AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

Issue 30, December 2021

Contents

President Message

Tommy Chan

Professor in Civil Engineering, Queensland University of Technology

Dear All,

Covid-19 seems to be never ending. I prepared this update when it was just announced that Australian borders shut on the eve of their opening. Earlier it was expected that fully vaccinated international students, skilled migrants and humanitarian visa holders could be returning to Australia from tomorrow (1 December 2021). One of my PhD students told me that he was so excited to meet his wife and son early next week, after two years of separation due to COVID-19. However now because of the recent five Omicron cases detected amongst returned travellers in Australia, the National Security Committee of cabinet last night decided to defer the step until December 15. It seems that many countries also restricted their borders again, e.g. Japan. Hopefully the situation affected by this Omicron variant will not be as bad as the start of the COVID-19 after we have gained so much experience and medical development in last two years.

In late October, Queensland released the draft State Infrastructure Strategy (SIS) presenting a vision of the State Government's infrastructure requirements over the next two decades. As the State Government identified Infrastructure as a critical component of Queensland's COVID-19 Economic Recovery Plan, they will use infrastructure investment to help boost up its economy and building up a 2032 Games legacy. Out of the 5 focus areas to target action in SIS, we consider that SHM could be very helpful to the Government to achieve its aims, e.g. digital infrastructure, improving connections between urban and regional areas aligned with the growth, developing productive infrastructure, assisting effective decision making, delivering quality infrastructure and effective use of data, digital and innovation. We look forward to this as multi-hundred-billion dollars investment will provide us more opportunity to implement SHM for its practical applications in Queensland. We are so glad that the Victorian Government appreciates so much the technologies of Structural Health Monitoring as they invest $50 million to develop a new technology that will remotely monitor bridges to better manage their maintenance. As stated in my President Message in the 28th Issue of ANSHM Newsletter,

We look forward to having more and more of SHM technologies could be implemented in Australia and no matter the local, State and the Federal Governments could realise how important it is the technologies of SHM to the country.

We hope that Queensland will be the next state having the government large investment on installing SHM technologies. However, avoiding being unable to identify any open and transparent bidding process in awarding the contract to a particular SHM service provider, it is also worthwhile to re-state our concern and expectation here:

We welcome more extensive application of SHM technologies in Australia, and what we are concerned is to ensure the potential users should have a correct expectation of their investment and it will be beneficial to all parties that if an open and transparent bidding process should be introduced for this kind of project. We should not be biased towards some companies and against others. We, ANSHM, with the experts and experienced engineers in SHM are happy and impartial to provide our expert advice to help the potential users of SHM, including various, Local, State, and Federal governments to find the best solution and the best choice for their problems related to SHM.

I originally like to give some discussion on the outcomes of the ARC DP22 round. However, it seems that the outcomes could not be available before I write this update on the last day of November, so I may discuss the outcomes in next updates.

Below are the updates of the month.

Research Collaboration

I am pleased to let you know that the preparation of the establishment of the ARC Research Hub RIIS has been going very well. Besides being the Theme Leaders of the Theme 4 of the Hub, Infrastructure Health Monitoring and Predictive Maintenance, Prof Bijan Samali of WSU and myself will also take up other important roles in the Hub. Prof Bijan Samali will be a

Co-Director of the Hub, looking after the Industry Engagement and Commercialisation and I will be the Research Training Director of the Hub, looking after the research training of the PhD students and the Post -Doc Fellows.

Regarding the ANSHM participation of the Hub, we have received 6 proposals when the first call of participation closed. Since the number of proposals is not many, it is not necessary to call a meeting for the ANSHM Collaboration Task Force Committee to rank the proposals. Bijan and I had a meeting on 16 November 2021 to review and discuss all the proposals submitted. Two of the proposals have not specifically put down the details of their proposed projects, like the aim and objectives of the proposals, how the proposed projects could benefit the Hub as well as ANSHM, aligned with the research needs of the Theme 4 Industry Partners and the amounts that the proposers were going to contribute to support the project, etc., so the two proposals could not be considered. Regarding the other 4 proposals, they are well written and aligned well with the research needs of the industry partners, so basically Bijan is happy to support them. However, there are still other issues we need to deal with as the registration of the PhD candidates working on the projects and how many projects that a particular university could work on. Because of the intellectual property requirements of ARC, we need to ensure that the IP generated from the project from a PhD candidate needs to be resided accordingly on any of the 4 universities of the Hub, i.e. the University of NSW, the University of Melbourne, Western Sydney University, and Queensland University of Technology (QUT). This creates an issue on using the amount to support a PhD candidate registered at a university other the Big 4. As mentioned earlier, we would like to use this opportunity to strengthen the research collaboration within ANSHM, so the principle is to have more of universities involved in this scheme, the better it will be, so we will control the allocation of the fund to ensure not to have a particular university (other than the Big 4 in the Hub) having too much fund allocated to it because not many other universities showing interest at start.
We will discuss all that in the forthcoming Executive Committee Meeting scheduled on 6 Dec 2021. It is also expected to have another call of participation in December 2021 or early January 2022 if necessary.

ANSHM 13th Annual Workshop

I suppose many of you should have registered for our ANSHM important annual event, 13th ANSHM Workshop. We have 63 registrations so far. Although the registration deadline is stated as 12 November 2021, we still accept late registrations. The deadline is set for the convenience of organising the workshop like estimating the number of delegates and who will be attending. Many thanks to those who have already registered which makes the work of the Organising Committee easier. Prof Jianchun Li and Prof Brian Uy are leading the 13th Workshop Organising Committee. As the time is getting closer and closer to the date of the Workshop, 9-10 December 2021, I can see their preparations are in full swing. Many thanks to them.

There will be 10 presentations on Day 1, and 6 project-based presentations on Day 2, covering the latest advancements on SHM and SHM applications for real life projects. For Day 1, each presentation will be lasted for 15 minutes plus 5 minutes Q&A with a 1-hr Panel Discussion concluding all the presentations, revolving around the topics presented in Day 1. For Day 2, in each Session (Session A and Session B) after the 3 presentations of the session, delegates could select and join various rooms for the corresponding 30-minute discussions. Besides, as the industry forum has been a highlight of our previous annual workshops, for this year we will have two separate panel discussions in Day 2 for the topics of Session A and Session B, respectively. We are pleased to let you know that we have invited representatives from the industry including those from the research organisations, private companies and road authorities to be the panellists.

Below is a snapshot summary provided by Prof Jianchun Li about this workshop:

The 13th Australian Network of Structural Health Monitoring Annual Workshop is to be online on **Thursday 9th – Friday 10th December.** The registration is still open (*registration link*). This annual event is brought to engage researchers with industries, share the progress of the major SHM projects and update the latest development and technologies in the broad area of SHM.

The 2-day ANSHM workshop in this year provides presentations and discussions on latest SHM technologies, in particular, the applications of SHM technologies via projects in Australia (*see flyer*).

- *Day 1 workshop program:* **A glance on the latest advances in SHM in Australia** *presented by Australian researchers, includes:*
    - **Session 1:** *Recent developments in Non-Destructive Testing (NDT) and Structural Health Monitoring (SHM)* - 5 invited presentations
    - **Session 2:** *Data-driven and Learning-assisted SHM* - 5 invited presentations
    - **Panel discussion** (live stream only)

- *Day 2: Applied Structural Health monitoring: current SHM Projects in Australia presented by Australian researchers with their industrial partners*
    - **Session A:** Digital Transformation in SHM of Civil Infrastructure
        - **Group discussions** #1
            - Theme Room 1: Industry 4.0
            - Theme Room 2: Digital Twin
            - Theme Room 3: Internet of Things (IoT).
        - **Panel discussions #1** (live stream only)

    - **Session B:** Practical challenges in SHM of Civil Infrastructure
        - **Group discussions** #2
            - Theme Room 1 - Cost effective decision making
            - Theme Room 2 - AI technologies
            - Theme Room 3 - Value of Information (VoI)

- **Panel discussions #2** (live stream only)

The detailed workshop program will be released in due course, which may be even earlier than this issue of the ANSHM Newsletter.

ANSHM Advisory Board Meeting and Annual General Meeting

Please be kindly reminded that we will have our ABM and AGM during the 13th ANSHM Workshop. The details for the two meetings are as follows:

ABM (Only for the ANSHM Advisory Board Members and Executive Committee Members):

Date: 9 December 2021 (Thursday)

Time: 15:00 to 17:00 (AEST)

Zoom details have been provided to all the members of the Advisory Board.

Please email me (tommy.chan@qut.edu.au) if you are unsure of the link

AGM (For any ANSHM Members:

Date: 10 December 2020 (Friday)

Time: 11:40 to 12:30 (AEST)

Registration for AGM will be conducted from **10:40 to 11:10 (AEST)**

As mentioned earlier, we endorsed the amendment of the ANSHM Rules Cl 6.3 in last year AGM (2020), addressing the issue on having online AGM as follows:

6.1 AGM meetings of the Association shall be held at least once each year:

(a) in a venue: or

(b) using technology that gives all Member Representatives a reasonable opportunity to participate; or

(c) a combination of (a) and (b),

to be determined by the Executive Committee.

Therefore, we will have no issue to conduct our forthcoming AGM online.

Election of Executive Committee Members

Besides, you should have received my message dated 15 November 2021 on *the Call for Nominations for Election of Executive Committee Members.* As the message sated, the nomination can be made by sending an email to me (tommy.chan@qut.edu.au) by 3 December 2021.

According to the Rules of ANSHM, the Nominations shall be called at least 14 days prior to the election during the forthcoming Annual General Meeting on 10 December 2021. The election will be conducted using a secure online voting system. For this time, the two-year term of office of the following EC members will be completed:

1. Alex Ng
2. Andy Nguyen
3. Colin Caprani
4. Jun Li
5. Lei Hou
6. Mehrisadat Makki Alamdari
7. Richard Yang

All these seven Executive Committee members are happy to continue their service in the Executive Committee and are willing to be re-elected for the term 2022 to 2023 will. In the upcoming Advisory Board Meeting, we will also review the Executive Committee including the number of members required.

Membership

Annual Membership Renewal

We need to renew our membership around the time of AGM. The plan is to have an email sent out after the ANSHM annual workshop to confirm their annual membership renewal. Because of the pandemic in this year and last year, it is not easy to confirm the core membership and yet we will still try to confirm this. For the next year annual workshop, it is most likely that it will be on real mode so it will be easier to manage to confirm who would like to stay as core members. In the email sent by A/Prof Alex Ng, our Membership Officer, it will be requested to indicate whether the member will attend next annual workshop.

Membership Record

Alex will also try to check the contact information of the members stored in the Membership Record. Besides, Alex will formulate a better system for our membership record to highlight those who are happy to contribute to ANSHM, like attending ANSHM Workshops, Seminars, Forums, facilitating Webforums, sharing their experience or needs in applying SHM, writing articles for the Newsletter, especially those from the industry. Please kindly assist Alex by responding his messages sending to you relating to these.

Publication generated from the 11th ANSHM Workshop

In the last update, I reported that we were approaching the last stage for preparing this monograph generated from the 11th ANSHM Workshop for the celebration ANSHM 10th Anniversary. We originally expected that we could be able to submit the camera-ready versions to the publishers by end of the month. However, as we aim for quality submission, we have requested the publisher to grant a further extension. The publisher has set a new deadline to end of January 2022. This could give us a better time to ensure the highest standard that we could achieve for this monograph. Once ready, we can submit our manuscript well before this deadline. At the time of preparing this update, all chapters have completed final revision except for one chapter still under final proofreading. Besides, only one copyright form is yet to be received.

Publication generated from the 12th ANSHM Workshop

The publication generated from the 12th ANSHM Workshop will be published as a special issue in Australian Journal of Structural Engineers. A/Prof Xinqun Zhu and I will be the Guest Editors of the special issue, with the support of Lei Hou, Richard Yang, Andy Nguyen and John Vazey as the editorial team members. Xinqun has sent invitation to the presenters of the 12th ANSHM Workshop to provide the title, authors, organization, and corresponding author of their papers to be submitted to the Special Issue. So far we have received two responses and more responses are expected.

Forthcoming Executive Committee Meeting

We have scheduled to have our next Executive Committee Meeting to be held on 6 December 2021. This will be an important meeting, besides discussing regular matters, it will be the last EC meeting before the 13th ANSHM Workshop. Hence it will have final rundown of the workshop to ensure the Workshop will be as successful as previous ones and to prepare for the coming ANSHM Advisory Board Meeting and the Annual General Meeting. If you have any items that you would like us to discuss, please send me an email by 3 December 2021.

In the next sections, we will have we will have two articles from our members. The first article is by the researchers from the University of Sydney, titled as *Crack propagation monitoring based on image processing and fractal dimension analysis*. The second article is a short technical note by the researchers from Western Sydney University, describing how they used big data analysis and numerical study to conduct the maintenance of “mud hole” defects on railway tracks by prioritisation.

Stay safe and healthy!

With kind regards,

Tommy Chan
President, ANSHM
www.ANSHM.org.au

Professor Tommy H.T. Chan PhD, ThM, MDiv, BE (Hons I), FHKIE, MIE Aust, CP Eng, NPER,

MICE, C Eng, RPE, MCSCE
President ANSHM (www.ANSHM.org.au)
School of Civil & Environmental Engineering, Queensland University of Technology (QUT)
GPO Box 2434, Brisbane, QLD 4001, AUSTRALIA.
Ph. +61 7 3138 6732; Fax. +61 7 3138 1170; email: tommy.chan@qut.edu.au;
Research profile | **Research publications** | **Google Scholar citations**

Crack propagation monitoring based on image processing and fractal dimension analysis

*Wei Zhang, Daniel Dias-da-Costa**
School of Civil Engineering, University of Sydney, Australia
**Email: daniel.diasdacosta@sydney.edu.au*

INTRODUCTION

Crack localisation and propagation can provide relevant information about the structural safety of civil infrastructures. Cracks can gradually grow, extend and coalesce to significantly reduce local stiffness and lead to severe damage (Munawar et al. 2021). Therefore, it is crucial to develop tools to monitor cracking at early stages. Visual observation is typically deployed in structural health monitoring (SHM); however, this can be time-consuming, labour-intensive, dangerous in some cases, and can entail human errors (Yao et al., 2014). In the past few decades, digital image processing (DIP) has been developed to mitigate the drawbacks of the conventional approach. In earlier studies, fundamental image filtering techniques were applied to extract and characterise cracks (Ogawa et al., 2019). The precision of those methods, however, can be impacted by background noise and shadows. More recently, machine learning (ML) became an active research field in SHH. Still, ML-based methods require a significant number of images to be manually labelled for model training, and typical multi-layer models of ML can result in high computational costs. Interestingly, despite the relevance of cracking and the development of many computational tools, only a limited number of articles have focused on monitoring crack events taking place over inspection periods. In particular, monitoring should be able to detect changes occurring on the cracked surface, rather than comparing two separate analyses on sets of images acquired at different points in time. The study presented here proposes an automatic image processing method that can identify and monitor crack propagation in uncontrolled environments and subject to camera movement, which can be of interest for in-situ applications (e.g. UAVs, handheld cameras). Compared with current DIP-based techniques, the new method is insensitive to background noise (e.g., stains) previously existing over the monitored surface.

METHODOLOGY

The proposed method comprises the following main steps: image registration, image deformation, single-pixel fractal dimension (FD) and crack change extraction algorithms – see Fig. 1. Accordingly, two input images (previous or past frame and reference frame) of the same cracked surface are provided from different inspections with a hand-held camera. An image registration algorithm is then applied to align the coordinate system of the two images. A displacement field is interpolated in the image deformation algorithm to predict surface pixel movements during the inspection period, and the texture information of the two images is extracted by a single-pixel FD analysis. Finally, any crack changes over the inspection period can be detected by directly subtracting the past frame FD from the reference frame FD results.

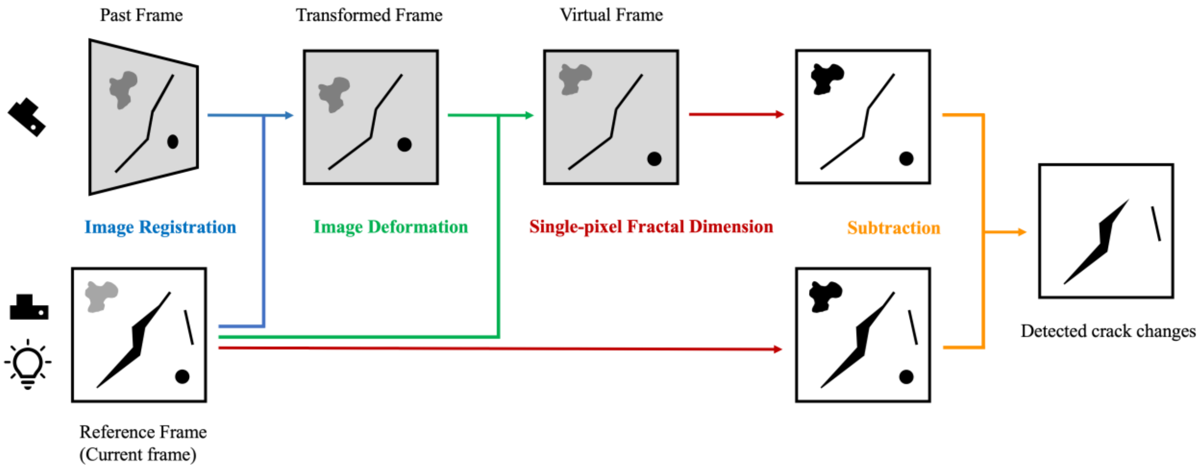

Fig. 1. Overview of the developed crack propagation monitoring framework.

Image Registration

Image registration is deployed to align images recorded from different camera poses into the same coordinate system. As shown in Fig. 2a, the KAZE feature detection and description algorithm (Alcantarilla et al., 2012) extracts and matches feature points among the previous and reference frames. A geometric transformation matrix is generated according to the relative positions of the matched feature points. Based on this matrix, the past frame is mapped into the same coordinate system as the reference frame.

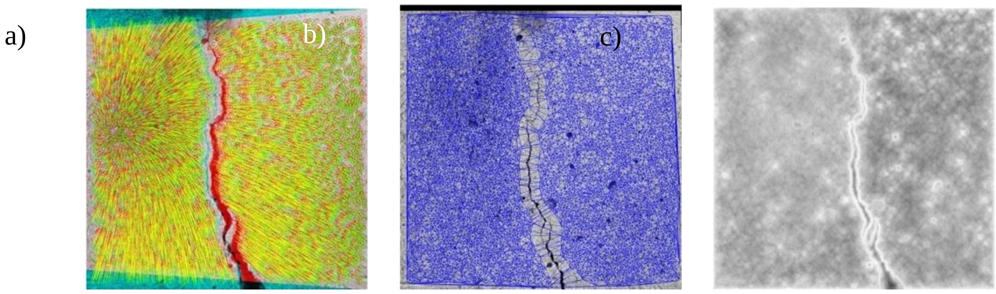

Fig. 2. a) KAZE feature detection and match, b) Delaunay triangulation, c) FD image.

Image Deformation

Due to the onset of cracking, crack propagation, and also changes in crack widths, which are events taking place over the inspected periods, pixels located within the structural surface will move. The image deformation process approximates the existing displacement field to be able to compute pixel movements and then applies them onto the transformed frame to generate a virtual frame – see Fig. 1. It should be mentioned that the displacement field is known at the matched feature points by directly subtracting their location values on the transformed and reference frames. The displacements for any other pixel not matching a feature point need to be interpolated. As shown in Fig. 2b, constant strain triangular finite elements are adopted from the Delaunay triangulation network generated on the transformed frame with nodes matching the feature points. The finite element network then supports the calculation of all displacements as described by Dias-da-Costa et al. (2017). By applying the displacement field on the transformed frame, a virtual frame is generated to predict how the structure surface would look at the same inspection time as the reference frame if the events related to cracking and changes in light conditions did not take place.

Single-pixel Fractal Dimension

The FD is an index related to the texture complexity and self-similarity obtained by calculating the ratio between pattern changes at different scales. Box-counting (BC) is often used for the calculation of the index (So et al., 2017). Cao et al. (2018) proposed a single-pixel BC method that extracts textures by calculating the fractal features of each pixel. Since this method provides a reliable and consistent result for images with different brightness and light conditions, it is adopted in the proposed study. Accordingly, an image of size $M \times N$ as a three-dimensional spatial surface with

(x, y) representing the pixel location and the third coordinate (z) denoting pixel intensity level is considered. For each pixel (i, j), a series of neighbourhood blocks of size $r \times r$ are selected, where the block scale r is an odd integer between 3 and $\frac{\min(M,N)}{2}$. For pixels in the edge of the image, zero intensity is utilised to complete the block. On each block, there is a column of boxes of size $r \times r \times h$, where h is the height of each box that can be calculated as the proportional grey level of blocks with different sizes $(r \times r)$,

$$\frac{G}{h} = \frac{min(M,N)}{r}, \tag{1}$$

where G is the total number of grey levels of the image. It should be mentioned that when calculating the number of boxes covering blocks, n_r, the conventional method by Cao et al. (2018) may produce box over-counting (Panigrahy et al., 2019). In this case, Lai's method (Lai et al., 2016) can be adopted to overcome such limitation., where n_r is given by:

$$n_r(i,j) = \begin{cases} \left\lceil \frac{g_{max} - g_{min} + 1}{h} \right\rceil, \text{if } g_{max} \neq g_{min} \\ 1, \text{if } g_{max} = g_{min} \neq 0 \\ 0, \text{if } g_{max} = g_{min} = 0 \end{cases}, \tag{2}$$

with g_{max} and g_{min} representing the maximum and minimum intensity values in each block.

Considering contributions from all blocks with different scales of r:

$$N_r = \sum_{ij} n_r(i,j), \quad (3)$$

in which case, the FD value for each pixel can be estimated from the least-squares linear fit of $\log(N_r)$ versus $\log\left(\frac{1}{r}\right)$, i.e.,

$$FD = \lim_{r \to 0} \frac{\log(N_r)}{\log\left(\frac{1}{r}\right)}. \quad (4)$$

Therefore, texture images of both the virtual frame and the reference frame can be generated by directly replacing the pixel intensity level with its estimated FD value, as shown in Fig. 2c.

Crack change extraction

After updating the frames as described in the previous step, virtual and reference frames differ only by the crack-related events, in which case by subtracting the virtual frame FD from the reference frame FD, a crack map can be obtained. Some common noise-cancelling methods, such as median filter and edge extraction are applied on the crack growth image to obtain a clearer result.

CASE STUDY AND DISCUSSION

Two groups of crack propagation images (size of 1024×1024 pixel per image) with different background noise are collected as inputs of the algorithm to verify the approach feasibility and measure the monitoring precision. The images were provided by a dataset built by Prof. Tuan Ngo's team from the University of Melbourne (Rao et al., submitted). A filter was applied to introduce the effect of image perspective and differences in brightness on past frames to recreate different image acquisition conditions. The critical steps and results for these two groups of images are illustrated in Figs. 3 and 4.

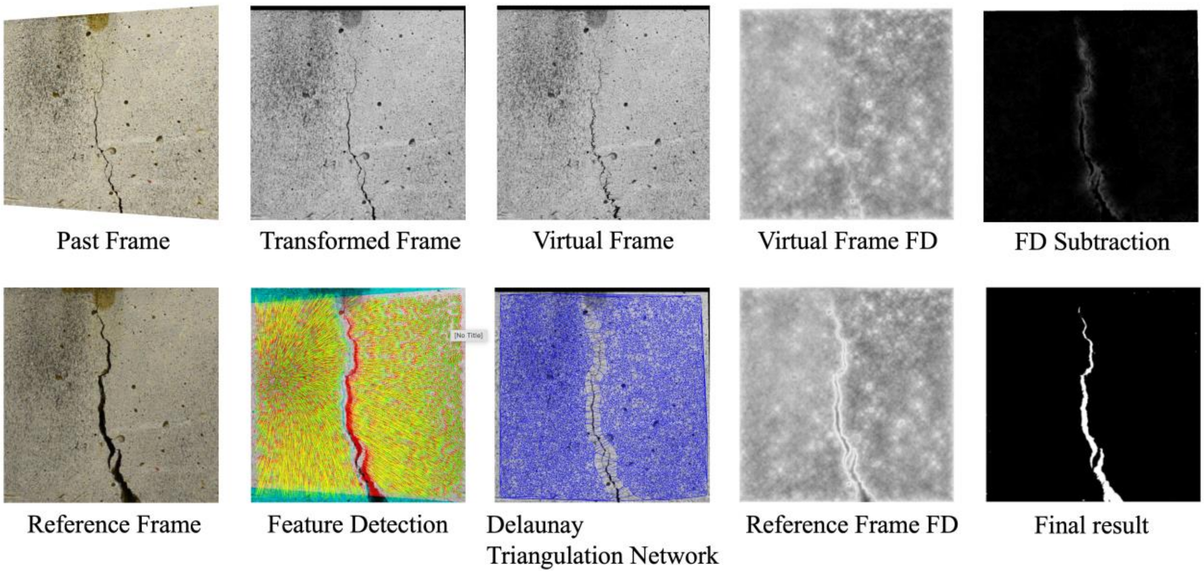

Fig. 3. Main steps and results for case 1.

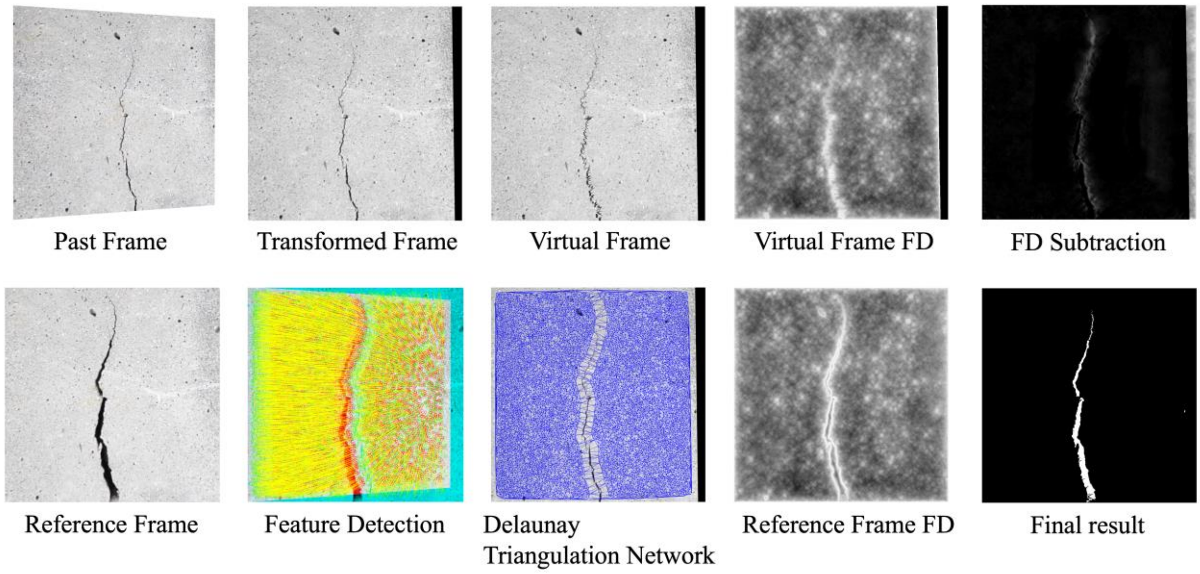

Fig. 4. Main steps and results for case 2.

Figs. 3 and 4 show that the proposed approach can extract the extended cracks in both cases. Despite the previous and reference frames having different camera angles and brightness conditions, the image registration successfully aligned the two frames into the same coordinate system, and all surface pixel movements could be recovered on the virtual frame. To evaluate the performance of the proposed approach, such as the algorithm ability to identify image pixels as background pixels (represented in black) and crack change pixels (white), three criteria (precision, recall, and F1 score) were calculated as follows:

$$\text{Precision} = \frac{TP}{TP+FP}, \tag{5}$$

$$\text{Recall} = \frac{TP}{TP+TN}, \tag{6}$$

$$\text{F1 Score} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}, \qquad (7)$$

where TP stands for true positives, FP for false positives, and TN for true negatives.

As shown in Fig. 5, ground truth images (GT) for the two cases were labelled manually. Results of the three criteria are given in Table 1.

Table 1: Results of the F-measure system three criteria for the two cases.

Case	Precision	Recall	F1
1	0.990	0.891	0.938
2	0.995	0.851	0.918
Average	0.993	0.871	0.928

Fig. 5. a) case 1 GT, b) case 1 extracted result, c) case 2 GT, d) case 2 extracted result.

From Table 1, it can be concluded that the proposed method could provide a consistent enhanced performance regarding the extraction of crack changes. Fig. 5 shows that nearly all surface imperfections could be removed during the process, with the method also being insensitive to differences in light conditions. Nevertheless, as identified in Fig. 5d, the implementation of the FD process may erode the crack boundaries, since the FD value for each pixel, which is computed from the least-squares linear fit, can be affected by outliers.

CONCLUSIONS

This study proposed an automatic crack propagation monitoring method with the potential to be deployed for application with handheld and UAVs in uncontrolled conditions. The algorithm was shown to be insensitive to initial imperfections of the surface of the specimen. It should also be mentioned that the method presented here does not rely on any thresholding process and manually inputted values. The method will be further tested in more realistic conditions with contamination of noise and different camera movements as to determine its robustness and accuracy in a future work.

ACKNOWLEDGEMENTS

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A Technical Note on the Maintenance of "Mud Hole" Defects on Railway Tracks by Prioritisation Using Big Data Analysis and Numerical Study

Ralph Zhang, Helen Wu, and Richard (Chunhui) Yang
School of Engineering, Design and Built Environment, Western Sydney University
E-mail: 17602059@student.westernsydney.edu.au; helen.wu@westernsydney.edu.au; r.yang@westernsydney.edu.au

(This works was accepted to present in ACCM2021, 13th-15th Dec 2021.)

ABSTRACT

Railway track maintenance is the work of ensuring railway infrastructure remains in good condition and provides the foundations for the railway traffic in safety. To achieve this, significant amounts of information and data are required to support track condition evaluation, risk assessment of potential track component failure, and maintenance planning. Mud holes result from the deterioration of ballast and present as severe track geometry defects and pumping action under the dynamic wheel loads. They are widely distributed on the heavy haul freight and passenger railway tracks. Within Australia, mud holes are one of the major reasons for "rough ride" of the train and temporary speed restrictions on track sections. In contrast to several decades ago, vast amounts of data have become available in recent years to track engineers and maintenance planners. However, the effective collection, processing, analysing, and utilisation of this "big data" for decision-making in track maintenance works and the creation of accurate maintenance plans is a challenge for the department of track maintenance. To effectively undertake the risk assessment and maintenance prioritization of

the mud-hole locations on the railway network, a specified analysis model is developed to carry out this work using the "big data." As a powerful numerical modelling tool, finite element models are created to simulate the mud pumping track. In this case, 5 bays of sleeper are considered as it is often found to be the critical case for rough riding (medium-wavelength track geometry defect). The effectiveness of different remedial actions is studied using finite element models by changing the material properties at the defective area for different maintenance practices.

KEYWORDS

Big data, maintenance, mud-hole, prioritisation, numerical study, railway track.

MUD HOLE DEFECTS

A "mud hole" is a kind of common and widely distributed railway track defect, where the sleepers are surrounded by mud rather than clean ballast. Mud-holes occur when the ballast becomes contaminated (or fouled) with fine materials. This can be due to severely deteriorated ballast condition, which is a breakdown of the ballast material and/or the failure of the formation (the track subgrade), which rises through the ballast. The fouled ballast retains water, prevents effective drainage, and usually results in poor track geometry. For the railway revenue, mud-hole is one of the major reasons for "rough ride" of the train and temporary speed restrictions on track sections. There are three types of mud holes, which are classified according to the cause of generation.

Fig. 1 Mud-holes occur when the ballast becomes contaminated (or fouled) with fine materials.

BIG DATA

Concepts of Big Data

Big data is data that are too large and complex to be handled by traditional databases. Big data can be formally defined as a collection of very huge data sets from which it is practically impossible to analyse and draw inferences. Rapid technological advancements led to an exponential increase in the size of data. Big data usually has a multidimensional structure and can be characterised by the five Vs: volume, velocity, variety, veracity, and value.

Application of Big Data for Track Maintenance

In recent years, the railroads industry has started to make extensive use of its big data. The industry's focus is on optimizing capital infrastructure and safely managing operations while keeping costs under control. One of the major reasons the railroad industry is so interested in leveraging big data is the potential for considerable value adding with relatively little expenditure. As pointed out by Zarembski (2016), "Rather than collecting new data from new sources, deep data analysis can provide new information from extant data, i.e. using data that is already available. Integrating multiple data sets and making sure data cross references is a big challenge".

METHODOLOGY AND ALGORITHM

Regarding the specially designed analysis model for mud hole prioritization work, all the factors affecting the generation of mud holes were categorised into two parts: the "system average damage factors" and "engineering adjustment factors."

The "system damage factors" are included in track maintenance practices and must be combined with all three major reasons for the development of mud holes, which are:

- deterioration of ballast
- drainage issues
- evenness of rail top surface (rail surface defects).

In quantifying the average "weight" of the three major factors, in terms of track maintenance, the approximate results were:

- deterioration of ballast: 40% – 50%

- drainage issues: 30% – 40%
- evenness of rail top surface: 20% – 30%

The design features and track conditions of individual track sections were used as the “engineering adjustment factors” to modify the risk ranking scores of these three major reasons.

A mathematical formula to represent the above general concept is:

$$S_{BH} = \sum_{i=3}^{3} \sum_{n=1}^{n} R_{BHi} \times F_{Mn}, n = 3 \; to \; 5$$

where,

S_{BH} = overall score of risk ranking for each mud hole location;

R_{BHi} = risk ranking scores of the three major reasons for the development of mud holes;

F_{Mn} = factors for each of the reasons (i.e. the “engineering adjustment factors”); and

n = number of factors.

NUMERICAL STUDY

The finite element model for the mud-hole track is shown in Figure 2, in which 5 sleeper spacings along the track is simulated as severe deteriorated ballast layer and track formation. This is used to represent one of the most typical rough riding which is initiated from mud-hole resulted medium wavelength track geometry defect.

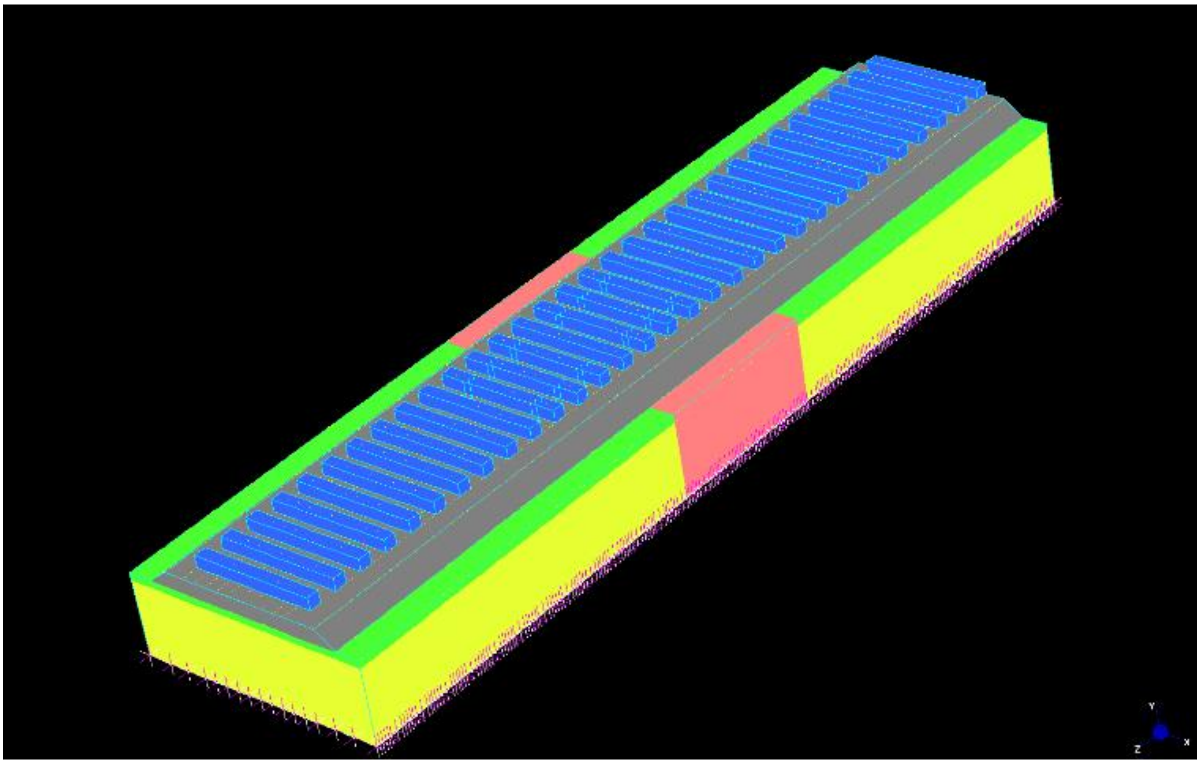

Fig. 2 FE Modelling of a railway track with mud pumping (red elements = mud pumping)

SUMMARY

As a practice of big data approach, the "Systematic Factors Weighted Method" model has been utilised to undertake the mud-hole prioritisation work. It has been shown that it is an accurate and effective method to systematically study, assess and prioritise the condition of bog hole locations.

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Conference News

- The 5th Australasian Conference on Computational Mechanics (ACCM2021), Sydney, Australia, 13th - 15th December 2021, organised by Assoc. Prof. Sarah Zhang, Prof Yang Xiang, and Prof Richard Yang.

  Webpage: https://westernsydney.edu.au/accm2021

- Mini Symposium "Advances in Bridge Monitoring Strategies: Novel Technologies and Information Fusion" in the 11th International Conference on Bridge Maintenance, Safety and Management (IABMAS2022), Barcelona, Spain, from 11 July to 15 July 2022. Organised by Prof. Kim, Dr Makki Alamdari, Dr. Zhang and Dr. McGetrick.
  Webpage: https://congress.cimne.com/iabmas2022/frontal/MiniSymposia.asp
  Abstract submission due: 9 July 2021
  Full paper due: 15 November 2021

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If you have any comments and suggestions, please contact

Newsletter Editors:

Dr. Mehrisadat Makki Alamdari, University of New South Wales.

Email: m.makkialamdari@unsw.edu.au

Dr. Jun Li, Curtin University.

Email: junli@curtin.edu.au

Dr Andy Nguyen, University of Southern Queensland

Email: Andy.Nguyen@usq.edu.au

Prof. Richard Yang, Western Sydney University.

Email: R.Yang@westernsydney.edu.au