An Improved Crack Detection Methodology for Effective Bridge Condition Inspection Practice

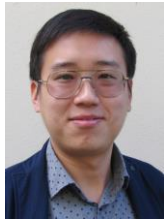
8th ANSHM Annual Workshop, 29 Nov 2016, Melbourne, Australia

Presenter: Hong Guan

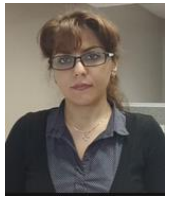
Professor, Griffith School of Engineering, Griffith University, Australia

Email: h.guan@griffith.edu.au

Authors



Dr Lei Hou, Lecturer
School of Engineering, Griffith University
lei.hou@griffth.edu.au



Miss Fereshteh Nayyeri, PhD Candidate
School of Information and Communication Technology, Griffith University,
fereshteh.nayyeri@griffithuni.edu.au

Dr Jun Zhou, Senior Lecturer
School of Information and Communication Technology, Griffith University
jun.zhou@griffith.edu.au

Dr Hong Guan, Professor
School of Engineering, Griffith University
h.guan@griffth.edu.au

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Background review

- Visual bridge condition inspections - assessing current deterioration status and assigning maintenance tasks - ensure ongoing serviceability.
- Limited government investment into new transport infrastructure placed increasing importance upon routine visual inspections.
- Significant amount of inspection data to be collected by inspectors, assessed by engineers and stored for future use.

Source: Context Sensitive Solutions (2005)

Background review

- Human vision-based bridge inspections - subjective and rely upon inspector to accurately capture all information.
- Entire manual process - costly and time-consuming.
- A number of safety risks are associated with field inspectors.
- Inspection requires experienced and highly trained personnel - shortage of required level of qualified inspectors.

Source: http://www.stantec.com

Overview of research objectives

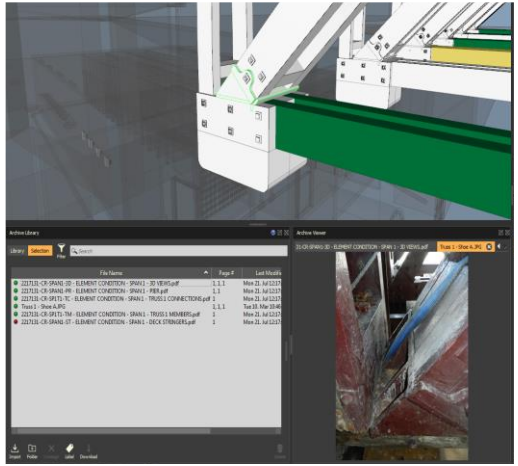
Develop an autonomous and integrated system for bridge inspections through the following two stages:

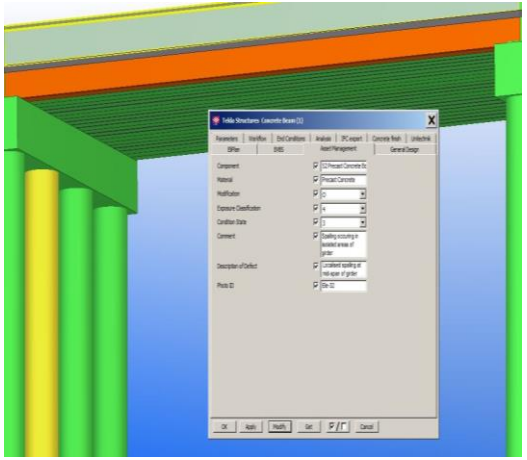
- Stage 1 (Completed) - Building semantic-rich bridge models from which the bridge asset information can be extracted and analysed to facilitate more effective bridge inspections and maintenance.

- Stage 2 (Ongoing) - Developing improved image processing techniques to allow detection of cracks and other defects.

Previous research

Stage 1 – Establishing a semantic-rich database for bridge asset management



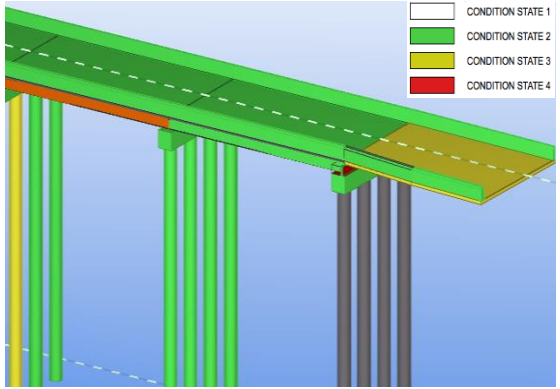


Using Building Information Modelling (BIM) to provide greater efficiency and innovation to the current bridge asset management practice

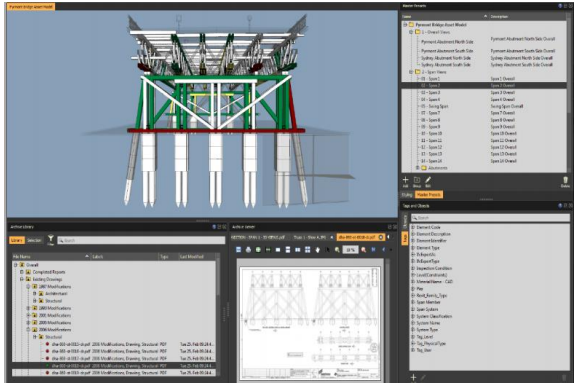
Previous research

Stage 1 – Summary of outcomes

- BIM was implemented to ensure collaboration and knowledge transfer across the entire lifecycle of a bridge project.
- Enable more efficient and informed decisions throughout the asset management phase.



Revit model with condition information assigned

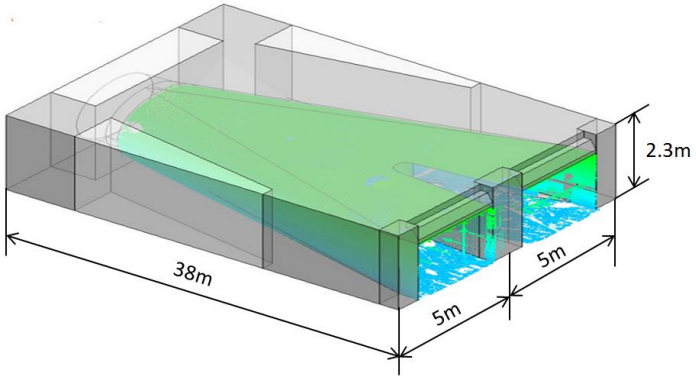


Truss shoe inspection

Sydney Pyrmont Bridge Inspection

Previous research

- 3-D laser scanned modelling (i.e. generating point clouds) of existing structure.
- Integrated with BIM to more effectively and efficiently monitor the current rate of settlement and changes in the geographical features of the structure.



3-D point cloud model overlay within BIM model

Date of Measurement	3-D Laser Scanner (mm)	Electronic Level Gauge (mm)	Disparity (mm)
April 2nd, 2015	-190.5	-197.5	-7
April 25th, 2015	-53	-47.5	5.5
May 28th, 2015	-128	-121.8	6.2

Comparison of settlement results from two monitoring approaches

Yongxin Floodgate Pumping Station Inspection

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Stage 2 - Improved image processing for bridge condition inspection

Aims to achieve two objectives:

1. Compare state-of-the-art image processing approaches such as *Edge Detection (ED)*, *Image Gradient (IG)*, and *Saliency*, propose an improved crack detection method based on the *Structure Extraction (SE)* technique and evaluate the effectiveness of *SE* against *ED*, *IG* and *Saliency*.

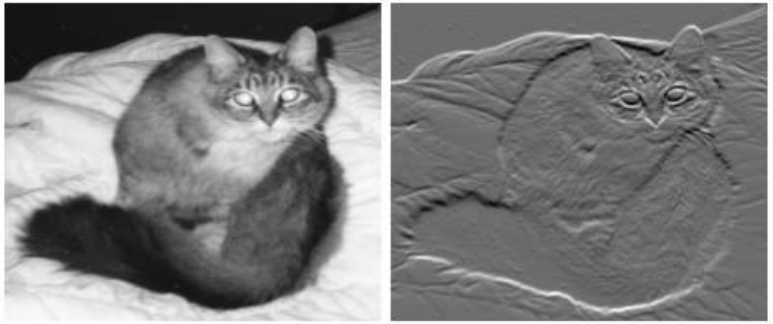
2. Future work will formulate a novel *deep learning* approach based on techniques such as image denoising and blind inpainting.

What are ED, IG, Saliency and SE?

Edge Detection (ED): determines boundaries of objects within images and identifies points as a set of curved line in an image where the image brightness changes sharply.

Original Image After ED

Image Gradient (IG): measures horizontal and vertical changes of color or image brightness values.



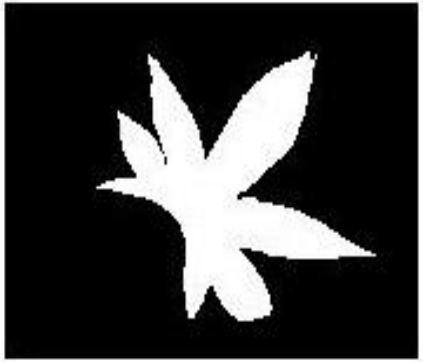
Original Image After IG

What are ED, IG, Saliency and SE?

Saliency: finds a region in an object that is different from its neighborhood in terms of texture, brightness, color, shape and all other properties, from which a salience map is built.

Original Image

Saliency map



After Saliency

What are ED, IG, Saliency and SE?

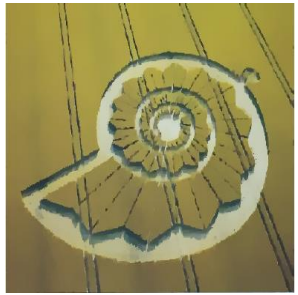
Structure Extraction (SE): Extracts semantically meaningful structures from textured surfaces and removes textures.

- More robust than ED and IG.
- Can also detect more complex structures than Saliency.
- SE can address the weaknesses of ED, IG and Saliency.

Original Image

After SE

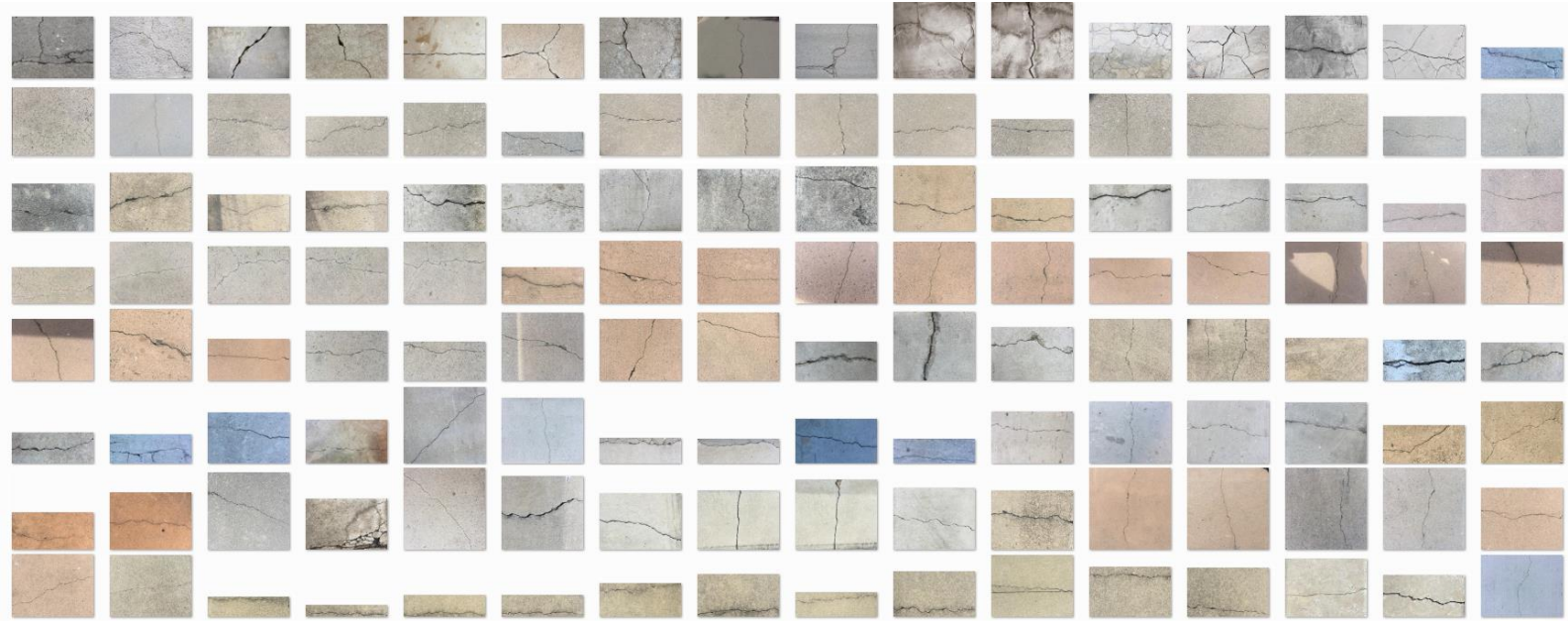
Original Image



After SE

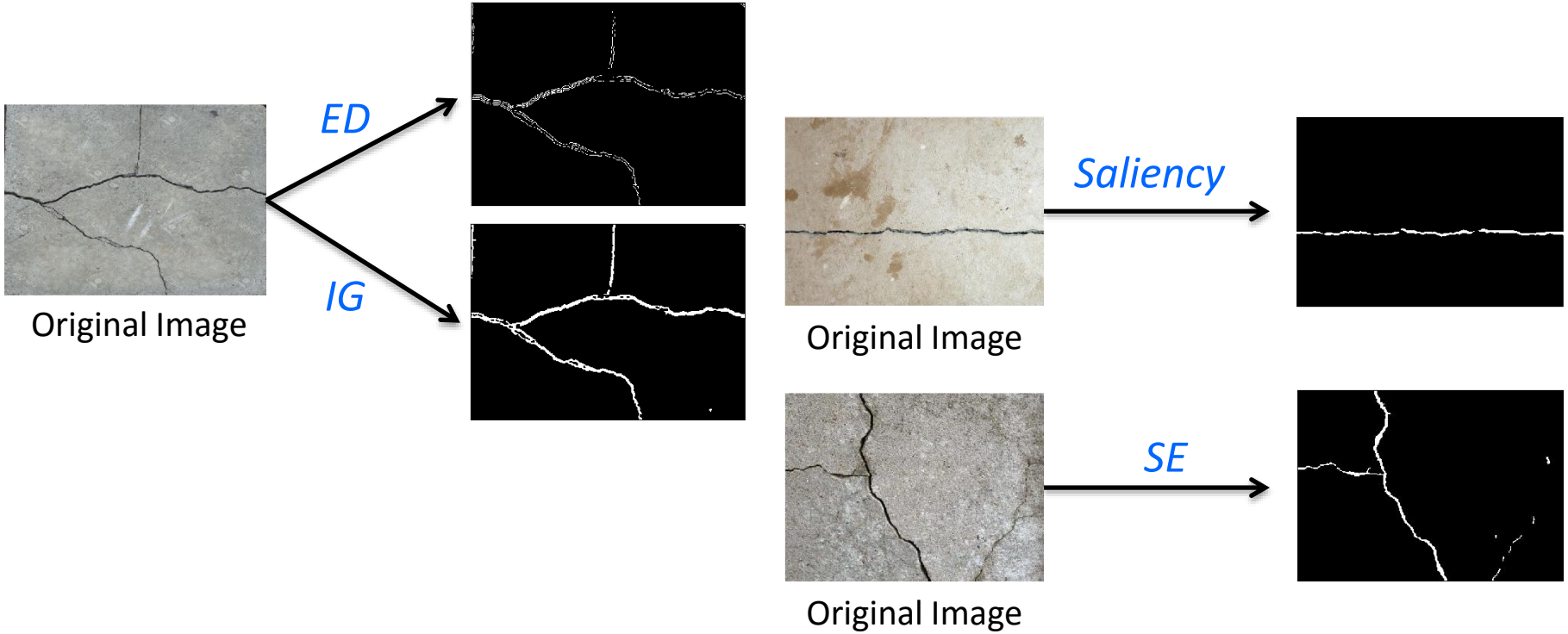
Crack detection

Collection of crack images



Crack detection

Outcomes of *ED*, *IG*, *Saliency* and *SE*



Qualitative evaluation of 4 methods

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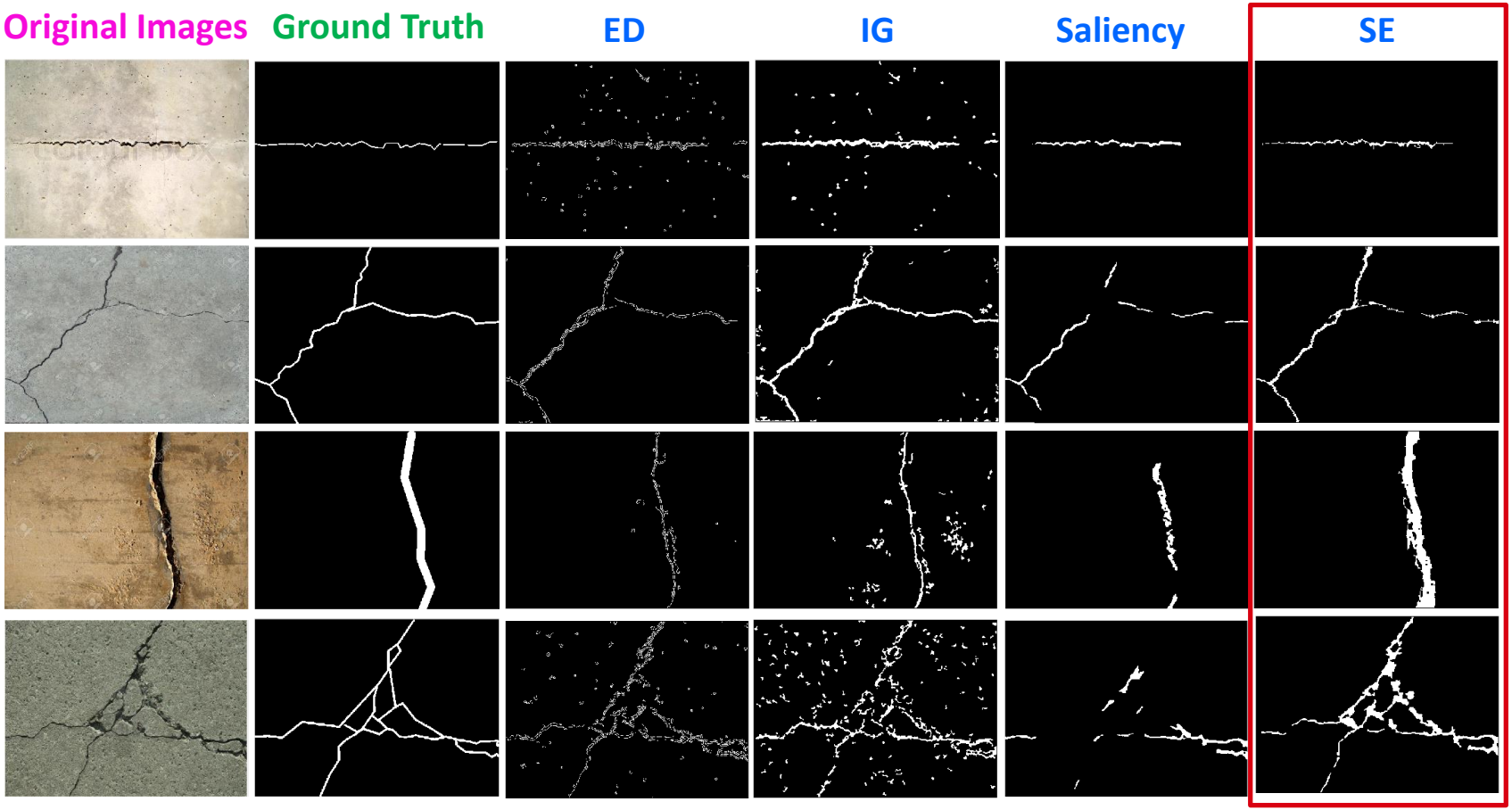

Qualitative evaluation of 4 methods

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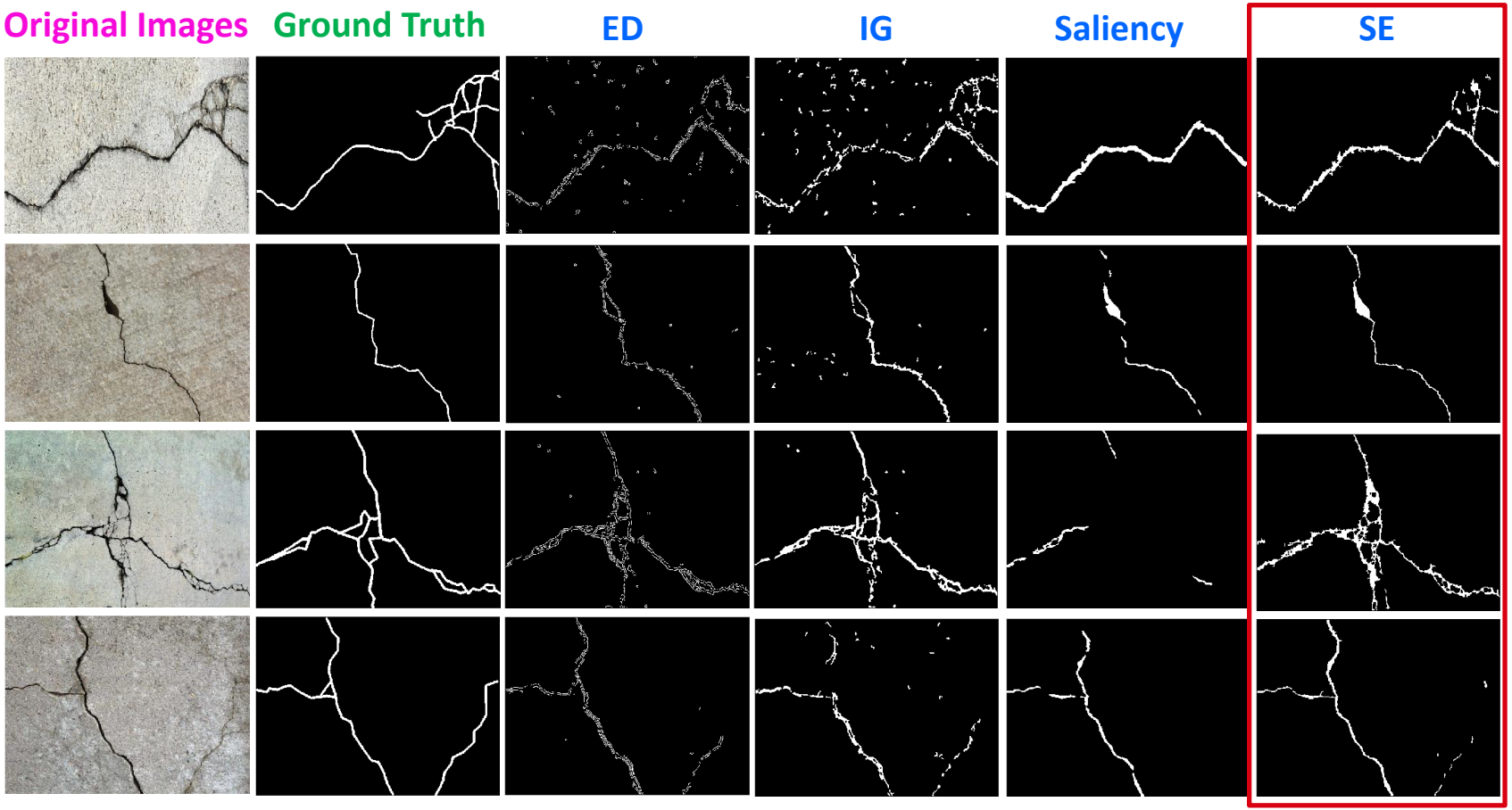
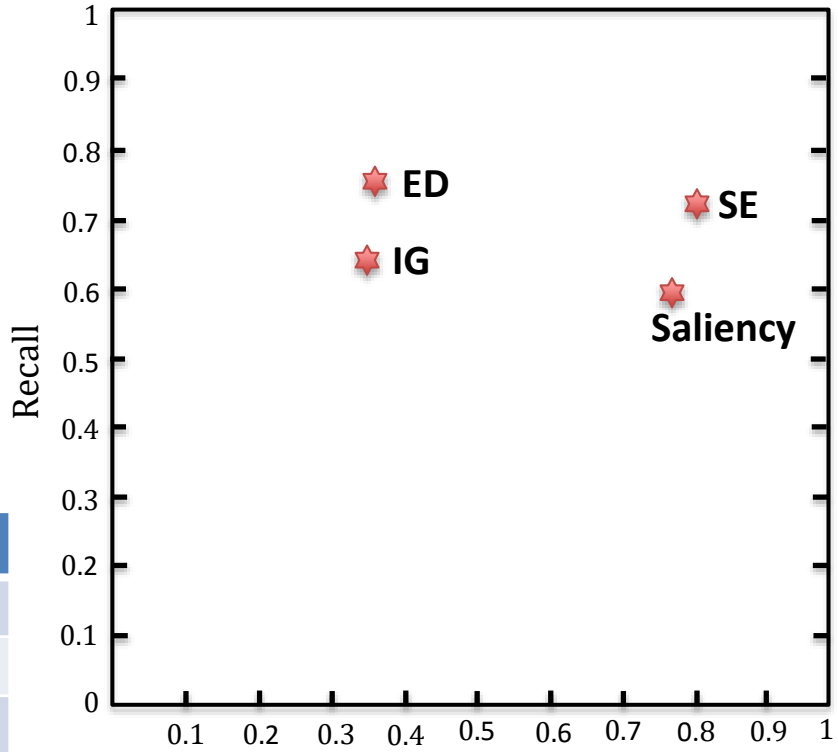


Quantitative evaluation of 4 methods

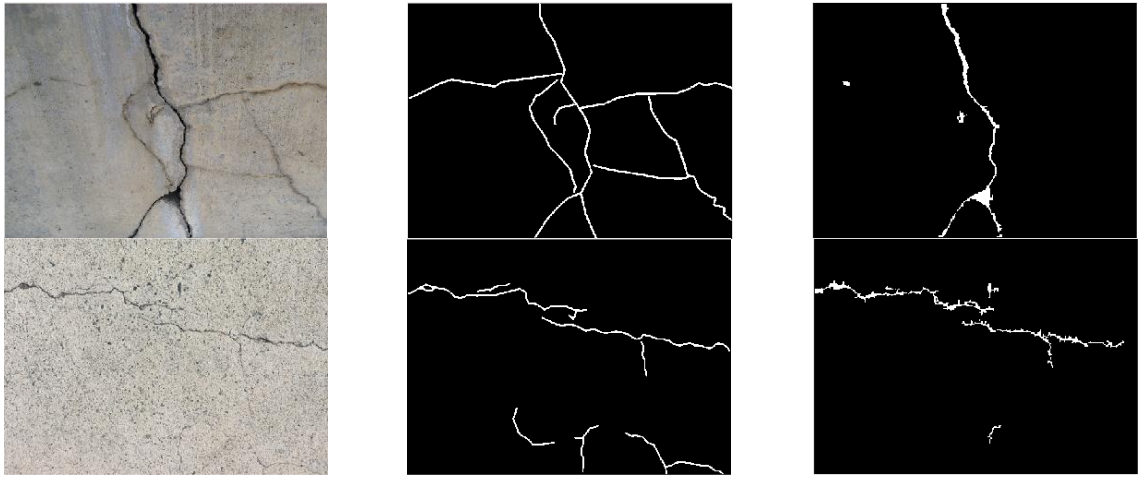
- **Precision** $= \dfrac{\text{Correctly Detected Pixels}}{\text{All Detected Pixels}}$
- **Recall** $= \dfrac{\text{Correctly Detected Pixels}}{\text{All Ground Truth Pixels}}$
- **F–Measure** $= 2 \times \dfrac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$

	Precision	Recall	F-Measure
Edge Detection (ED)	0.365	0.744	0.440
Image Gradient (IG)	0.358	0.656	0.388
Saliency	0.769	0.589	0.624
Structure Extraction (SE)	**0.802**	**0.752**	**0.770**



Limitations of SE

Original Images | Ground Truth | SE



- Complex scenarios unable to be handled by SE

Rough texture

Complex background

Strong brightness change

Deep learning based approach

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- A novel method for detecting cracks by calculating the difference between an original and inpainted images which can be generated via deep learning and sparse image representation.

- Deep learning is more intelligent in automatically extracting useful structures from images, through extensive training of a large amount of data.

- The method will be evaluated based on both qualitative and quantitative measures on an image dataset acquired from real case bridge inspection tasks.

Summary of findings

- Four crack detection approaches are compared. SE is proven to be more advantageous than the ED, IG and Saliency methods.
- SE is still limited in dealing with more complex scenarios.
- To tackle these problems, a novel approach based on the deep learning concept will be developed for more intelligent and robust crack detections.

Thank
you

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