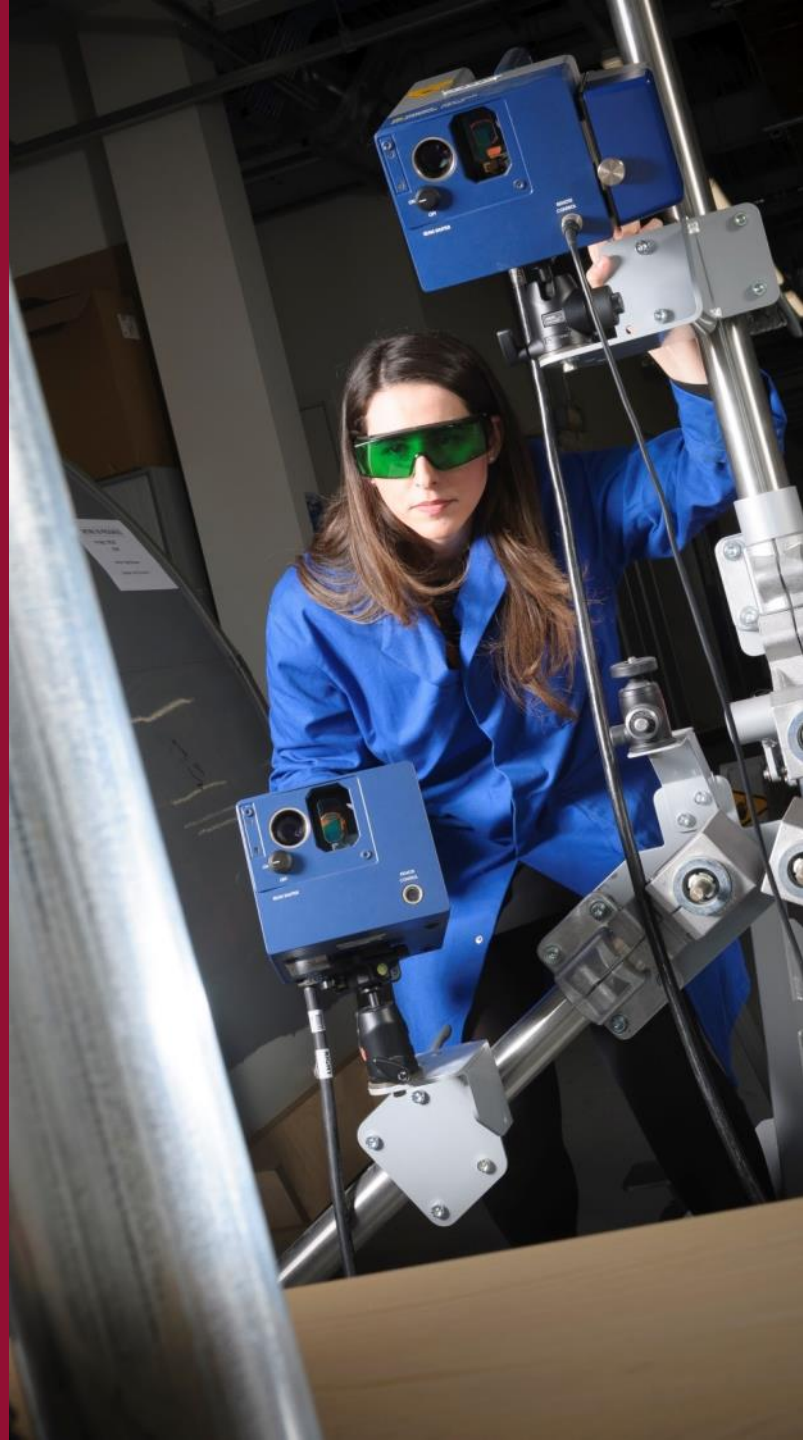
# AI enabled biofouling monitoring and non-invasive fouling removal system for offshore wind turbine monopile structures

**Bojie Sheng**

**Switzerland, 29-01-2019**



# Overview

- Introduction and background
- Robot system
- AI software for fouling detection
- Conclusions

# Introduction and background

- **Types of fouling on monopile**

Biofouling can be categorised as microfouling which is the formation of biofilms and bacterial adhesion, and macrofouling which is the attachment of large organisms.

The main differences in species composition and structure in the biofouling community exists between different depths.

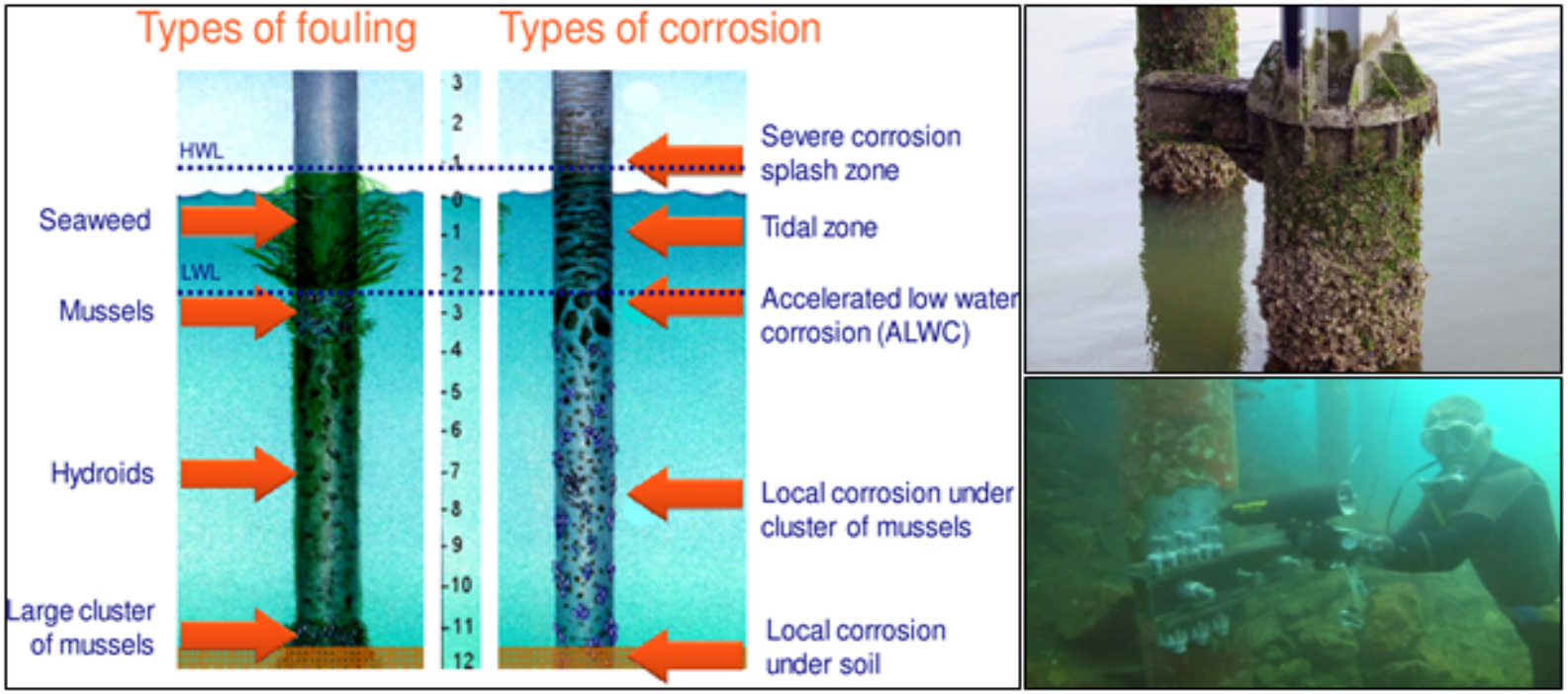



Figure 1: Biofouling growth and the distribution of corrosion in OWT monopoles

# Introduction and background

- **Current cleaning methods**

❑ Anti-fouling paint: releases small particles killing the growth that attaches to its surface, but the particles stay in the sea where they cause serious damage to marine life.

❑ Divers or remotely-operated vehicles (ROV): removes the growth mechanically by brush or high pressure water blasters. However, the coating of the structure could be damaged such that it becomes more prone to corrosion issues if not re-coated.

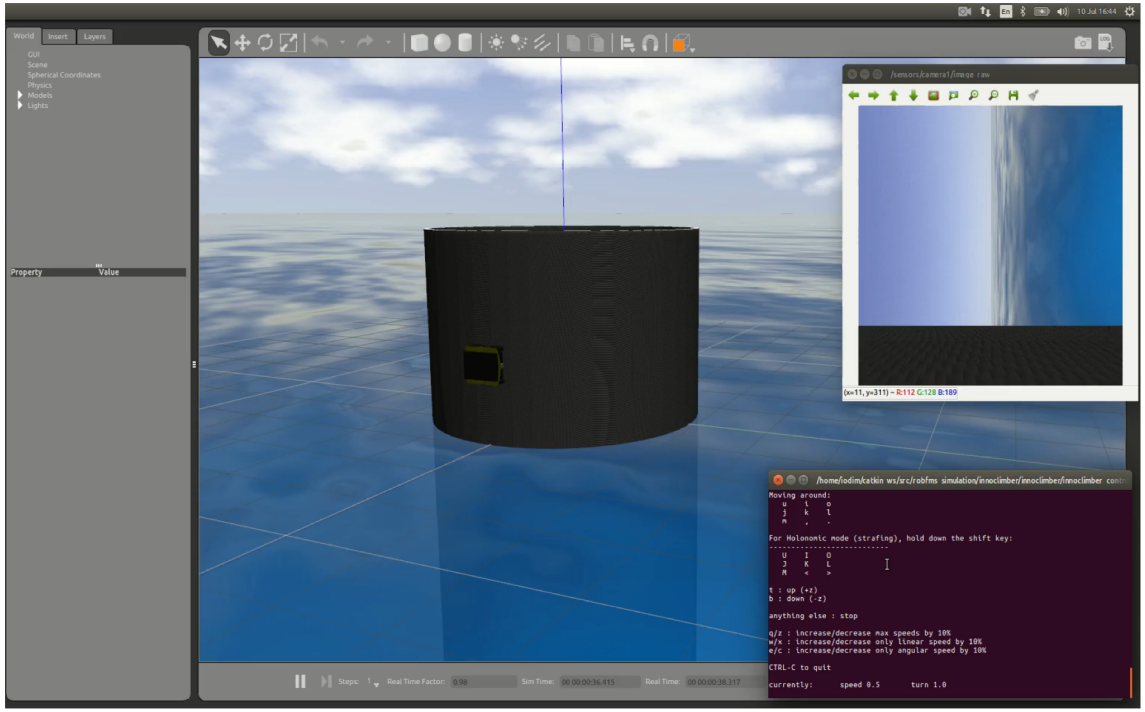
- **Improvements required for current cleaning methods**

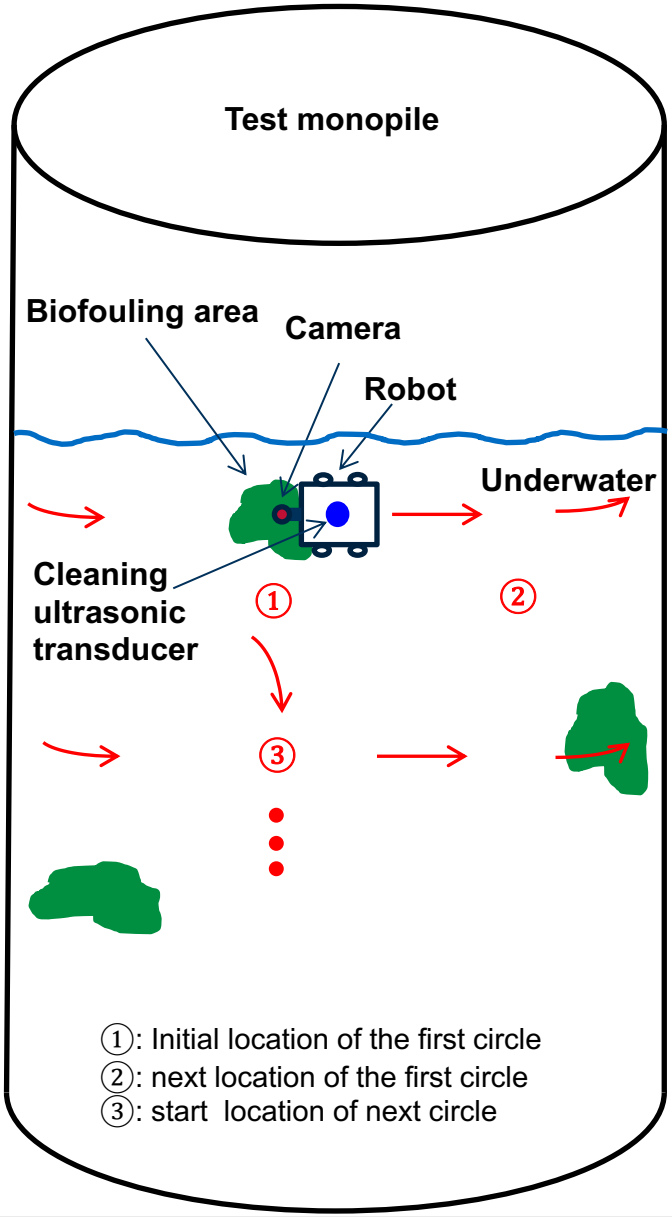
❑ A promising method of fouling removal that has recently surfaced is the use of ultrasound, which has been applied to clean fouling on ship hulls by (BIC).

Table 1: Comparison of fouling removal methods

| Cleaning Method | Intrusiveness (damage risk) | Geometrical constraints | Effectiveness | Cost |
|---|---|---|---|---|
| Chemical coating | H | H | M/H | M/H |
| Abrasive cleaning | H | L | L | H+ |
| Ultrasonic cleaning | L | L | H + | L |

# Robot system





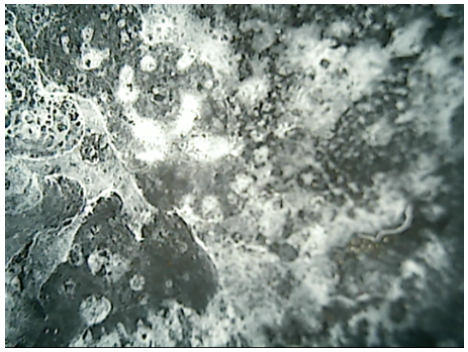
# AI software for fouling detection

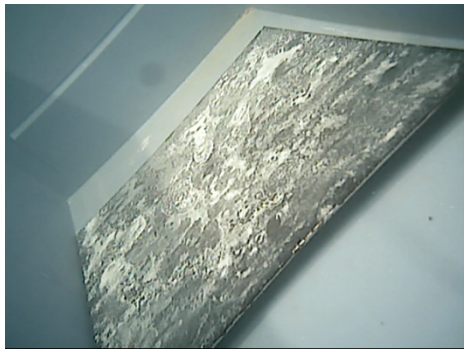
## 1. Image data collect in lab for AI recognition

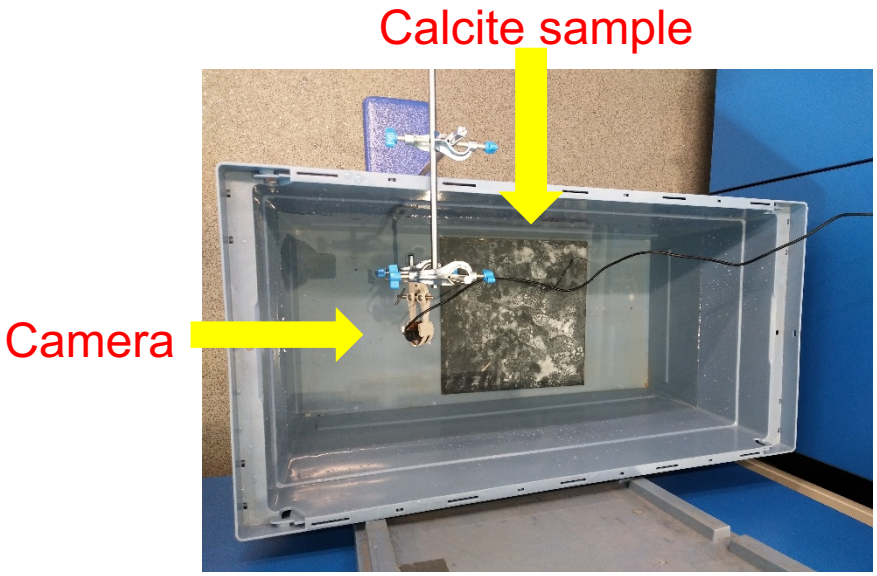
Image acquisition for each calcite sample under:

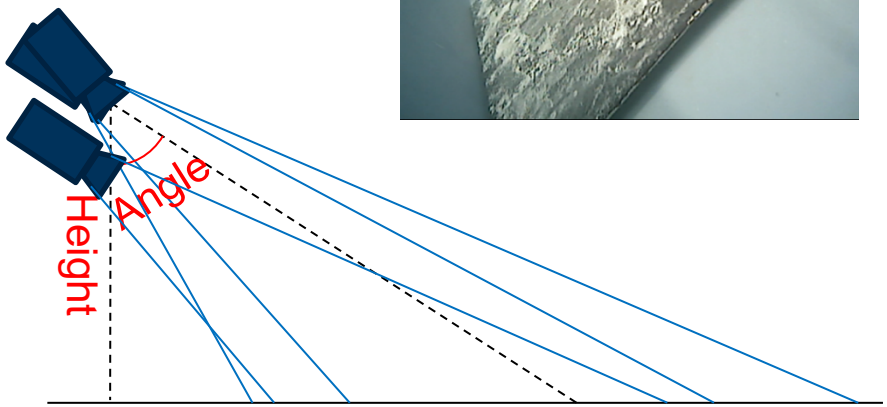
- 4 different angles: 30, 40, 50, 60 (°)
- 5 different heights:160, 180, 200, 220, 240 (mm)
- 2 different light conditions: light, no light

Therefore, 40 images are captured for each sample.







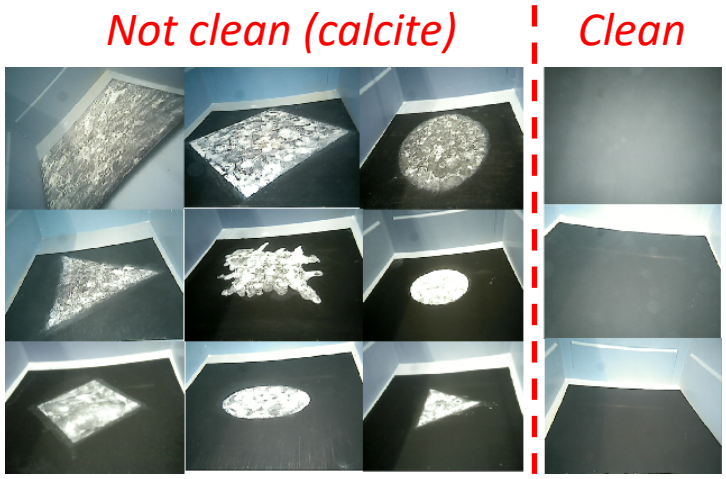



# Calcite recognition through deep learning models

## Dataset I:

- Not clean data: 9 calcite samples with different shapes – 360 images
- Clean data: one clean sample – 120 images

Transfer learning method is applied to address limited experimental data

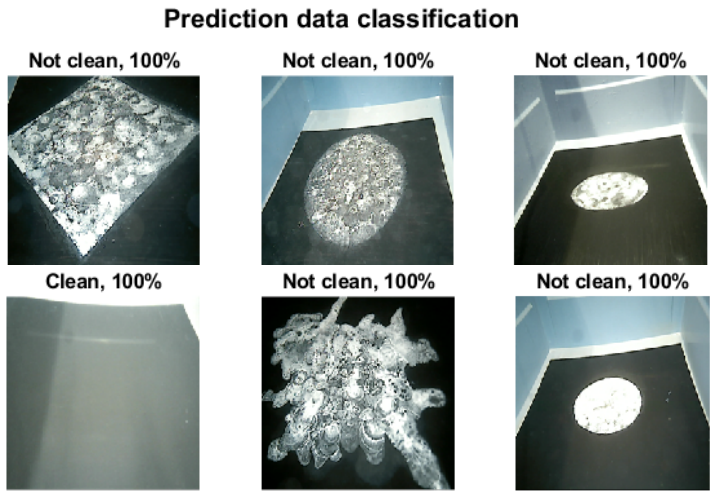



## Training, validation and prediction:

Training: 60%, validation: 30%, prediction:10%

## Results:

| Models | Model size (MB) | Accuracy | Processing Speed (/image) |
|---|---|---|---|
| AlexNet | 220 | 100% | 6 s |
| VGG16 | 515 | NA | NA (too large) |
| GoogleNet | 22 | 100% | 2 s |
| ResNet50 | 84 | 100% | 7.5 s |
| ResNet101 | 151 | NA | NA (too large) |
| SqueezeNet | 3 | 100% | 0.8 s |



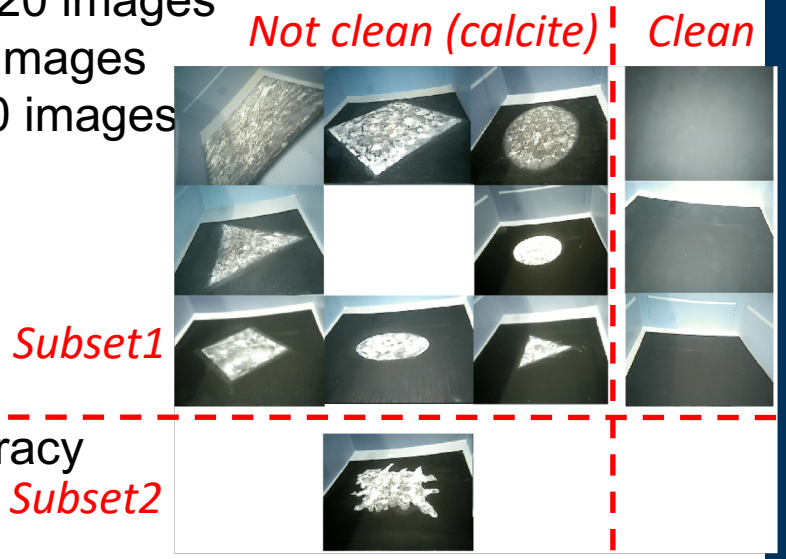

*"SqueezeNet" is the best model comparing with accuracy and processing speed.*

# Calcite recognition through deep learning models

## Dataset II: -- investigation of prediction for unknown pattern

Subset1
- Not clean data: 8 calcite samples – 320 images
- Clean data: one clean sample – 120 images

Subset2 Not clean data: 1 calcite samples – 40 images

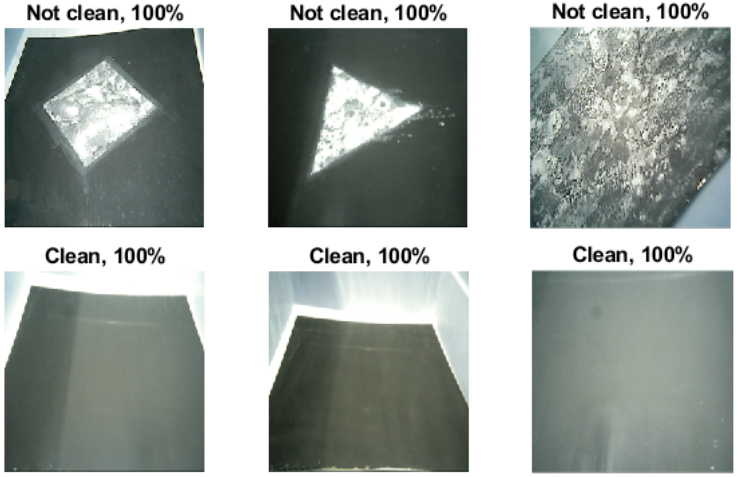


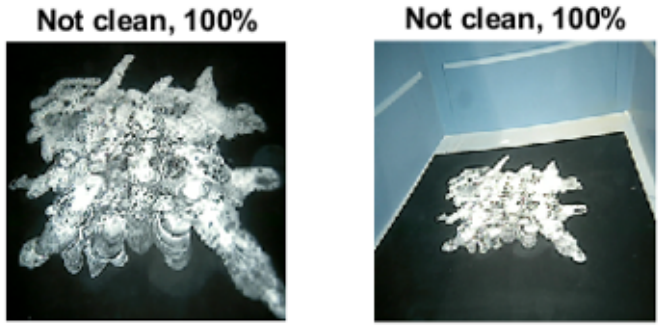

**Training, validation based on subset1:**

Training: 60%, validation: 30%

**Prediction results for:**

- Known pattern (10% of subset1): 100% accuracy
- Unknown pattern (Subset2): 100% accuracy



# AI software for different fouling detection

**More samples are prepared for AI detection:**

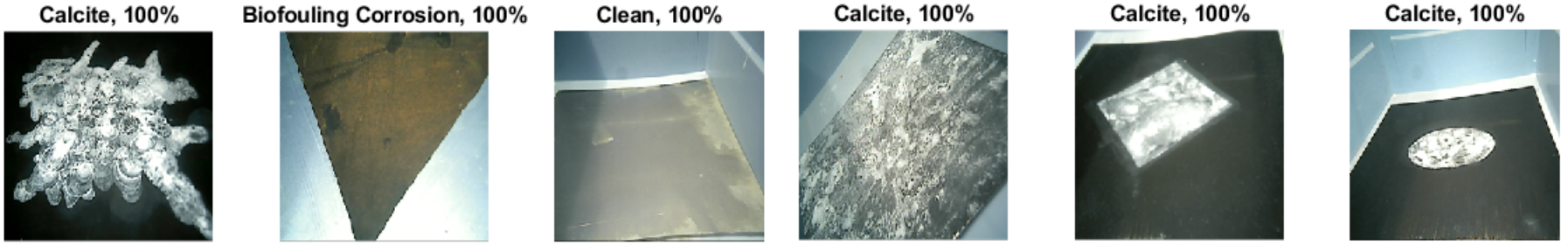
- Different sample background colors: black, silver
- Different objectives: Biofouling mixed with corrosion, calcite, clean, corrosion

**Dataset III:**

| Label | Count |
|---|---|
| Biofouling Corrosion | 240 |
| Calcite | 360 |
| Clean | 240 |
| Corrosion | 120 |

**Prediction results for:**

- Known pattern: 100% accuracy
- Unknown pattern: 100% accuracy



# Conclusions

- Deep learning (DL) models are used for automatic fouling recognition.
- Different fouling experimental data (biofouling mixed with corrosion, calcite, corrosion and clean) are applied to train and test DL models.
- Due to limited experimental data, transfer learning method is applied to address the challenge.
- As the marine robot is operated through an embedded system (Raspberry PI) with limited computing processing power, "*SqueezeNet*" is the best model comparing with classification accuracy, model size and processing speed between different DL models (*i.e. AlexNet, VGG16, GoogleNet, ResNet50, ResNet101 andSqueezeNet*).

# AI enabled biofouling monitoring and non-invasive fouling removal system for offshore wind turbine monopile structures

# Thank You

Innovate UK

InnoTecUK™ Innovative Technology & Science Ltd
Setting Standards for Robotic and A

Brunel University London

BIC