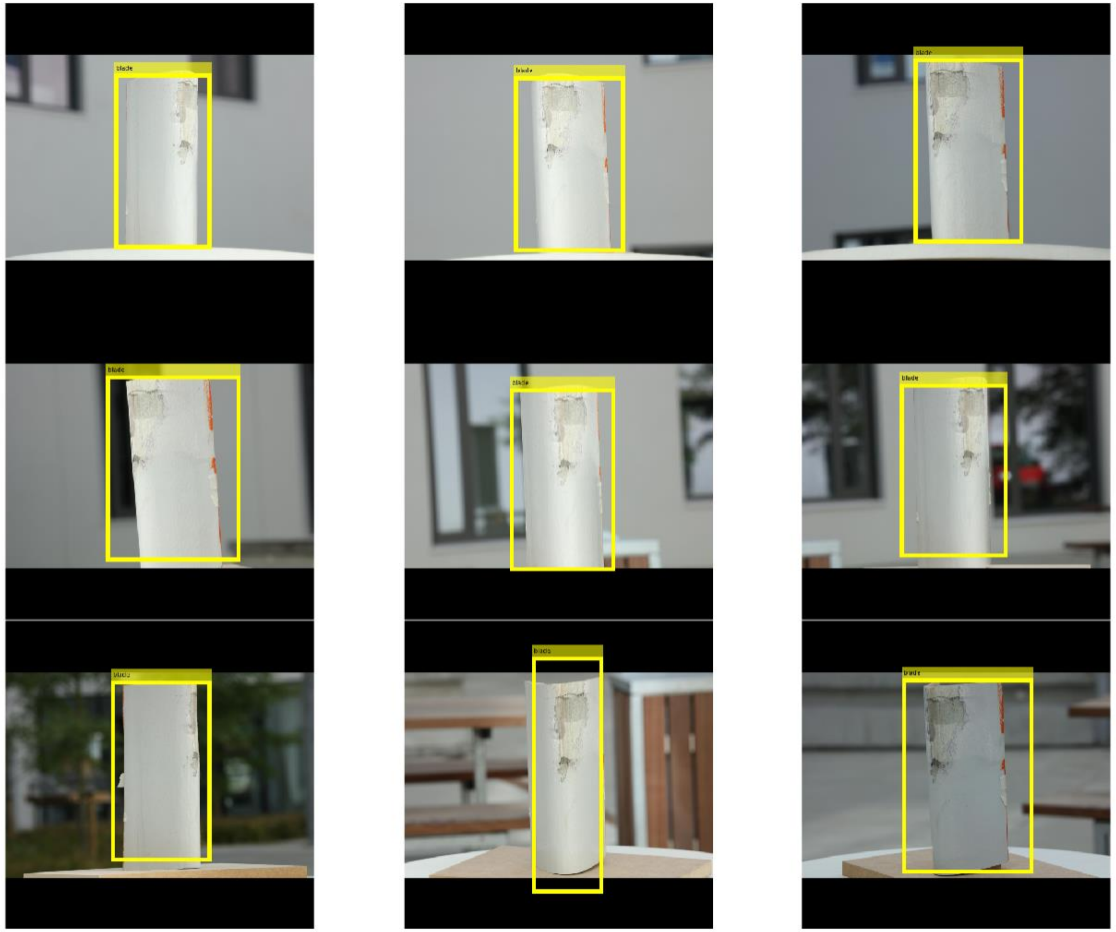
```
detector = yolov4ObjectDetector("tiny-yolov4-coco","blade",anchorBoxes,InputSize=inputSize);

options = trainingOptions("adam", ...
    InitialLearnRate=0.001, ...
    MiniBatchSize=4,...
    MaxEpochs=200, ...
    Shuffle="every-epoch", ...
    ValidationData=valDS);

detectorTrain = trainYOLOv4ObjectDetector(preprocessedTrainDS,detector,options);
```

```
Computing Input Normalization Statistics.

**************************************************************************
Training a YOLO v4 Object Detector for the following object classes:

* blade
```

Epoch	Iteration	TimeElapsed	LearnRate	TrainingLoss	ValidationLoss
1	1	00:00:11	0.001	2407.7	2746
1	10	00:00:44	0.001	504.49	432.31
1	20	00:01:18	0.001	144.33	138.46
2	30	00:01:52	0.001	76.456	75.908
2	40	00:02:27	0.001	48.541	51.499
3	50	00:02:59	0.001	39.563	40.005
3	60	00:03:32	0.001	32.804	33.864

Training and evaluation



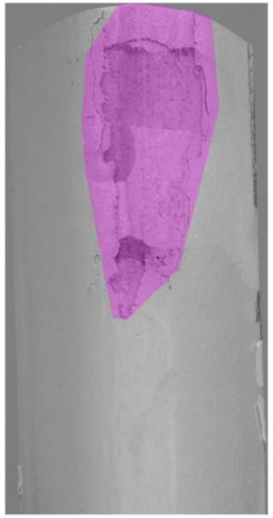


Take-Home Messages

Control your data gathering environment

Importing Data

Crop to Blade



Detect Damaged Area

Classical image processing and deep learning can be complementary

	Classical Image Processing	Deep Learning
Data Requirements	Low	High
Data Labelling	Not required	Algorithm / workflow dependent *Time consuming*
Algorithm Development	Potentially complex	Learnt from data
Anomalies	Must account for manually *Likely to be missed once deployed*	Learnt from data *Depends on algorithm*
Explainability	Complete	Low by default *Tools exist to improve*
Execution Speed	High	Slow *Specialized hardware can improve*

Onramps - Learn the basics in 2 hours or less

Image Processing Onramp

2 hours | Languages

Learn the basics of practical image processing techniques in MATLAB.

Computer Vision Onramp

1.5 hours | Languages

Learn the basics of computer vision to design an object detector and tracker.

Machine Learning Onramp

2 hours | Languages

Learn the basics of practical machine learning methods for classification problems.

Deep Learning Onramp

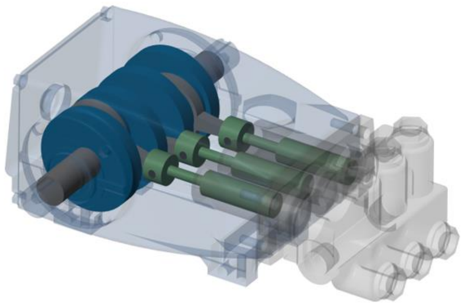
2 hours | Languages

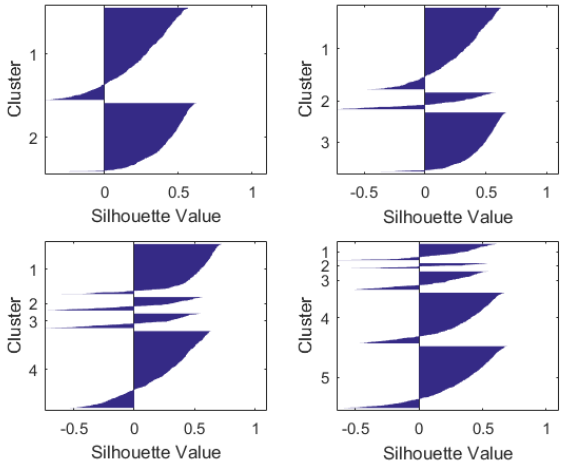
Get started quickly using deep learning methods to perform image recognition.

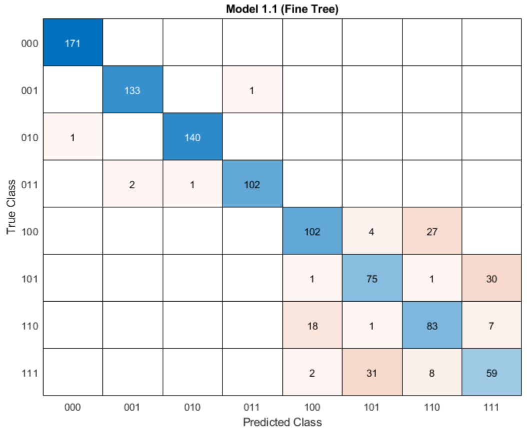
Training Course: Predictive Maintenance with MATLAB

Topics included in this 2-day course:

- Importing and organizing data
- Creating custom visualizations
- Fault Detection/Classification
- Preprocessing to improve data quality, and extract time and frequency domain features
- Estimating Remaining Useful Life (RUL)
- Interactive workflows with apps







[See detailed course outline]

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