AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

CIVIL ENGINEERS ANSHM

Newsletter

Issue 31, March 2022

Contents

President Message

Tommy Chan

Professor in Civil Engineering, Queensland University of Technology

Dear All,

First of all, I would like to extend our warmest welcome to Peter Runcie of Natirar Consulting Services to the Advisory Board of ANSHM. In the last Advisory Board meeting on 9 Dec 2022, he was proposed to be invited to join the Advisory Board. Besides, Mahes Rajakaruna of Main Roads Western Australia suggested to have Yasoja Gunawardena replacing him serving at ANSHM AB from Main Roads Western Australia. Similarly, Prof Wije Ariyaratne also suggested Parvez Shah to serve at the Advisory Board representing Transport for NSW. The two suggestions were endorsed by the ANSHM Executive Committee (EC) in the last EC meeting on 21 Feb 2022. Both Parvez and Yasoja have also accepted the invitation.

Peter, Parvez and Yasoja, Welcome on Board!

Actually, Peter is not new to us as he had been sitting at ANSHM Advisory Board for many years until 2018. He left the board because of the change of his job nature. It was a loss to ANSHM when he stepped down from the Advisory Board because he had been a valuable asset of ANSHM. Now his work is more related to SHM and I am so glad that he joined us again. We also thank Mahes for his continuous support and contribution to ANSHM. It's a pity that he could not sit at the Advisory Board because of his time commitment but thank him so much for recommending Yasoja to replace him representing Main Roads Western Australia in the Advisory Board. We believe Yasoja will continue Mahes' support to ANSHM. Parvez will also strengthen the connection between TfNSW and ANSHM.

Also, the membership applications of Prof Jun Ma from University of South Australia and Dr Bipin Shrestha from SMEC were approved in the last EC meeting on 21 Feb 2022.

Jun and Bipin, Welcome on Board as well!

At the start of 2020, United Nations Secretary-General António Guterres stated that "The New Year has begun with our world in turmoil". However, when the February of 2022 arrives, it seems that it is more correct statement to describe the situations in 2022. When we are approaching the end of February, besides being in the pandemic caused by the COVID-19, Russia invaded Ukraine, and Queensland and New South Wales are experiencing floods like the disaster in 2011. When I am writing this update, it is the fourth day of the Russian invasion and many places in Queensland and North NSW are affected by the floods. Queensland Premier Annastacia Palaszczuk said the intense weather like an unrelenting rain bomb hitting the state is "like an unpredictable cyclone". Something unpredictable could be very disastrous. We who are conducting research on Structural Health Monitoring, is trying to develop various techniques to predict risk happened to a structure earlier so that risks could be mitigated, timely decision could be made, and works could be done to save lives and costs.

Although at the moment, we are still not sure when the Russian invasion of Ukraine could be stopped or when the Queensland and NSW floods stop and we could be recovered from the floods, it seems that the pandemic caused by COVID-19 could end soon. The director of the World Health Organization's (WHO) Europe office said in the early February that Europe is entering a "plausible endgame" to the pandemic (4 Feb 2022 ABC.net.au). Australia has also reopened its international border on 21 February 2022 for the first time in nearly two years, except Western Australia, the borders (interstate and international) will open on 3 March 2022. Also, the Victorian premier, Daniel Andrews, announced that from 25 Feb 2022 masks will only be required in certain settings including public transport, hospitals and primary schools, and for workers in hospitality, retail and large events in Victoria. Similarly, the Queensland premier, Annastacia Palaszczuk, also said her government would relax the requirement to wear masks in most indoor settings, from 4 March 2022. Nevertheless, some infectious disease experts consider such relaxation might not signal the end of the pandemic. Anyway, let's hope for the best and get used to live with Covid-19 with our life returns to normal as much as possible. I am also pleased to keep receiving information inviting me to join various face to face rather than on-line conferences. QUT has also allowed business travels, mainly intestates, as well.

Below are the updates of the month.

ANSHM Achievements and Activities 2021

In the last AGM, I gave a report on ANSHM achievements and activities. I hereby summarise them as follows:

1. *Membership*

   ANSHM has grown a lot since its establishment in 2009. We have now more than 100 members from 57 (54 last year) organizations that include 20+1 universities (1 from University of Surrey), 26 private companies, 6 government authorities and 3 research institutes. The numbers of universities and private companies are increased by 1 and 2 respectively since last year.

2. *Newsletter*

   In 2021, we have four quarterly newsletters from issue 27 to issue 30. We have a breakthrough to have articles not only from the academics but also from the industry. The Editorial team has done a good job to chase up to have at least two articles for each issue.

3. *Special Issues/Monograph*

   To celebrate the 10th anniversary of ANSHM and showcase our developments in the last 10 years, we prepared our 2nd Monograph and the editorial work has almost completed. There are 11 chapters. We hope to have everything ready by the end of January 2022. The Founding President of ISHMII, Prof Aftab Mufti will write the preface for the book.

4. *Technical Workshop*

   We originally planned to have at least one technical workshop to be held in 2021. However, because of COVID-19, we need to postpone it to 2022 when the pandemic is under control.

5. *ANSHM Web Forum*

   Again, it was impacted by COVID-19 and we will explore and see how it could be done next year.

6. *13th ANSHM Workshop*

   Same as last year, because of COVID-19, the Workshop was held using a virtual mode. Compared with previous ANSHM Workshops, this workshop has a breakthrough to have more involvement with the industry and interaction.

7. *ANSHM Special Session*

   Dr Andy Nguyen, A/Prof Alex Ng and myself organised an ANSHM Mini-Symposium (MS-26) in ISHMII-10, which was conducted fully on-line.

8. *SHM Guidelines*

   We submitted a tender for an Austroads project (ABT6203 Structural and Real-Time Bridge Health Monitoring) on preparing SHM Guidelines. In our submission, we requested some changes of terms and conditions of the consultancy agreement with AustRoads based on the advice of the QUT Legal but these were not accepted, so we withdrew our submission. Now the Guidelines are prepared by RMIT and we provided comments on its draft. It is under the industry review.

9. *SHM Standards and Specifications*

   It has been identified in the Advisory Board Meeting in 2020 to prepare SHM standards and specifications. It is very important to help us clarify a lot of unnecessary expectations from industry. Last year progress of this this task was largely impacted by COVID-19. We will continue to work on it next year.

10. *ANSHM Website*

    Updates have been conducted regularly. We will continue to improve the webpage to help promote ANSHM more

11. *ANSHM Who's Who*

    It is on hold. We hope that it could be done in the coming year.

12. *Research collaboration.*

    i. ANSHM has been working on promoting SHM implementation via research collaboration through various Collaboration Platforms, e.g. Industrial Transformation Research Hubs, Smart Crete CRC and Building 4.0 CRC.

    ii. The Victorian Government announced to invest 50 million on remote monitoring bridges for better maintenance. We hope more states in Australia to have this kind of investment to demonstrate the benefits of SHM.

iii. Prof Bijan Samali of WSU and myself are leading a SHM Theme in the newly awarded Research Hub with an ARC funding of $4.98M. We will try to make it as a great opportunity to engage ANSHM participation in the Hub for better collaboration within ANSHM to work on SHM projects in the Hub.

13. *Successes in ARC Grant Applications*

Same as last year, many of the ANSHM Executive Committee members and Advisory Board members receiving ARC funding supports which include three Discovery Projects, two Linkage Projects respectively in DP22 and LP21 rounds totalling an amount of $ $2,237,385.

To summarise, although we are in the pandemic, ANSHM still performed well in 2021. I should really thank all Executive Committee members and the Advisory Board members for their continuous supports and hard work during this difficult time.

First Executive Committee Meeting in 2021

Our 1st Executive Committee Meeting in 2022 was held on 21 Feb 2022. Based on the tasks identified during the discussions in the last Advisory Board Meeting on 9 Dec 2021 and the last Annual General Meeting on 10 Dec 2021, we have allocated the EC members roles and duties as follows.

i. Prof Jianchun Li as the Deputy President of ANSHM will continue to prepare Who's Who of SHM in Australia for people to better understand what we have been doing and what we have achieved, plus a directory of our expertise in various areas of SHM, the follow-up work of 13th ANSHM Workshop, as a Research Collaboration Task Force member, and hosting 14th ANSHM Workshop with Prof Brian Uy of UNSW if it is decided to have a physical ANSHM Workshop to be held in Sydney .
ii. Prof Richard Yang of WSU to be a co-Editor of ANSHM Newsletter and assisting A/Prof Xinqun Zhu of UTS on organising technical workshops.
iii. A/Prof Xinqun Zhu of UTS is in charge of organising technical workshops/Short Courses with the assistance of Prof Richard Yang and preparing SHM technical notes.
iv. Dr Andy Nguyen of USQ will be our External Affair and act as a co-Editor of ANSHM Newsletter while Dr Mehri Mehrisadat Makki Alamdari of UNSW is having her special leave until October 2022.
v. A/Prof Colin Caprani of Monash U will be in charge of preparing SHM standard/guidelines and as a Research Collaboration Task Force member.
vi. Dr Ulrike Dackermann of UNSW will be our Workshop coordinator and assist Colin to work on SHM standard/guidelines
vii. A/Prof Alex Ng of UoA will continue to be our Membership Officer and as a Research Collaboration Task Force member.
viii. Prof Hong Guan of Griffith University will continue to be in charge of ANSHM Webpage and follow-up work of ANSHM 2nd Monograph.
ix. A/Prof Jun Li will continue to be a co-Editor of ANSHM Newsletter and as a Research Collaboration Task Force member. .
x. Prof Tuan Ngo of UoM will continue to be working in a task force for the Exploration of Funding Opportunities and research collaboration together with Jianchun, Alex, Colin and myself.

xi. Dr Lei Hou of RMIT will continue to work on Webforum including the use of social media platforms like Youtube, Facebook, LinkedIn, etc.

xii. John Vazey as a member of the Advisory Board will continue be our Internal Affairs and Industry Coordinator.

xiii. Dr Mehri Mehrisadat Makki Alamdari of UNSW is having her special leave until October 2022.

Research Collaboration

As mentioned earlier that, the establishment of the ARC Industry Transformation Research Hub on Resilient and Intelligent Infrastructure Systems in urban resources and energy sectors (RIIS in short) will create great opportunities for us to collaborate to conduct research on SHM. ARC has approved an amount of $4.98M for this Hub. Its Theme 4, being led by Prof Bijan Samali and myself, is Infrastructure Health Monitoring and Predictive Maintenance which is mostly on SHM. We have around a total of $2.7M ($1.2M from ARC and $1.5M from 2 Industry Partners) of funding to conduct research on SHM. The Hub Director agreed to support the original plan of ANSHM participation in the Hub and will support researchers (PostDoc and PhD students) to be recruited by RIIS working under various ANSHM EC members as their supervisors at their corresponding universities as long as the projects are aligned with the research specified in the agreement with the industry partners. The formerly project participants of approved EOIs will be informed about the specified research areas of the relevant industry partner/s in Them 4 and formulated their projects accordingly to ensure the research areas specified in the agreement will be covered in the projects. EOIs of new collaborations will also be called later.

ANSHM 2nd Monograph

I am so pleased to let you know that our 2nd Monograph, celebrating 10th Anniversary of ANSHM has entered the Page Proofs stage of production and will be published soon. Now the Chapter Coordinators are requested to proofread and index their chapters and Prof Hong Guan, Prof Jianchun Li and myself aim to send the correct poofs to Nova Science Publishers Inc.., the publisher of the book by the deadline of 7 March 2022.

There will be 11 chapters in the book, as follows:

- Chapter 1: Damage Detection and Model Updating of Civil Engineering Structures
- Chapter 2: Effective Sensitivity-Based Model Updating of Cable-Stayed Bridges Considering Monitoring Data Variability
- Chapter 3: Smart and Mobile Sensor Networks for Bridge Structural Health Monitoring: An In-Situ Experimental Study
- Chapter 4: Damage Detection of Submerged Structures Using Guided Waves
- Chapter 5: Classification for Images of Corroded Steel by Image Processing Technology
- Chapter 6: Data-Driven Structural Health Monitoring Based on Deep Learning Techniques
- Chapter 7: Robustness of Deep Transfer Learning-Based Crack Detection Against Uncertainty in Hyperparameter Tuning and Input Data
- Chapter 8: Smart Automated Road Fault Detection for Improved Road Maintenance Planning in Australia
- Chapter 9: Applications of Non-destructive Damage Evaluation and Structural Health Monitoring in Railway Track Maintenance

Chapter 10: Risk Management and Prioritisation of Rail Service Failures in Railway Track Maintenance
Chapter 11: Digital Twin Approach for Lifecycle Management of Large-Scale Civil Infrastructure

It can be seen that the eleven chapters are organised in five topic clusters: physical model-based updating and damage detection for bridges and buildings (Chapters 1, 2), smart and mobile sensor networks for bridges and partially submerged structures (Chapters 3, 4), data-driven machine learning based SHM method (Chapters 5 to 8), SHM in railway track maintenance and management (Chapters 9, 10), and finally, digital twin approach for lifecycle management of large-scale civil infrastructure (Chapter 11).

Publication of the book is expected within approximately six weeks after Nova Science receives the final page proofs of the entire manuscript. Publication in digital form takes place at approximately the same time as the printed version.

Top Scientists in ANSHM

Elsevier has created a publicly available database of over 100,000 top-scientists that provides standardized information on citations, h-index, co-authorship adjusted hm-index, citations to papers in different authorship positions and a composite indicator, classifying the Scientists into 22 scientific fields and 176 sub-fields. The selection is based on the top 100,000 by c-score (with and without self-citations) or a percentile rank of 2% or above. I am so pleased to notice that many ANSHM Advisory Board members and Executive Committee members are on the list of this percentile rank of 2% or above, indicating their status in their fields. Besides some are even on the top 1% or higher of this top scientist list. For details, please refer to https://elsevier.digitalcommonsdata.com/datasets/btchxktzyw/3.

The ANSHM Newsletter

In the next sections, we will have two articles from our members. The first article, written by researchers from James Cook University and Rockfield Technologies Australia, discusses the role and current status of Digital Twins in Asset Management whereas the second article presents the way USQ's researchers make use of standard smartphones and artificial intelligence (AI) to create a modern cost-efficient smart tool that can assist a municipality in dealing with incoming road repair requests greatly improving current road asset maintenance planning and management practice.

When I was writing this President message, I am very concerned about the conditions of Ukraine and the people there as well as those who lost their loved ones or their homes because of the floods. My heart especially hurts for them. May peace and strength be with them!

Stay safe and healthy!

With kind regards,
Tommy Chan
President, ANSHM
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Digital Twins in Asset Management

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Overview

Digital Twin (DT) is the digital abstraction of a physical entity, built as an aggregation of multiple data sources, models, simulations and bi-directional data flow across the physical and virtual objects. There is increasing interest in the use of the DT for state assessment, damage detection, optimization, control, "what-if" analyses and Remaining Useful Life (RUL) assessments. Development of the DT is supported by (a) Numerical Simulations, (b) Multi-Physics Modeling, (c) Data driven modeling assisted by Deep Learning and Machine Learning and (d) Hybrid approaches (synthesis of b & c). An adaptable eight dimensional model of DT enabling digital monitoring and functional improvement across the life cycle of an entity is shown in Figure 1 (Stark, 2019). An environment of Industry 4.0 or Smart Manufacturing consists of Cyber Physical Production Systems (CPPS), increasing volumes of data generated from the assets, Industrial Internet of Things (IIoT), cost-effective sensors, advanced computing and communication capabilities as well as use of technologies like Augmented Reality (AR) and Virtual Reality (VR). A framework of enabling technologies for the DT supporting the convergence of physical and virtual entities is presented in Figure 2 (Tao, 2019).

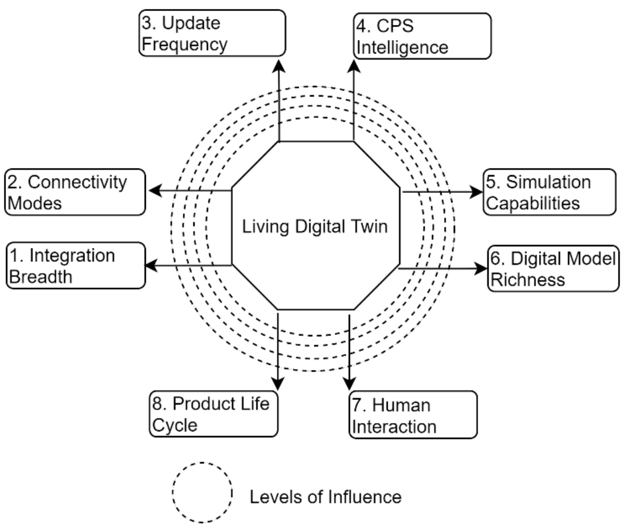

Figure 1. Eight Dimensional Model of DT

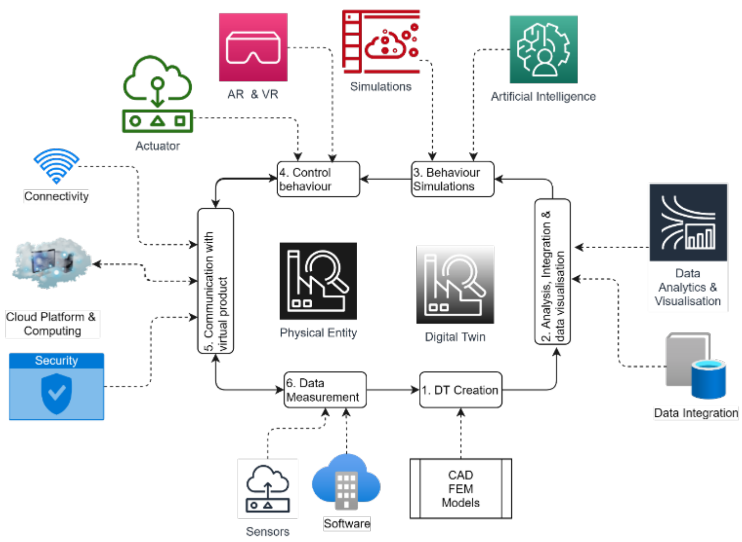

Figure 2. Enabling technologies for DT

Apart from being the single source of truth, repository of data and decisions, the DT also learns from historical state data, has means for visualization and functions as interface for training stakeholders.

DT for Asset Management

The value driver for asset maintenance strategies has shifted over the years from Preventive through Condition Based to Predictive and ultimately to knowledge enabled Prescriptive Maintenance. Decision Making in Asset Management requires appropriate tools and techniques throughout the asset life. However, increase in complexity of asset systems leads to gaps in understanding their operational performance and associated risks. Throughputs required to meet the business demand, necessity to continue operating until a planned shut-down, concurrent influence of multiple failure modes and unknown failure modes are some of the reasons for such uncertainty. Modeling and response anticipation to all such scenarios is not possible during the system design and construction stages. As an artefact supporting asset life cycle, the DT in such an environment is required to be reusable, interoperable, maintainable and extendable throughout its own life cycle.

Building Information Modelling (BIM) functions as the basis for DT-embedded asset management in the built environment. One of the initial steps in the operational phase is to iron out the discrepancies across the as-built and as-constructed versions of the infrastructure in BIM. Finite Element Models incorporating time-dependent variations in properties and validated using sensor data is a key element in the DT development. This, combined with an overlay of risk model is significant for decision making in the case of assets like dams and bridges with little warning of deterioration, limited understanding of failure mechanisms and extreme event consequences. There is fair amount of confidence in sensors and data acquisition systems for structural response characteristics, geometry changes and loading. Integrating the large datasets, effective data processing and converting the outcomes to wholesome actionable advices an area requiring further work. DT applications for smart buildings, precincts and open spaces providing services for energy management, space utilization, anomaly detection, maintenance optimization and structural health monitoring are being developed.

Summary

Although the DT is found to be promising across multiple engineering domains, the current state of development has not reached a level of maturity acceptable to industry practitioners. Being an emerging field, majority of use cases with DT are at component level while the end goal is to have such instances integrated to represent a complete asset system. Managing multiple sensors with differing sampling rates, seamless communication across data capturing systems, missing data and faulty sensors are some of the constraints associated with DT data. On a related note, the capabilities and stakeholder appetite for full control of physical entity by the DT is not yet realized. Accessibility of the developed DT by collaborating stakeholders from different organizations is crucial and inevitable, and necessitates access rights, secure data sharing and cyber security,.

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Automated Road Fault Detection for Improved Maintenance

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Road pavements deteriorate overtime and require timely maintenance to ensure they deliver expected levels of service. However, the increasing footprints of roads and highly manual inspection practices bring considerable challenges for asset inspectors to ensure road faults are detected and repaired without delay. Many municipalities receive multiple daily requests that include images from members of the public to repair road faults, yet these are often checked manually, which is a time consuming and labour-intensive exercise. To this end, this article presents an automated method to process road fault images taken and submitted to a local municipality by members of the public using a standard smartphone. The premise of work is to introduce a modern cost-efficient and less labour-intensive smart tool using artificial intelligence (AI), assisting a municipality in dealing with incoming road repair requests greatly improving current road asset maintenance planning and management practice.

Introduction

It is common knowledge that local municipalities are responsible for the maintenance of road pavement. Often, members of the public are provided with various tools to submit requests for repair for a range of public infrastructure including road pavement. With ever increasing reliance on road networks to provide reliable and safe transportation for our daily lives, the need for a road pavement to be in good repair is paramount [1]. For every request submitted to the local municipality, an inspector is required to assess it and determine the course of action. This involves time consuming and tedious manual assessment of the image to determine the type of faults (cracking, potholes). In today's technological transformation, road pavement faults can be easily identified through Artificial Intelligence (AI), and the faults in any image can be recognised using Deep Learning (DL) fed into the AI database to make it more intelligent. As such, an automated smart, less labor intensive and cost-efficient tool is warranted to help municipalities address existing practices for better maintenance planning.

Image acquisition and processing

There currently are various image capturing devices commercially available which can be used to take good quality images. Smartphone cameras, handheld cameras or cameras mounted on vehicles (trucks or cars), trains, bikes and unmanned aerial vehicles (UAVs) are in use for infrastructure inspections [2]. Smartphones have become a necessity these days and are carried around by almost all members of the public. An application on a smartphone or other device where an image may be uploaded tends to be more attractive to use.

For this study, a total of 863 photos of road surfaces were collected from the City of Albury in New South Wales (NSW) using a mobile photo capturing application, these were subdivided to construct a database of 12,598 images containing pavement cracking and unrelated objects visible from within the road reserve. This is because most Convolutional Neural Networks (CNN) used for transfer learning, known as pretrained CNNs, in MATLAB, require small images of less than 300 pixels in horizontal and vertical dimensions. Therefore, in this implementation, each raw image was split into 252 sections. Figure 1 below shows montage of tiled image generated.

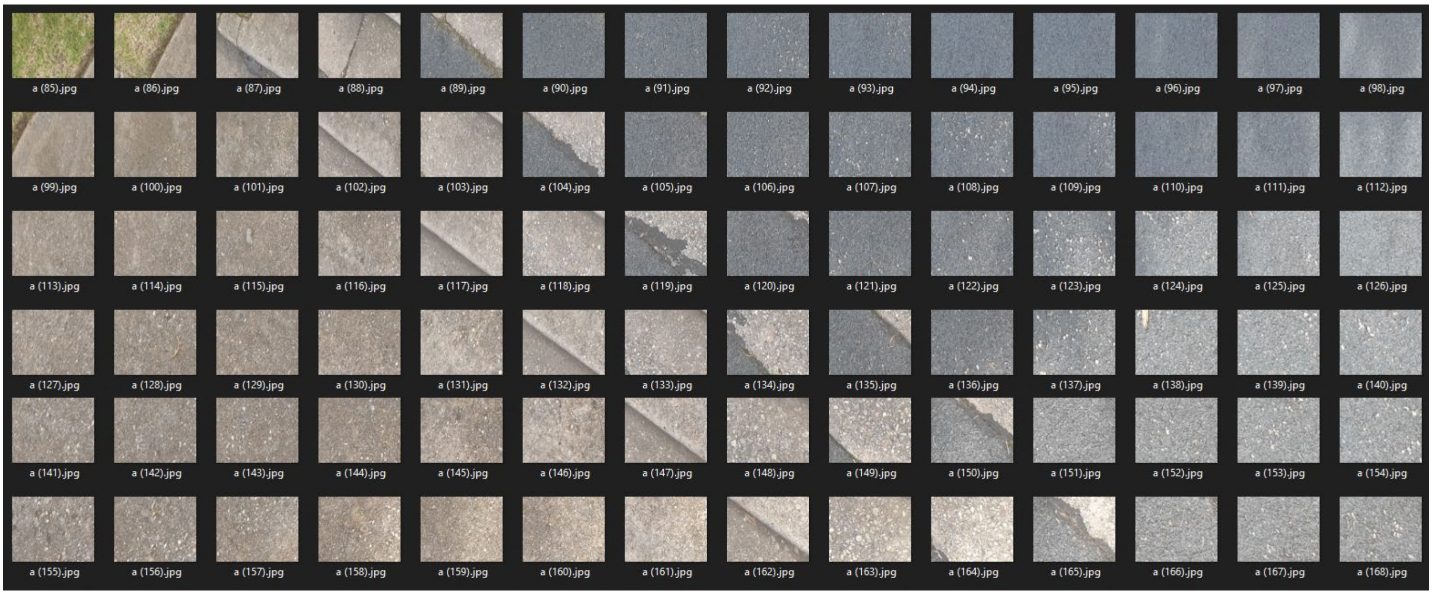


Figure 1. Montage of Tiled Image

AI-driven Road Fault Detection

AI is a form of programming that is able to learn from data inputs rather than having to program the software, the learning process is referred to as machine learning. The type of machine learning that can effectively cope with big data, as well as utilise this this data to improve the outcome is called DL. Amongst different neural networks used for DL, CNNs are well documented and proven to be effective for processing image data.

AI and DL systems have been used for road fault detection over the last few years. These systems have been designed and created to collect data on vast road networks, report their conditions, recognise faults, and classify them according to severity [3]. The advantage of utilising AI and DL is that they can perform quick checks, provide a confidence score, and ensure the data entered is true and accurate. This makes them very effective over a range of applications such as road surface or pavement cracking, the most common form of failure within a road network. MATLAB was chosen as

the programming tool, due to its accessibility to people who are new to programming including an abondance of example codes that can be downloaded and repurposed.
The image classification used DL in transfer learning, where a pre-trained CNN was used to classify the assembled image dataset [4]. The image database was tested at two stages with the results shown in Table 1.

The first stage involved using the raw image dataset containing 863 images with both CNNs (GoogLeNet and AlexNet). The raw image database was initially tested on five labelled categories intended to sort the cracks into sub-categories based on their severity; but this resulted in low accuracies due to an insufficient number of images for some categories. The study was then reduced to a two-category system i.e., crack versus no crack. The second stage, data sets consisted of tiled images while maintaining the two-category system (crack versus no crack). As described before, this is where each raw image was subdivided into much smaller images to retain the original resolution while achieving the pixel requirements of the transfer learning software.

Table 1. Validation score

Neural Network	**Database Size (Image)**	**Database Type**	**Category**	**Validation Accuracy (%)**
GoogLeNet	863	**Stage 1** - Large Images	5	60.61
AlexNet				47.31
GoogLeNet			2	72 to 84.69
AlexNet				65.06
GoogLeNet	252	**Stage 2** - Tiled Images	2	100
GoogLeNet	12,598			95.67

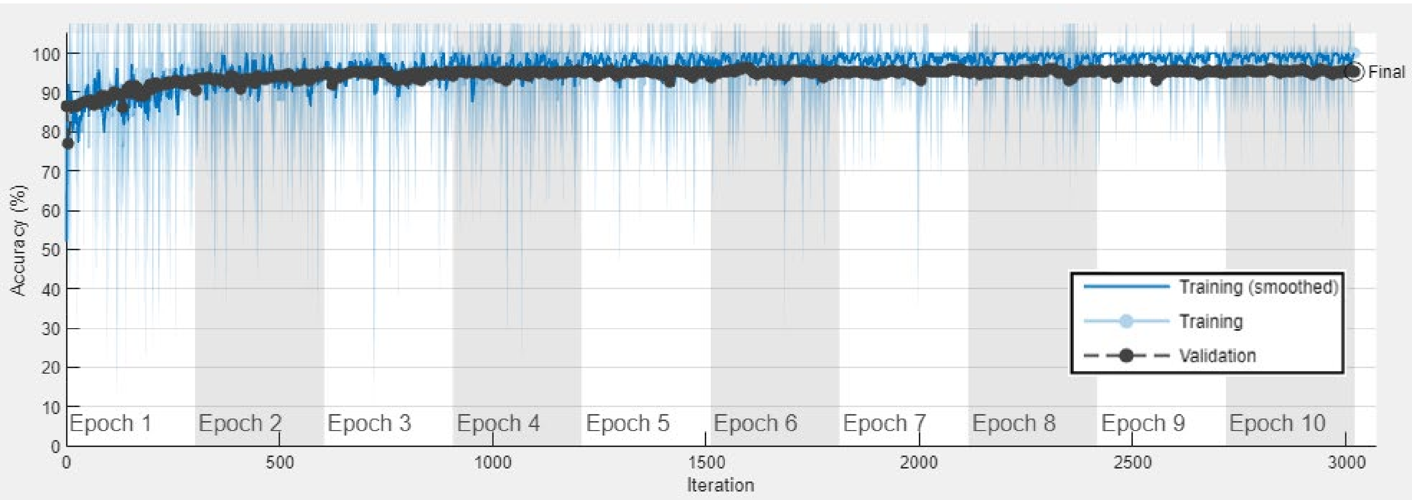
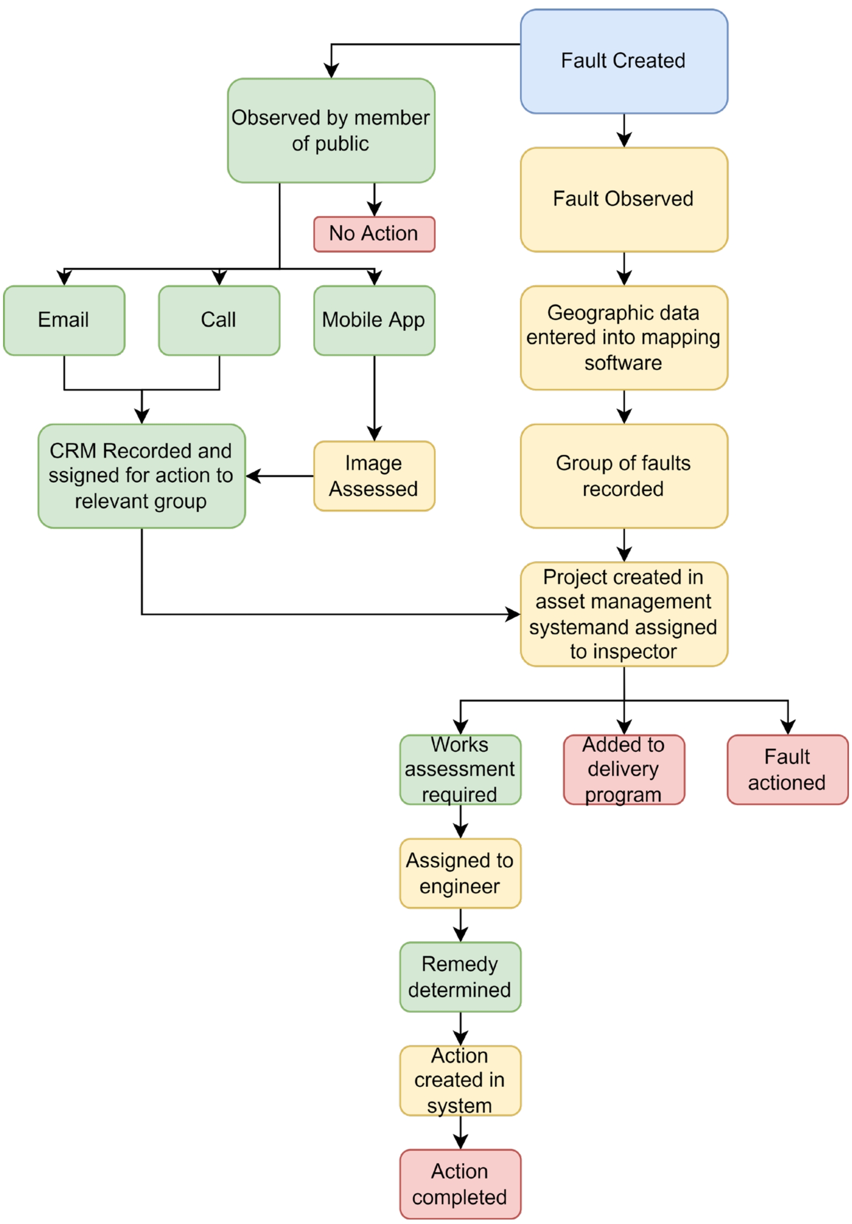


Figure 2. Learning Progress Plot of 12,598 Tile Dataset Case

Figure 2 demonstrates the achievement of a validation rate of 95.71 per cent. The training data session showed a learning rate of 100%, which was a 5% disparity against validation. The accuracy of this training database could be considerably increased in conjunction with image submissions from public members. This shows that supplied images can be assessed through this AI-enabled system in almost real-time and the inspector can decide whether action is required in timely manner.

Improved asset maintenance



With the integration of an AI-enabled tool into an asset management system, municipalities can significantly reduce labor-intensive processes, increase positive customer experience and make better maintenance planning decisions. This AI-driven tool can perform a significant amount of work very quickly using AI. It only requires strategic decision-making on behalf of the asset staff. This enables asset inspectors and engineers to focus on innovation and strategic decisions. In turn moving to transform the traditional asset management system into smarter and more sustainable asset management in line with the modern smart cities' movement. Although requiring an investment in time and infrastructure, the proposed AI-enabled tool can be repurposed for any image classification task a smart city management team wishes to put it to.

Figure 3 shows the proposed model for municipalities to integrate the proposed AI-enabled tool into the asset management system.

Figure 3. Proposed AI Integrated Asset Management System

Conclusion

In Australia, there are hundreds of thousands of kilometers of road pavement maintained by municipalities. By implementing an AI-enabled fault recognition system into an existing asset management system, a municipality will significantly improve their ability to make more and better decisions vastly increasing their capability to provide a safe and reliable road network and deliver a superior road user experience.

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Conference News

- **9th Asia-Pacific Workshop on Structural Health Monitoring , 7-9 December 2022, Cairns, QLD, Australia. https://www.monash.edu/engineering/shm**

- **8th World Conference on Structural Control and Monitoring 5-8 June 2022, Orlando, Florida, USA. http://www.8wcscm.org/**

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www.linkedin.com/groups/ANSHM-Australian-Network-Structural-Health-4965305

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