Infrastructure Engineering Graduate Research Conference 2024

Beyond Green: Transforming Research into Sustainability

THE UNIVERSITY OF MELBOURNE

CONFERENCE PROCEEDINGS

IEGRC-2024

Infrastructure Engineering Graduate Research Conference

BEYOND GREEN

TRANSFORMING RESEARCH INTO SUSTAINABILITY

21 OCTOBER 2024 @ RYDGES MELBOURNE CBD

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forword

It is with great pleasure that we present the proceedings of the Infrastructure Engineering Graduate Research Conference (IEGRC) 2024. This year's theme, "Beyond Green - Transforming Research into Sustainability," underscores our commitment to advancing sustainable solutions within the field of infrastructure engineering. Upholding our tradition of engineering excellence, IEGRC 2024 offered a remarkable occasion for all attendees, particularly graduate researchers, to showcase their innovative work and gain valuable insights into the sustainability-driven research of their peers.

Receiving constructive feedback is a vital part of the research process, sparking new ideas and broadening one's perspective on ongoing projects. As we know, research truly reaches completion when it is effectively communicated and shared. This emphasizes the importance of developing strong oral presentation and written communication skills, which are essential for conveying complex ideas clearly and persuasively in both academic and industry settings. IEGRC provides an ideal platform for graduate researchers to hone these skills, supporting their growth and contributing to the advancement of sustainable practices in engineering.

I would like to express my sincere gratitude to all the keynote speakers, panellists, session chairs, staff, the organizing committee, and everyone who contributed to making IEGRC 2024 a success. A special thank you goes to the RHD students who presented and enriched this book of proceedings with high-quality research content. Together, we continue to push beyond conventional approaches and explore transformative pathways to sustainability in infrastructure engineering.

Professor Andrew Western,

Head of Department,

Department of Infrastructure Engineering,

The University of Melbourne.

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Acknowledgements

The Organising Committee of the Infrastructure Engineering Graduate Conference 2024 (IEGRC 2024) extends its heartfelt gratitude to the keynote speakers, panellists, and the esteemed members of the University and the Department of Infrastructure Engineering for their invaluable contributions. Their roles as judges for best paper submissions and presentations, session chairs, moderators, and volunteers were crucial to the success of the conference.

Opening address

Professor Mark Cassidy

Deputy vice-chancellor (Research) of the University of Melbourne

Keynote address

Ms. Susan Harris

Chief executive officer, Intelligent Trasnport Systems (ITS) Australia

Panellists

1. **Dr. Kiernan Fowler - Moderator**

   Senior lecturer, Department of Infrastructure Engineering, University of Melbourne.
2. **Dr. Serryn Eagleson**

   Digital advisory Lead, Arup
3. **Prof. Alex Felson**

   Elisabeth Murdoch Chair, Landscape Architecture, University of Melbourne.
4. **Dr. Patricia Sauri Lavieri**

   Senior Lecturer, Department of Infrastructure Engineering, University of Melbourne.

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Session chairs

- A/Prof. Xuemei Liu
- Dr. Tharaka Gunawardena
- Dr. Wim Bovill
- Dr. Yuhang Zhang
- Dr. Amir Khodabandh
- Dr. Serene Ho
- Dr. Samintha Perera
- Prof. Russell Thompson
- Dr. Joey Voermans
- Dr. Philip Christopher
- Dr. Shuangmin Shi

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- Chuan Qin
- Sasindu Samarawickrama
- Liuhui Tu
- Nimisha Kattumunda
- Jiayu (joy) Yao
- Kunwar Abhishek Singh
- Isrrah Malabanan
- Jie Qi
- Lingli Zhao

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

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- Abdullah Anwar - GIES - Vice President
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- Liyuan Jian - GIES - Student Advocacy Officer
- Aravind Poshnath - GIES - General Committee Member
- Pramod Dilashan- GIES - General Committee Member

Special thanks to the Rydges Melbourne (CBD) staff and the event photographer for their invaluable contributions to IEGRC 2024. Their exceptional work ensured a memorable conference.

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

About the proceedings

Welcome to the Infrastructure Engineering Graduate Research Conference (IEGRC 2024), hosted by the Department of Infrastructure Engineering at the University of Melbourne.

This conference proceeding features a collection of abstracts from presentations spanning eight diverse disciplines within the field of Infrastructure Engineering. These abstracts highlight the depth and breadth of research undertaken by PhD candidates at various stages of their doctoral journey within the department.

In addition to the research presentations, this volume includes a summary of the insightful panel discussion centred on the conference theme, "Beyond Green: Transforming Research into Sustainability." This theme inspired meaningful conversations and fresh perspectives on sustainability in Infrastructure Engineering.

We are also pleased to showcase the outstanding achievements of students through the awards presented during the conference. This compilation reflects the innovative research and dialogue that define IEGRC 2024 and the commitment to excellence within the Department of Infrastructure Engineering at the University of Melbourne.

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Graduates Infrastructure Engineering Society
Department of Infrastructure Engineering
The University of Melbourne.

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Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

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Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Event Agenda

Time	Description	
8:30 - 9:00 AM	**Attendees Arrival and Registration**	*Meeting Place Foyer*
9:00 - 9:15 AM	**Welcome Message** Seongyeol Park - President, Graduate Infrastructure Engineering Society Professor Andrew Western - Head of the Department of Infrastructure Engineering	*Center Stage 1*
9:15 - 9:25 AM	**Opening Address** Professor Mark Cassidy, Deputy Vice-Chancellor (Research), the University of Melbourne	*Center Stage 1*
9:25 - 9:50 AM	**Keynote Address** Topic: Pioneering Holistic Solutions for Sustainable Infrastructure Ms. Susan Harris, CEO, Intelligent Transport Systems Australia	*Center Stage 1*
9:50 - 10:30 AM	**Group photo, Morning tea**	*Center Stage 2, Meeting Place Foyer*
10:30 - 12:30 PM	**Presentations - Forum 1- 5**	*Center Stage 1, Meeting Rooms 1-4*
12:30 - 1:30 PM	**Lunch**	*Center Stage 2, Meeting Place Foyer*
1:30 - 3:30 PM	**Presentations - Forum 1- 5**	*Center Stage 1, Meeting Rooms 1-4*
3:30 - 4:00 PM	**Afternoon Tea**	*Center Stage 2, Meeting Place Foyer*
4:00 - 5:00 PM	**Panel Discussion** Topic: Bridging the Gap by Transforming Research into Industry-Ready Sustainable Solutions Moderator – Dr. Kiernan Fowler, Senior Lecturer, IE Department Dr. Serryn Eagleson, Digital Advisory Lead, Arup Dr. Patricia Sauri Lavieri, Senior Lecturer, IE Department Prof. Alex Felson, Elisabeth Murdoch Chair of Landscape Architecture	*Center Stage 1*
5:00 - 5:30 PM	**Award Ceremony and Closing Ceremony** Thank you, Speech - Prof. Lihai Zhang, Research Higher Degree Coordinator	*Center Stage 1*
5:30 - 6:30 PM	**Networking Session**	*Meeting Place Foyer*

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Welcome message

Seongyeol Park

President, Graduate Infrastructure Engineering Society -2024

"Today, under the compelling theme 'Beyond Green: Transforming Research into Sustainability,' we seek to explore the vital role of infrastructure engineering in sustainable development"

Professor Andrew Western

Head of Department of Infrastructure Engineering

"Effective communication of research is vital for every researcher, whether in academia or industry. Consistent practice is key, with emphasis on being an active listener and an engaged questioner"

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Opening Address

Professor Mark Cassidy

Deputy vice-chancellor (Research) of the University of Melbourne

"With 5,000 PhD students, including 250 in this department, we aim to support each researcher's growth while making a positive impact in Australia and beyond. We focus on applying our knowledge practically to benefit society, using a well-rounded approach that balances environmental, economic, and social sustainability. This department is a strong example of that commitment."

Keynote address

Ms. Susan Harris

Chief executive officer, Intelligent Trasnport Systems (ITS)

"Across all disciplines, the more we advance in sustainable practices, the greater the impact we can create in our work"

IEGRC 2024 SPLENDID CAPTURES OF THE DAY

21 October 2024

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 01 – Morning session- Structural engineering

Session chair: Dr Tharaka Gunawardena

Presentation title	Presenter
Probability Based FEM of Corroded RC Beams	Aliakbar Yaghoubzadehfard
Feasibility of Repurposing Liquified Natural Gas (LNG) Tanks for Liquid Hydrogen Storage	Amila Premakumara
Module-to-core Connection for Modular Tall Building	Arjun Kandel
Experimental and numerical study into vehicular collision on the bridge parapet	Chuan Tong
Creating Housing Solutions for Displaced Populations	Kavitha Vipulananda
Macro Modelling of Buildings for Seismic Performance Evaluation	Deelaka Sathsara Jayaweerarathne
A numerical model to predict thermo-mechanical behavior of molten salt thermal energy storage tank	Santosh Mishra
Importance of Integration between Sawmilling Process and Prefabrication Manufacturing Requirements	Harshani Dissanayake
Smart AI Enabled Robotic Technologies for Plastic Waste Sorting	Hasala Sakvithi Rohanawansha
Investigation on Impact Resistance of Concrete Barrier Strengthened with UHPFRC	Jie Sun
AI-Driven Loco-manipulation for Quadruped Robots	Chuan Qin
Dynamic Carbon Accounting Framework for Engineered Wood Production	Yi Qian
Assessment of the Thermal Performance of Large-Scale Liquid Hydrogen Storage Tanks	Upeka Gunarathne
Enhancing the Recycled Concrete aggregate properties via Thermo mechanical treatment method	Vithushanthini Arulkumar

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 01 – Afternoon session- Structural engineering

Session chair: A/Prof Xumei Liu

Presentation title	Presenter
Design of high-strength concrete filled steel tubular columns under nonuniform fires	Lalita Lama
Development of Waste Wood Composites for Load bearing Engineered Wood Products	Isuri Tamura Amarasinghe
Numerical Modelling of Liquid Hydrogen Boil-off	Merinnage Susiri Vidarshaka Costa
Numerical Analysis of Steel-Concrete Composite Shear Wall at Elevated Temperature	Nav Raj Bhatt
A study on the durability of bamboo strips using the constant immersion method	Nimisha Kattumunda
Impact of Progressive Expansion of Dataset on CNN Performance in Plastic Waste Sorting	Nuwan Dewapurage
Seismic performance and earthquake design of composite modular buildings	Omar Ahmed Mohamed Morsy
Sustainable Structural Insulated Panel System for a Decarbonised Construction Industry	Rannulu Nipun De Zoysa
Optimisation framework for design-to-delivery of prefabricated timber systems	Sasindu Randil Samarawickrama
Characterisation and Double-Sided Pullout Study of Recycled Flowline Steel Fibres	Vito Nathaniel Lokito
Missing Data Imputation for Structural Health Monitoring Using Modified WGAIN-GP	Sumit Saha
High-temperature Stability of Innovative Geocrete for Thermal Energy Storage (TES)	Tran Phuc Nghia

Infrastructure Engineering
Graduate Research Conference 2024

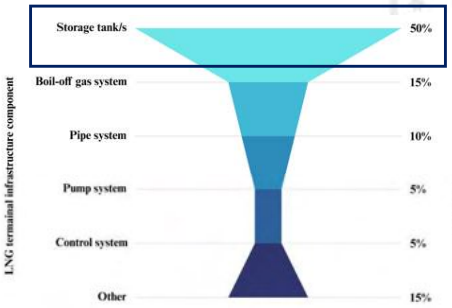
Feasibility of repurposing liquified natural gas (LNG) tanks for liquid hydrogen (LH2) storage

Name - Udagedara Amila Kanchana Premakumara
Email – apremakumara@student.unimelb.edu.au
Supervisors – Dr Shanaka Kristombu Baduge, Dr Jude Perera, Dr Sadeep Thikarathne, Prof. Priyan Mendis
Discipline – Structural Engineering

INTRODUCTION

The operational mandate of the global LNG industry in 2023 stood at 404 million metric tonnes, a record high. In contrast, the long-term sustainability of LNG as a primary fuel is deteriorating, particularly in light of the carbon neutral objectives that have been established for 2050. Regasification and liquefaction facilities at numerous LNG terminals would become obsolete with the proposed objectives. For these LNG terminals, the storage tanks are the costliest component, comprising approximately 50% of the terminal capital cost. Therefore, the potential to adapt these storages to accommodate liquid hydrogen (LH2) has been recognised as a viable alternative.

Figure 1 - LNG terminal components and associated cost shares [1]

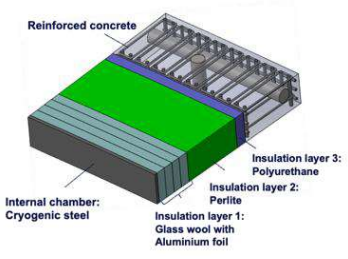


METHODOLOGY

This simulation assessed the performance of the tank in static and dynamic stress conditions along with heat in leak possible due to insufficient insulation.

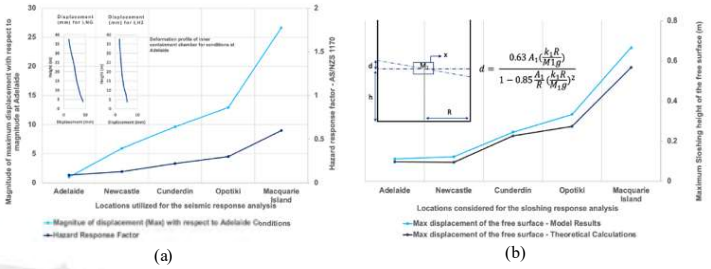
- A detailed design of a typical 200,000 m^3 LNG storage was carried out and examined for structural and seismic performance through finite element and numerical analyses, accounting for the full containment design philosophy.
- Heat transfer through the shell side of the tank was simulated using the finite element analysis considering conduction, convection and radiation. A cross-sectional homogeneous sample of 1/19780th of the total area LNG tank shell was modelled during the simulation

Figure 2 - Cross Section of the considered full containment LNG Tank



RESULTS & DISCUSSION

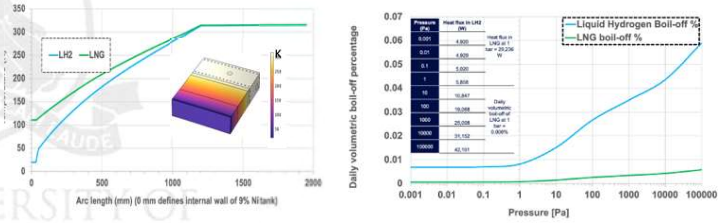
4.1 Seismic evaluation



(a) (b)

Figure 3 – (a) Seismic performance of the tank with LH2 and LNG filled conditions, (b) - Sloshing response of the 50% filled state of LH2 for different seismic conditions [2]

4.2 Thermal evaluation



(a) (b)

Figure 4 – (a) Performance of the existing insulation system with LH2 – Temperature distribution of the shell section, Impact of vacuum insulation – (b) Daily volumetric boil-off percentage vs vacuum pressure within the insulation system

4.3 Conclusions

The inner chamber is competent in holding LH2 without failing against buckling, lateral deformation, sloshing, and base shear, given that the inner containment chamber material is capable of handling -252.58 ^{0}C temperature.

Further development of supports is required to provide a high vacuum in the current insulating space for LH2 storage and reducing thermal conductivity.

Storing LH2 using the existing shell insulation structure will experience 1.2 – 1.5 times heat flux compared to LNG. However, the density difference between LH2 and LNG contributes to the biggest difference of the daily volumetric boil-off rate calculations.

Application of vacuum insulation to existing insulation at least up to 1 Pa can significantly reduce LH2 boiloff, and replacing the existing insulation system with alternative insulation materials can reduce the volumetric boiloff rate up to 0.04% at 1 bar pressure.

REFERENCES

[1] Schreiner, F., Riemer, M., & Wachsmuth, J. (2022). Conversion of LNG Terminals for Liquid Hydrogen or Ammonia.
[2] Housner, G. W. (1963). The dynamic behavior of water tanks. Bulletin of the Seismological Society of America. Vol. 53, No. 2, pp. 381-387

Module-to-core Connection for Modular Tall Building

Name: Arjun Kandel
Email: akandel@student.unimelb.edu.au
Supervisors: Prof. Huu-Tai Thai, Prof. Tuan Ngo
Discipline: Structural Engineering

INTRODUCTION

Modular construction helps to achieve sustainable development by minimizing the cost, construction time and waste product. Moreover, using composite modules helps not only to reduce the sectional size of structural components but also improves the fire performance of the building. These days, many cities have encountered housing crisis. Implementing modular construction technology to build the tall buildings helps to mitigate this problem.

In case of tall modular building, central core should be provided to resist the lateral loads. However, there is a lack of suitable connection between composite module and composite shear wall. This research aims to develop the innovative module-to-core connection for composite modular tall buildings using novel connector and holo-bolts. Moreover, this research presents the structural behaviour of proposed connection under different loading scenarios including horizontal pulling load and vertical sliding load.

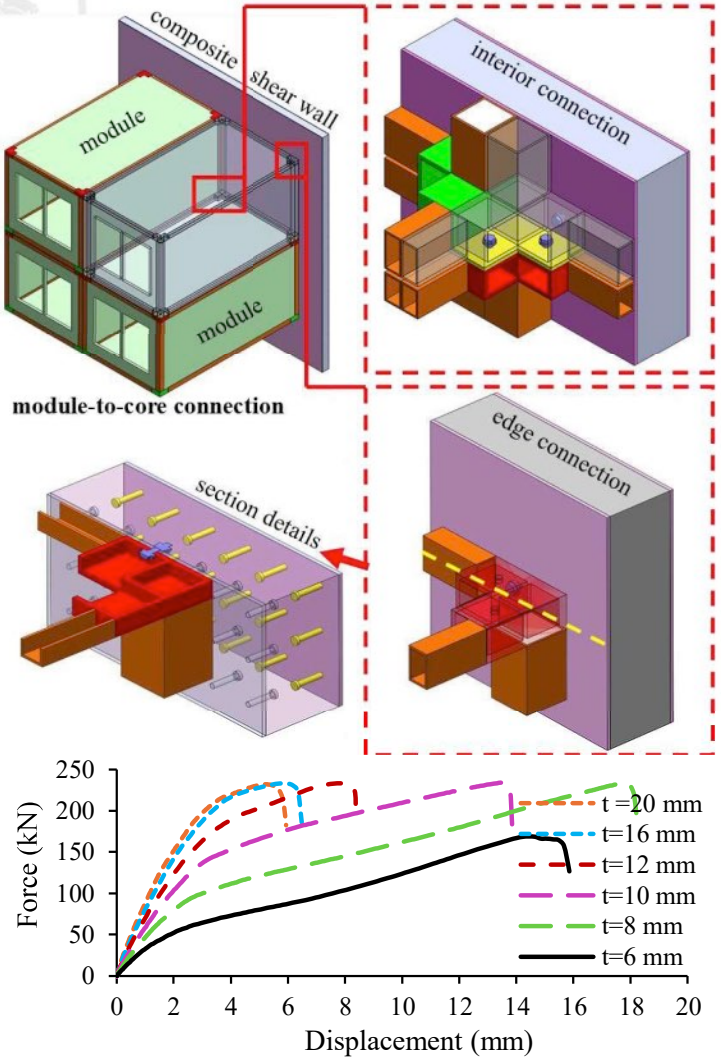
METHODOLOGY

Bolt holes are provided in the vertical plates of novel connector to connect composite module to the composite shear wall with the help of holo-bolts. To study the structural behaviour of proposed connection, finite element analysis is carried out in ABAQUS software. Two adjacent modules and shear wall are considered for the study.

Structural behaviour of the connection is studied under the horizontal pulling load and vertical sliding load. Influence of different key parameters on the performance of module-to-core connection are studied meticulously. The considered parameters are diameter and grade of bolt, thickness of steel plate of composite shear wall and vertical plate of novel connector and spacing of studs on steel plate of shear wall around the connection. Based on the parametric study, the ultimate capacity and failure mechanism of connection are evaluated. Moreover, this research provides the design recommendation for module-to-core connection for composite modular tall buildings.

RESULTS & DISCUSSION

This research develops the innovative connection between composite module and composite shear wall. Results show that the ultimate capacity of connection under horizontal pulling load and vertical sliding load can be increased by increasing the diameter and grade of the bolts. The ductility of the connection under horizontal pulling load can be achieved by selecting suitable thickness on vertical plate of novel connector and steel plate of composite shear wall. Similarly, providing additional studs on steel plate of shear wall around the connection between module and shear wall helps to eliminate the initial cracking of concrete.



Effect of vertical plate thickness of connector

Experimental and numerical study into vehicular collision on the bridge parapet

Name: Chuan Tong
Email: tonct@student.unimelb.edu.au
Supervisors: Prof. Nelson Lam, A/Prof. Xuemei Liu, Dr. Jude Shalitha Perera
Discipline: Structural Engineering

INTRODUCTION

- The risk of vehicle collision on bridges is becoming higher with the increase of the vehicle amount and vehicle collision is one of the main causes for bridge failure around the world.
- For vehicular collisions on parapets of bridges, the common interests are on the parapet itself without considering the effect of the deck and substructure. Most prevalent design codes for bridges adopt an equivalent static force approach to manage vehicle collisions on parapets, often ignoring the crucial dynamic characteristics of structures. The transmission mechanism of collision actions from the superstructure to the foundation is still unclear.
- This research aims to investigate and resolve uncertainties on the transmission of vehicular collision on a bridge parapet considering dynamic behaviour.

METHODOLOGY

- Use a three-legged frame specimen simplified for the transverse behavior of the bridge to preliminarily investigate the transmission mechanism of the vehicular collision within the bridge superstructure
- Simulate the three-legged frame specimen by Matlab program to investigate the dynamic response under vehicular collision action
- Conduct the pendulum impact test series on the three-legged frame specimen to validate the vehicular collision action transmission mechanism from superstructure to substructure.
- Derive hand calculation method to estimate the maximum response for scaled-down simplified model and extend the outcome to scaled-up simplified model

RESULTS & DISCUSSION

- The majority of design standards adopt an equivalent static design force to deal with the vehicular collision on the parapet of the bridge which can result in over-designing of the bridge and its foundation, especially in situations where the equivalent static force is of greater magnitude than the lateral seismic action, since the dynamic property of bridge and transient nature of the design action have not been taken into account.

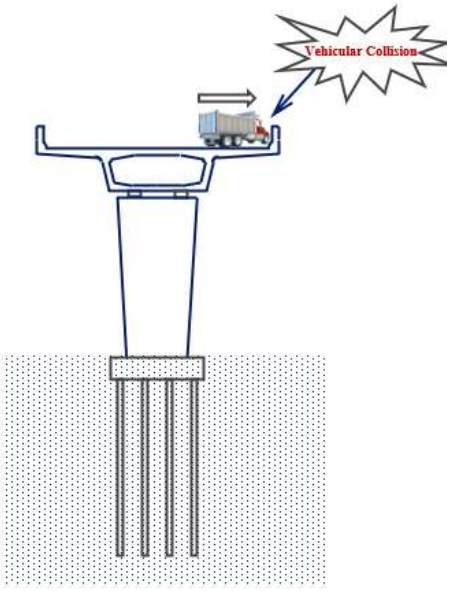


Figure 1. Schematic of vehicular collision on the parapet of the bridge

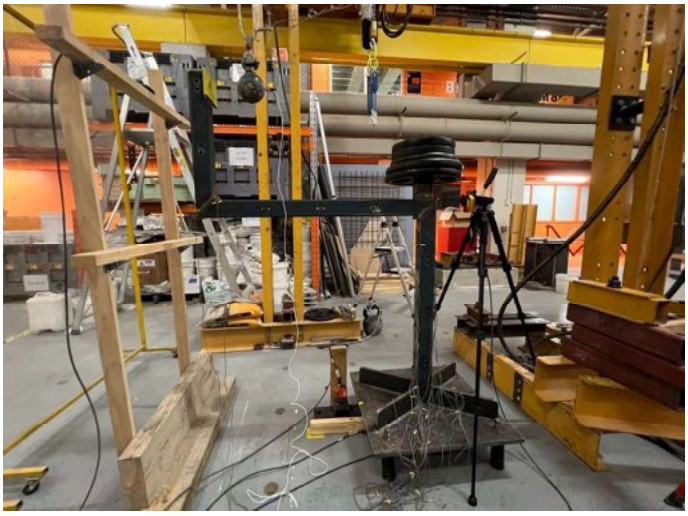


Figure 2. Setup of pendulum impact test

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Graduate Research Conference 2024

Macro Modelling of Buildings for Seismic Performance Evaluation

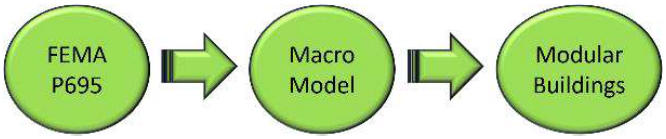
Name: Deelaka Sathsara Jayaweerarathne
Email: djayaweerara@student.unimelb.edu.au
Supervisors: Prof. Nelson Lam, Dr. Elisa Lumantarna
Discipline: Structural Engineering

INTRODUCTION

The vulnerable seismic behaviour of modular buildings need to be thoroughly evaluated in the preliminary design stage. The seismic performance evaluation is carried out using seismic performance factors where the quantification is conducted through the methodology implemented in FEMA P695. The quantification of seismic performance factors involves large number of non-linear incremental dynamic analyses which is a time-consuming process. Currently, there are lack of resources to fast-track the seismic performance evaluation process of modular buildings including rocking buildings in the initial design stage. Therefore, in the industry, linearization is used which is a simplified seismic performance evaluation process incorporating response modification factor (R). Historically R factors have been derived based on expert's opinion which is insufficient for new forms of constructions as buildings will be in danger when wrong factors are assigned. Therefore, this research mainly aims in developing an effective and viable way of evaluating the seismic performance of modular buildings based on macro modelling which allows large number of non-linear time history analyses to be conducted without excessive time.

METHODOLOGY

In this research, a simplified mode shape function will be developed incorporating Timoshenko beam theory to obtain mode shape of modular buildings including rocking buildings. Incorporating the developed mode shape function, macro model will be developed to fast-track the Incremental Dynamic Analysis (IDA). Finally, an algorithm will be developed to quantify the seismic performance factors according to FEMA P695 through macro modelling for performance-based design of modular buildings.



RESULTS & DISCUSSION

- Online program has been developed to fast-track the nonlinear time history analysis of rocking buildings incorporating macro model.
- Mode shape functions for first three modes have been developed in the form of polynomials incorporating the Timoshenko Beam Theory.

$$\tilde{\phi}_j(x) = a_{1,j}x + a_{2,j}x^2 + a_{3,j}x^3$$

Where $a_{1,j}$, $a_{2,j}$, $a_{3,j}$ are functions of flexural-to-shear stiffness ratio and j represents the mode number.

- This development will helps practicing engineers to evaluate the seismic performance of new forms of constructions such as modular buildings including rocking buildings in the preliminary design stage.
- Further, this approach will be helpful to carry out performance-base design of modular buildings in the initial design stage efficiently.

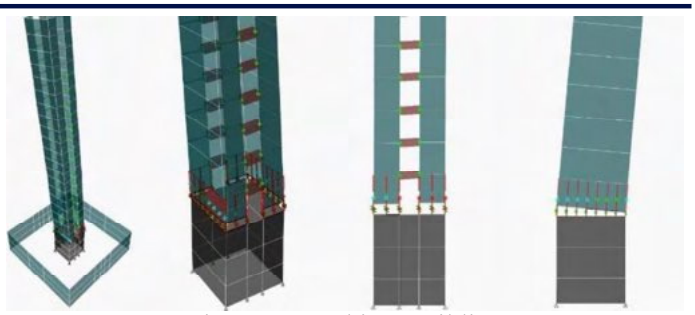


Figure 1: Rocking Building

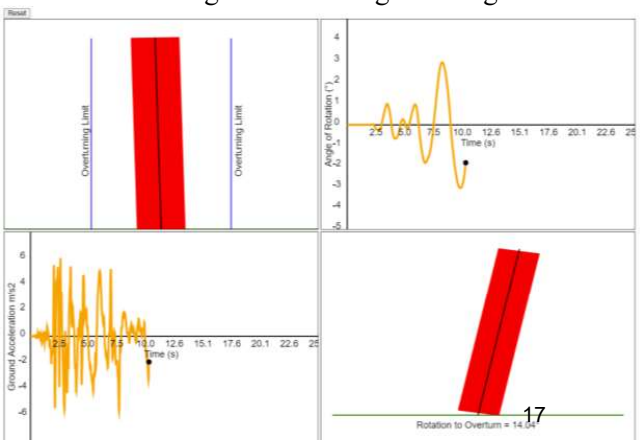


Figure 2: Online Program for Rocking

THE UNIVERSITY OF MELBOURNE

Infrastructure Engineering Graduate Research Conference 2024

A numerical model to predict thermo-mechanical response of molten salt thermal energy storage tank

Name: Santosh Mishra
Email: santoshm@student.unimelb.edu.au
Supervisors: Dr. Tuan Nguyen, Prof. Tuan Ngo
Discipline: Structural

INTRODUCTION

- Thermal energy storage in molten salts (MS) is a promising and economic solution for reliable supply from renewable energy sources
- This technology requires MS to be stored in a safe and insulated tank for up to hours or a week which can be used during the nights or when the wind stops blowing
- Despite its potential, there have been several failure incidents in MS tanks caused by varying hydrostatic and thermal operating loads
- We have developed a numerical model that can predict the thermo-mechanical behaviour of MS tanks under different loading and exposure conditions
- Simulated responses are validated against the real plant data: "Solar Two" in the US and "Andasol" in Spain
- The research aims to provide efficient numerical tool to understand the critical parameters in MS tank design and mitigate associated failures.

METHODOLOGY

- Subsequent models, thermal followed by mechanical are developed in ABAQUS
- Geometry, materials and boundary conditions are taken from relevant literature
- Model takes the input of salt's variable hydrostatic load and operating temperature (290-565 ºC)

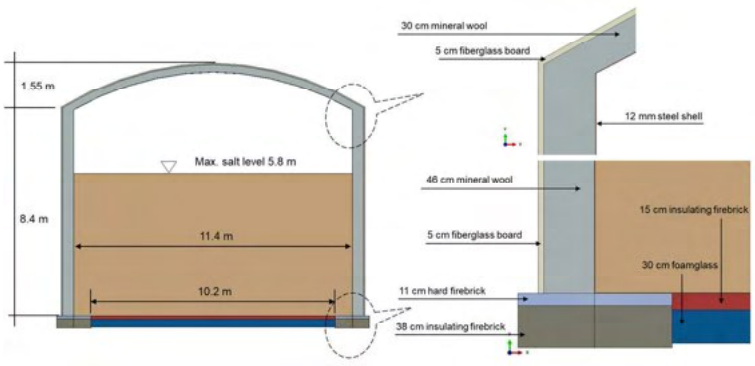


Fig 1. Schematic representation of "Solar Two" model developed in Abaqus

RESULTS & DISCUSSION

Table 1: Total heat loss (kW) from "Solar Two" tanks

Tanks	Level	Solar two exp.	Solar two calculated	Arújo and Gabriel	Ren et al.	**Current numerical**
Hot tank (565 ºC)	Full (5.8 m)	102 ± 21	98	90.5	98.98	**98.44**
	Empty (0.9 m)	-	-	83.63	90.34	**87.59**
Cold tank (290 ºC)	Full (5.8 m)	44 ± 6.6	45	47.3	45.95	**47.79**
	Empty (0.9 m)	-	-	45.23	44.71	**40.77**

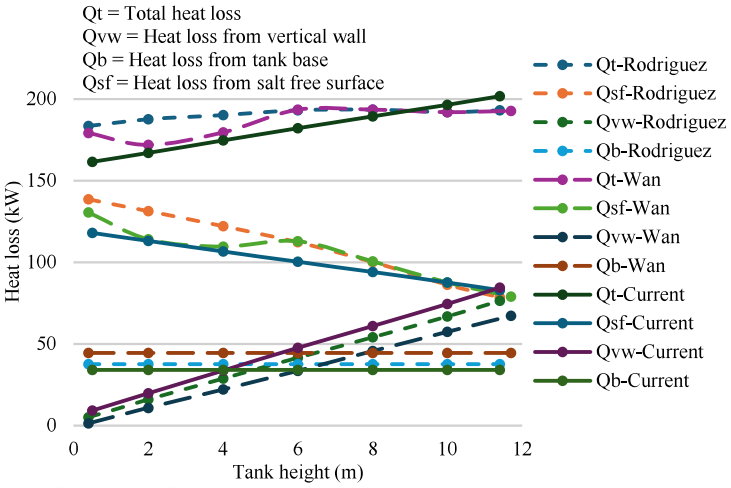


Fig 2. Thermal validation "Andasol" hot tank: heat loss profile at different salt inventory levels

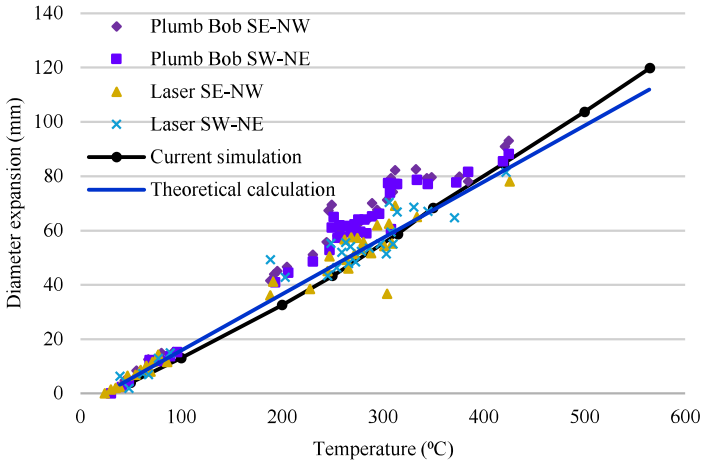


Fig 3. Thermo-mechanical validation of "Solar Two" hot tank against measured data: tank diameter expansion due to thermal and hydrostatic loads

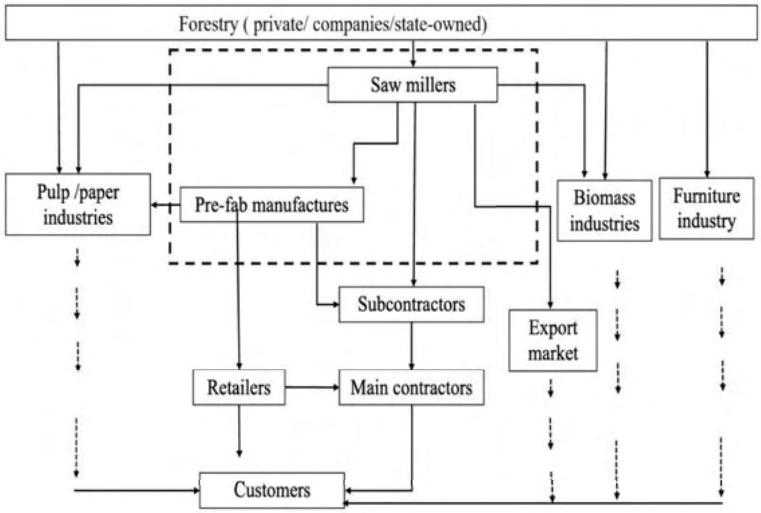
- Simulated values/responses are generally in a good agreement with the measured data; model can be used to study the MS tank failures
- Total heat loss from the tank slightly increases with increasing inventory level; radiation between salt free surface and non-wetted tank wall is significant

Integration between Sawmilling Process and Timber Prefab Manufacturing Requirements

Name: D. M. H Dissanayake,
Email: harshanidiss@student.unimelb.edu.au
Supervisors: Dr. Tharaka Gunawardena, Prof. Priyan Mendis
Discipline: Structural Engineering

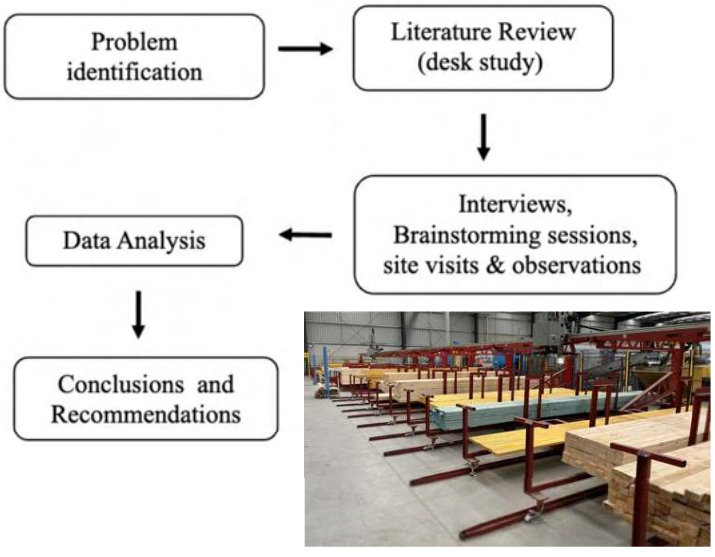
INTRODUCTION

In the timber supply chain, sawmills and prefabrication timber manufacturers play a crucial role. Sawmillers convert raw timber into structural products, while prefabrication manufacturers utilize these materials to fabricate essential components, such as wall and roof frames, for industrialized house-building.



In the Australian context, there is currently no integration between sawmills and prefabrication manufacturers, leading to mismatches between sawmill products and the specific requirements of prefabrication processes.

METHODOLOGY

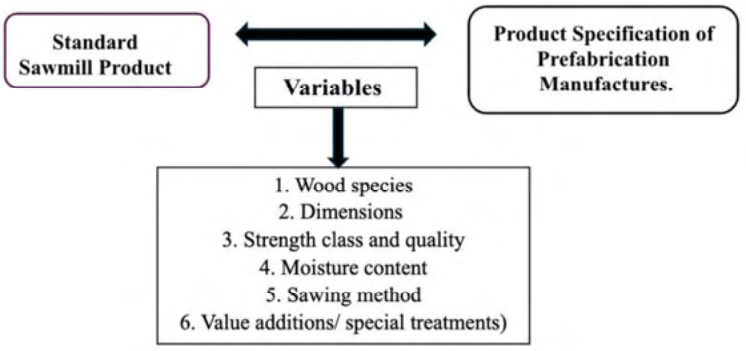


RESULTS & DISCUSSION

Prefabrication timber manufacturers generally purchase and store commonly available timber planks, placing special orders only when specific customer requirements emerge.

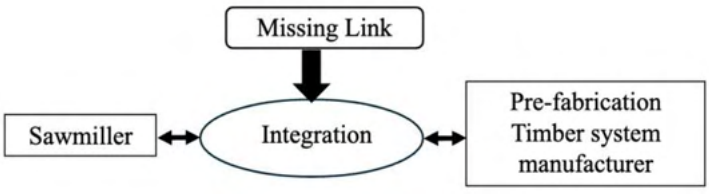
The following are the associated challenges identified during the site visits to Prefabrication manufacturers:

- Inconsistent timber quality due to various suppliers.
- Storage inefficiencies and delays due to reliance on available stock.
- Product specification is different from the standard products.
- Waste generation from offcuts and production modifications creates financial burdens whereas Sawmillers produce substantial waste with commercial value.



Integration between sawmills and prefabrication manufacturers can:

- Reduce waste by producing defect-free timber, minimizing excessive trimming and customization.
- Incorporate low-grade timber or offcuts into prefab systems, enhancing material utilization.



To optimize the sawmilling process and ensure alignment with prefabrication requirements, it is crucial to introduce a framework that emphasizes collaboration and communication between sawmills and manufacturers

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Infrastructure Engineering
Graduate Research Conference 2024

Smart AI Enabled Robotic Technologies for Plastic Waste Sorting.

Name: Hasala Sakvithi Rohanawansha Pitiduwa Gamage
Email: hasala.pitiduwa@student.unimelb.edu.au
Supervisor: Dr. Shanaka Kristombu Baduge, Prof. Priyan Mendis
Discipline: Structural Engineering

INTRODUCTION

Efficient plastic sorting is crucial for recycling, but manual methods are labour-intensive. Automation, driven by deep learning and AI, has shown promise in waste recycling. To enhance plastic identification, Hyperspectral Imaging complements RGB cameras, but real-time synchronization remains a challenge, and a significant gap lies in the domain. High-quality AI training datasets are essential for accuracy, while evaluating their performance on different object detection algorithms. Furthermore, optimizing the pick-and-place process, including addressing gripping issues, is vital for overall system efficiency.

This study seeks to develop a prototype waste plastic sorting system that integrates RGB-Hyperspectral imaging and check the overall operational accuracy and efficiency with different object identification algorithms. Also, it seeks to enhances the picking operation through a newly developed picking algorithm for commercial waste plastic sorting applications, contributing to effective waste management and environmental sustainability.

METHODOLOGY

The system building procedure consists of building a delta robot-based prototype for waste plastic sorting. Simultaneously, available different CNN based object detection models will be tested for their performance in waste plastic identification. A comprehensive data base for object detection will be prepared considering the Australian consumer patterns. Image capturing of waste plastic running on industrial conveyor will be utilized to train the selected model.

Real-time RGB and Hyperspectral fusion will be explored for performance, synchronization, and ease of communication to select the most efficient method. The next phase involves the identification of parameters affecting end effector (gripper) trajectory and cycle time. These parameters will be used to develop an algorithm to optimize the cycle time and maximize the overall efficiency of the system.

RESULTS & DISCUSSION

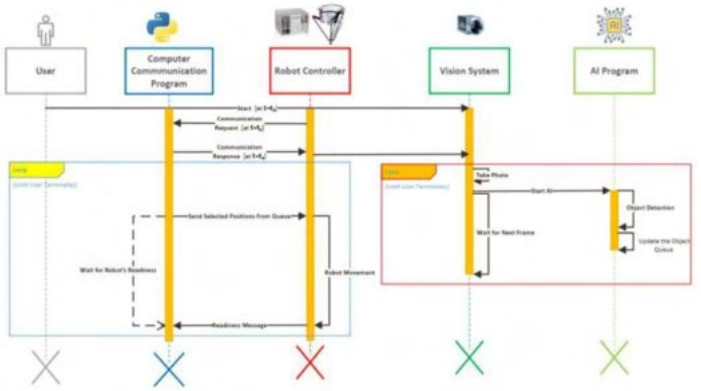


Figure 01: Robot and AI System Sequence Diagram

Figure 02: Prototype Robot Unit With Modified Gripper

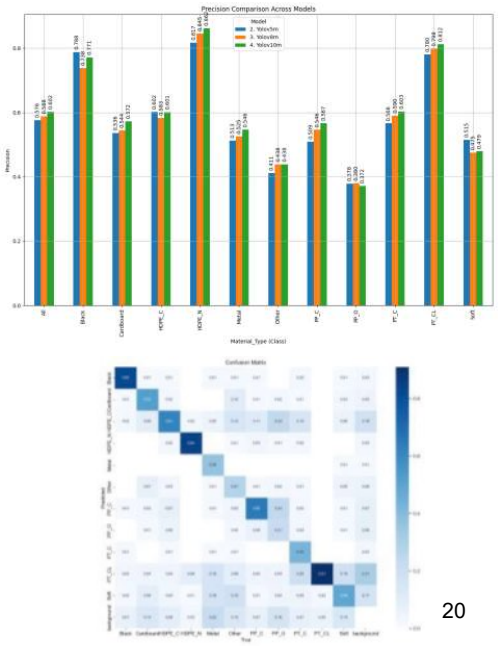


Figure 03: CNN Based Model Trainings Results (Confusion Matrix and Precision)

Investigation on Impact Resistance of Concrete Barrier Strengthened with UHPFRC

Name: Jie Sun (Frank)
Email: jies5@student.unimelb.edu.au
Supervisors: Prof. Nelson Lam, A/Prof. Xuemei Liu, Dr. Jude Shalitha Perera
Discipline: Structural Engineering

INTRODUCTION

- Concrete barriers, such as road barriers, bridge parapets and rockfall barriers, are among the most common structures to protect the public from impact hazards. However, RC barriers designed and constructed decades ago may not satisfy the current standards for road safety, and rehabilitation work becomes necessary.
- UHPFRC exhibits exceptional properties, including very high strength (both in tension and compression), tensile strain-hardening, and improved energy absorption capacity. These properties provide solutions to enhance the impact resistance of existing RC barriers.
- This research aims to study the effectiveness of a composite system consisting of a layer of UHPFRC membrane and RC barrier in improving the impact resistance when barriers are subjected to vehicular impact loading.

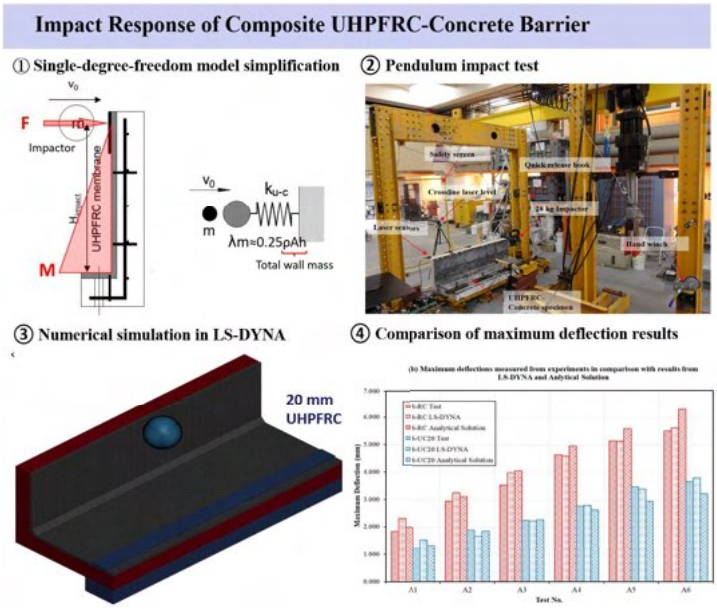
METHODOLOGY

- **Analytical Solution:** To predict the impact response of the UHPFRC-concrete barrier, an analytical procedure has been developed on the energy and momentum conservation principle, the constitutive model of UHPFRC and moment-curvature analysis.
- **Experimental Study**: An instrumented pendulum impact test was conducted to investigate the flexural behaviour of the UHPFRC-concrete barriers under impact loading at the top centre of the specimen, and deflection and reinforcement strain recorded in the test were used to validate the analytical model and scale-down numerical model.
- **Numerical Simulation**: Finite element modelling was created in LS-DYNA, including a scale-down model for the test specimens and the scale-up model for the full-size bridge parapet subjected to vehicular impact. The scale-down model, validated by experimental and analytical results, is the basis of the parametric studies and the scale-up model.

RESULTS & DISCUSSION

- The primary findings of the research demonstrate the effectiveness and design feasibility when employing the UHPFRC membrane to enhance the impact resistance of RC barriers. Generally, the proposed composite UHPFRC-concrete system significantly decreased the maximum deflection at the top centre of the cantilever parapet for the same impact scenario by 34% ~ 50% compared to the RC control specimen.
- The analytical solution has been shown to predict the maximum deflection that matches reasonably well with the experimental measurements and the scale-down numerical model for the composite UHPFRC-concrete specimen. By using a simple layer of UHPFRC membrane, the reinforcement strain was distributed more uniformly across the wall, with a significantly reduced peak value. The validated analytical procedure and scale-up numerical model can be extended to the full-size composite UHPFRC-concrete bridge parapet under vehicular impact loading.

FIGURE/DATA



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AI-Driven Loco-Manipulation for Quadruped Robots

Name: Chuan Qin
Email: qincq1@student.unimelb.edu.au
Supervisors: Dr Shanaka Baduge, Prof Priyan Mendis, Dr Sadeep Thilakarathna, Dr Gihan Ruwanpathirana
Discipline: Structural Engineering

INTRODUCTION

Quadruped robots have demonstrated significant potential for complex tasks in unstructured environments, yet their limited manipulation capabilities restrict their broader application. Loco-manipulation, which integrates both locomotion and manipulation, is crucial for expanding their role in search and rescue, infrastructure inspection, and service robotics. While much research has focused on locomotion, recent advancements in Reinforcement Learning (RL) and Computer Vision (CV) are opening new possibilities for combining locomotion with manipulation tasks. The vision systems provide essential real-time environmental understanding, allowing robots to interpret and interact with their surroundings. By leveraging these AI-driven approaches, including Vision-Language-Action (VLA) Models for enhanced scene interpretation, quadruped robots can achieve higher levels of autonomy, navigating and manipulating objects more effectively in dynamic, real-world environments.

However, due to the inherent differences between simulated environments and the real world, the transfer from simulation to real-world applications, known as the sim2real gap, presents significant challenges. In summary, our research aims to leverage AI-driven policies to address the loco-manipulation capabilities of quadruped robots while simultaneously bridging the sim2real gap for effective real-world deployment.

METHODOLOGY

As shown in Figure 1, the proposed methodology leverages a VLA model to guide the loco-manipulation capabilities of a quadruped robot. The VLA model takes in both image inputs and language instructions, then outputs the necessary 7D robot actions for the robotic arm mounted on the quadruped. This process requires fine-tuning the VLA model using self-collected datasets, ensuring different hardware configurations work properly. During training RL policy in Isaac Gym, which incorporates domain randomization and adaption methods to address the sim2real transfer challenge. Finally, the control policies $\pi(At|St)$ optimize both locomotion and manipulation actions dynamically, ensuring that quadruped robots perform grasping tasks in complex, real-world environments effectively.

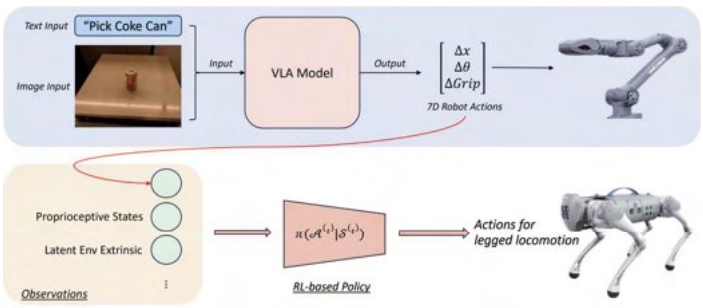

Figure 1. Research Methodology

RESULTS & DISCUSSION

Currently, we have successfully trained a whole-body policy capable of tracking the actions of the End-Effector (EE). In simple terms, quadruped robots can perform loco-manipulation by following a predefined EE trajectory, seamlessly coordinating their locomotion and manipulation tasks. As shown in Figure 2, the robot demonstrates excellent performance in the simulation environment, precisely following the given EE trajectory with robust metrics. The next step is to integrate the actions generated by the VLA model, replacing the predefined trajectory to enable autonomous loco-manipulation.

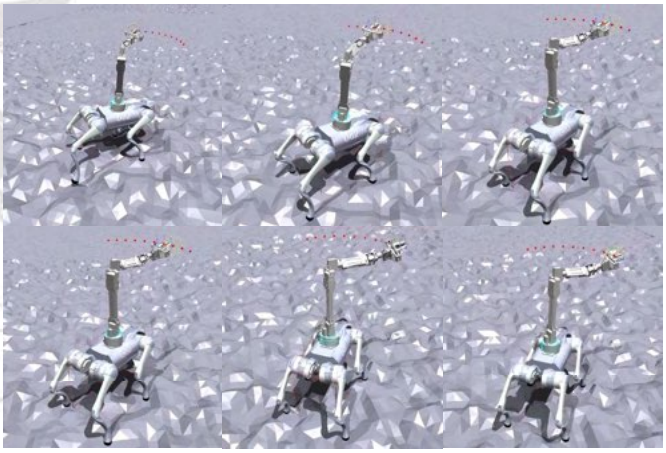

Figure 2. Experiment Results

This approach holds potential for broader applications, such as enhancing manipulation tasks in humanoid robots. Moreover, the sim2real transfer method as shown in Figure 3, successfully applied here, can be extended to other robotic tasks, improving the generalization across different environments.

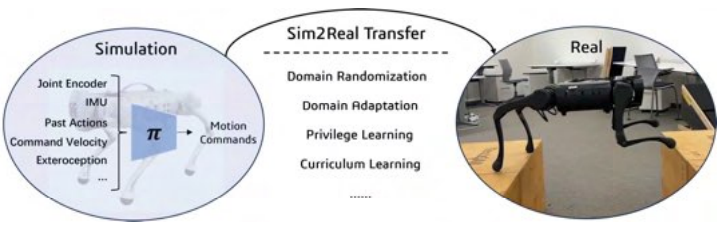

Figure 3. Sim2Real Methods

However, the limitations of this method are closely tied to the performance of the underlying VLA model. Fine-tuning the model for specific tasks requires substantial preliminary work, including extensive data collection and computational resources.

Further efforts will focus on fine-tuning the VLA model and integrating the trained model into the motion control system of quadruped robots, aiming for a more robust loco-manipulation and then, deploying it in real-world environments to validate the effectiveness of the sim2real transfer method.

Infrastructure Engineering
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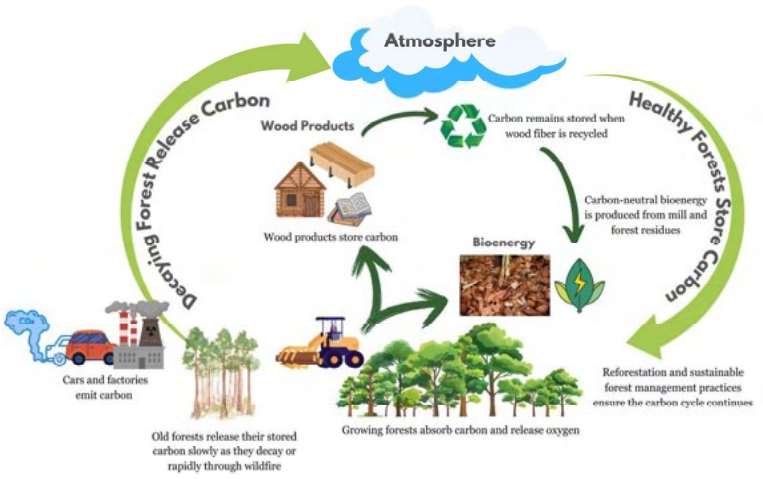
Carbon accounting of engineered wood production

Name: Yi Qian
Email: yqqian2@student.unimelb.edu.au
Supervisors: Dr Tharaka G., Prof. Priyan M., Prof. Lu A.
Disciple: Structural

INTRODUCTION

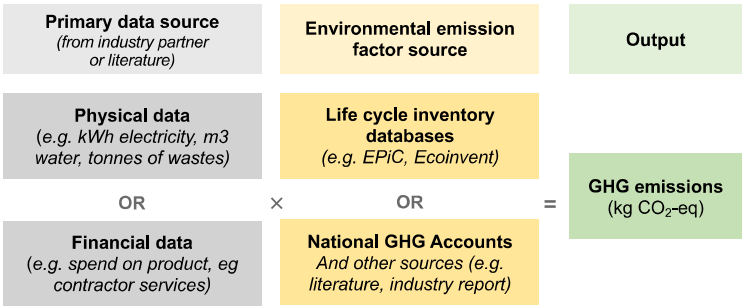
Australia has committed to increase the use of timber in the built environment by 2030 at the 28th Conference of Parties (COP28) in December 2023. Timber products offer significant potential for decarbonisation in the construction sector through two primary mechanisms: substitution and carbon storage. Hence, this study aims to develop a framework to assess carbon emissions from each process of timber products manufacturing.

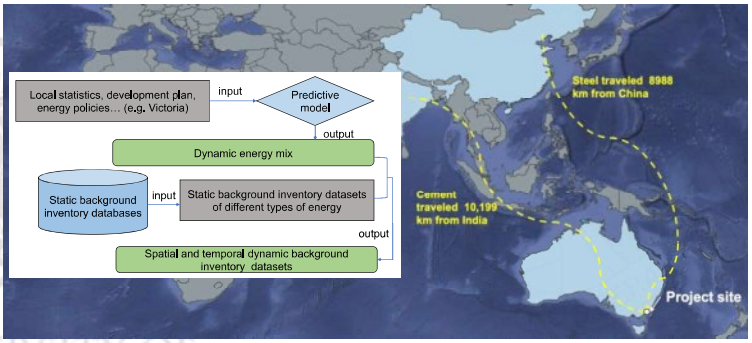


METHODOLOGY

Two primary methods are used to calculate carbon emission: the first method is based on physical data, such as electricity consumption, water use, and waste production. These data are combined with emission factors (EF) sourced from life cycle inventory databases, including EPIC and Ecoinvent. The second method utilizes financial data, which reflects expenditures on products and services, and correlates these with National GHG accounts or other relevant industry reports. This financial approach serves as a proxy to estimate emissions where physical data may not be available.

To conduct a dynamic life cycle assessment (LCA), spatial factors such as forest growth rate, species composition are monitored to calculate carbon sequestration, which allow us to model dynamic carbon stock. Temporal factors such as forest succession and growth, harvesting and thinning to assess long-term emission. By incorporating these dynamics with carbon accounting, LCA can provide both direct emissions (from operations and land use) and indirect emissions (from materials, chemicals, and energy inputs used in forestry operations).

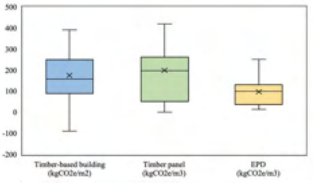


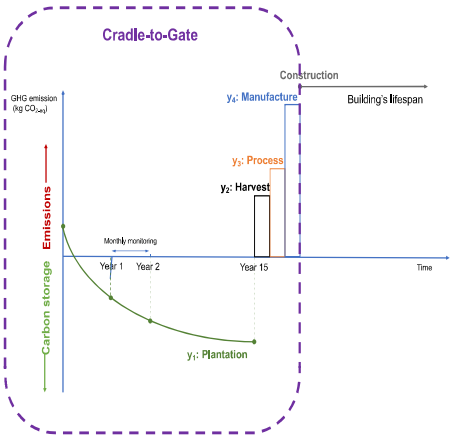


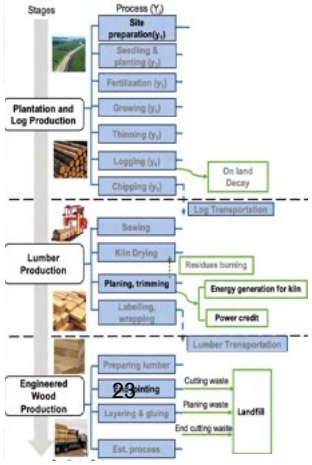
RESULTS & DISCUSSION

A conceptual carbon accounting framework were developed, including inventories for plantation, log production, timber production and panel production stages. Benchmark studies showed that carbon emissions from timber construction, panels and Environmental Product Declarations (EPDs) vary, mainly because different system boundaries, databases and assumptions are applied. A dynamic LCA of forestry systems is needed to calculate carbon emissions and carbon sequestration.

	Timber-based building ($kgCO_{2e}/m^2$)	Timber panel ($kgCO_{2e}/m^3$)	EPD ($kgCO_{2e}/m^3$)
CE_{med}	160.0	203.5	96.0
$CE_{25\%}$	109.1	129.0	34.1
$CE_{75\%}$	250.7	239.0	122.2





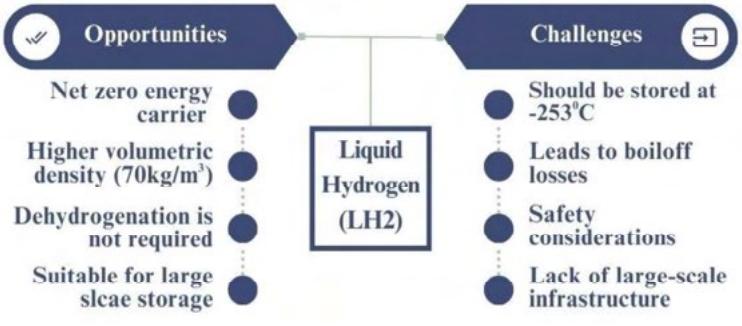


Infrastructure Engineering
Graduate Research Conference 2024

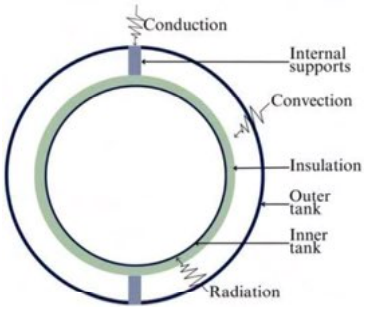
Assessment of the Thermal Performance of Large-Scale Liquid Hydrogen Storage Tanks

Name: Upeka Gunarathne
Email: gunarathneg@student.unimelb.edu.au
Supervisors: Dr. Shanaka Baduge, Dr. Sadeep Thilakarathna, Prof. Priyan Mendis
Discipline: Structural Engineering

INTRODUCTION



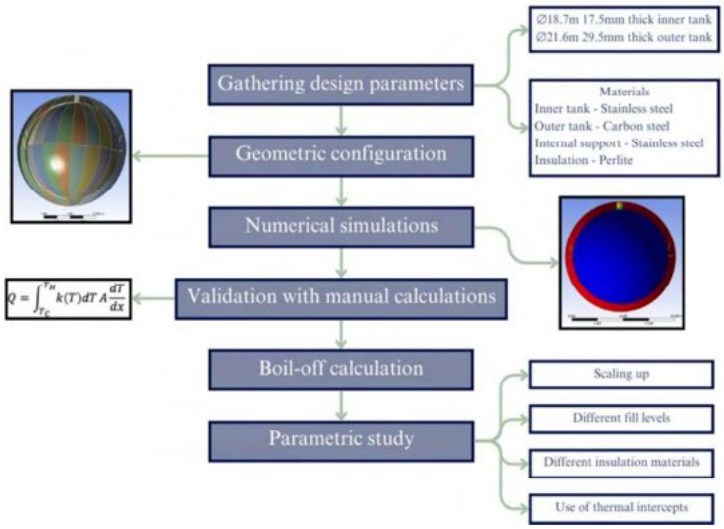
To store LH2 at -253°C, minimizing heat leaks is crucial, as they can occur via conduction, convection, and radiation. To reduce heat transfer, the tanks are vacuum jacketed and insulated with specialized materials. Understanding the thermal behaviour of these tanks is essential for efficient and safe storage of LH2.



Basic constituents of a LH2 storage tank

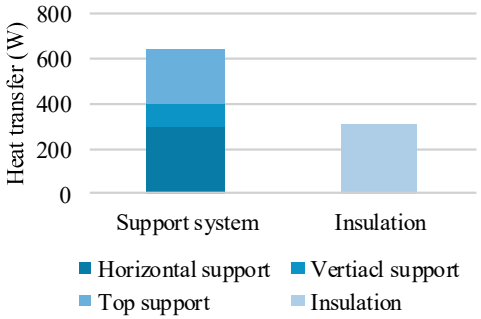
METHODOLOGY

The world's second-largest LH2 tank, with a capacity of 4,200 m³, located at NASA's Kennedy Space Centre, was chosen to evaluate the thermal performance of large-scale LH2 storage systems.



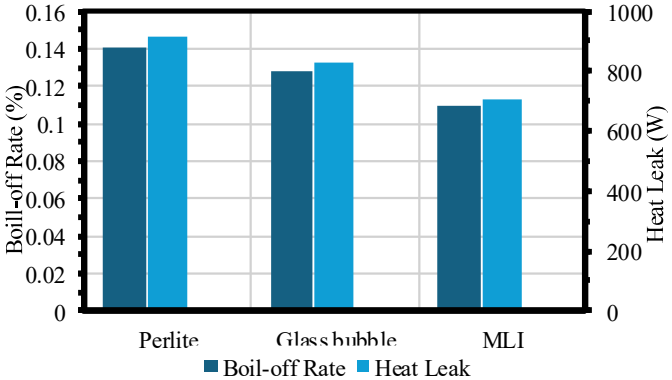
RESULTS & DISCUSSION

It was found that the majority of heat leakage occurs through the internal support structure.



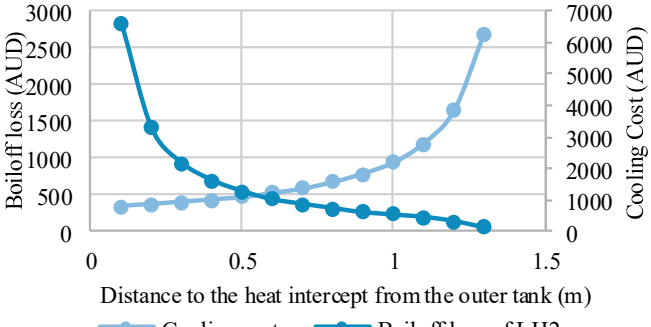
Heat transfer from each component of a large scale LH2 tank

The use of superior insulation materials will reduce the boiloff and heat leak, but the impact is limited.



Heat leak and boiloff rates for different insulation materials

Use of thermal intercepts can reduce the heat leak by supports, but it must be optimised to be fully effective.



Distance optimization for thermal intercepts

Infrastructure Engineering
Graduate Research Conference 2024

Enhancing Recycled Concrete Aggregate Properties via Thermo-Mechanical Treatment

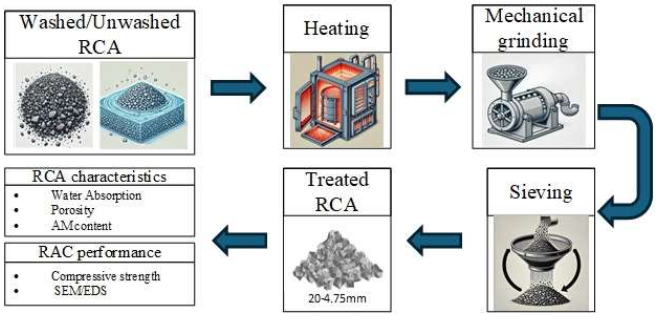
Name: Vithushanthini Arulkumar,
Email: varulkumar@student.unimelb.edu.au
Supervisors: Dr. Tuan Nguyen and Prof. Tuan Ngo
Discipline: Structural Engineering

INTRODUCTION

Rapid population growth and urbanization have significantly increased global demand for buildings and infrastructure. Concurrently, demolishing old structures has generated vast amounts of construction and demolition (C&D) waste, with recycled concrete aggregate (RCA) accounting for approximately 60-70% of all recycled products. However, RCA's application in new concrete is limited by its lower strength, higher water absorption, and durability concerns compared to natural aggregates (NA). These challenges, primarily due to the presence of adhered mortar (AM), often result in RCA being downcycled rather than fully utilized in structural concrete. To promote circularity in the construction industry, enhancing the quality of RCA through scalable and sustainable methods is critical. Thermo-mechanical treatment (TMT) has shown potential for improving RCA by removing or strengthening AM, making it comparable to NA in terms of performance. This study investigates the combined effects of the washing process and TMT at varying temperatures on the properties of RCA and its recycled aggregate concrete (RAC) performance.

METHODOLOGY

The treatment process involves various stages as illustrated below.



Crushed concrete from a C&D waste facility in Melbourne was sieved to obtain untreated RCA (U-RCA). Both Washed and unwashed RCA were heat-treated at 400°C, 500°C, and 600°C for 2 hours, followed by mechanical scrubbing using a ball mill. Treated RCA macro properties (water absorption microstructure through X-Ray µCT (AM content and porosity), were evaluated. Treated RCAs were used to prepare N32-grade concrete, tested for compressive strength and ITZ thickness determined using SEM/EDS.

RESULTS & DISCUSSION

The key findings of the research work are,

- Washed RCA (W-TMT) has a better performance than the unwashed (D-TMT) one in all interested properties.
- W-TMT-RCA treated in 600°C temperature shows a superior performance due to its ability to remove two-thirds of the AM.
- Treated aggregate RACs showed increased compressive strength, with SEM/EDS confirming improved ITZ thickness compared to U-RCA.

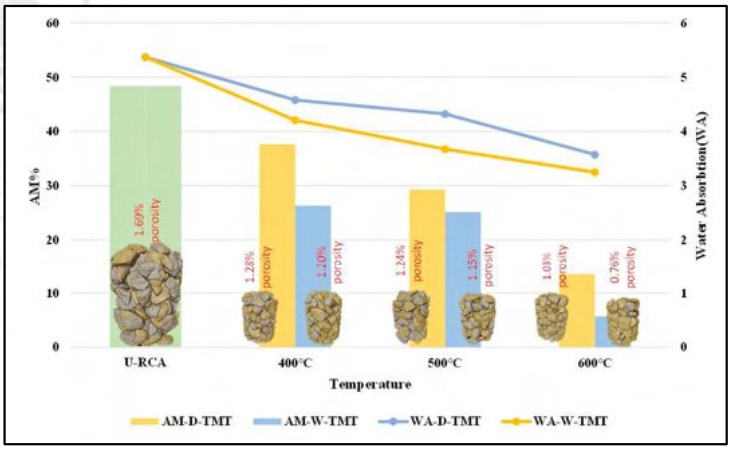


Fig 1:AM content, Porosity and Water Absorption of Untreated and all treated RCA at different Temperatures.

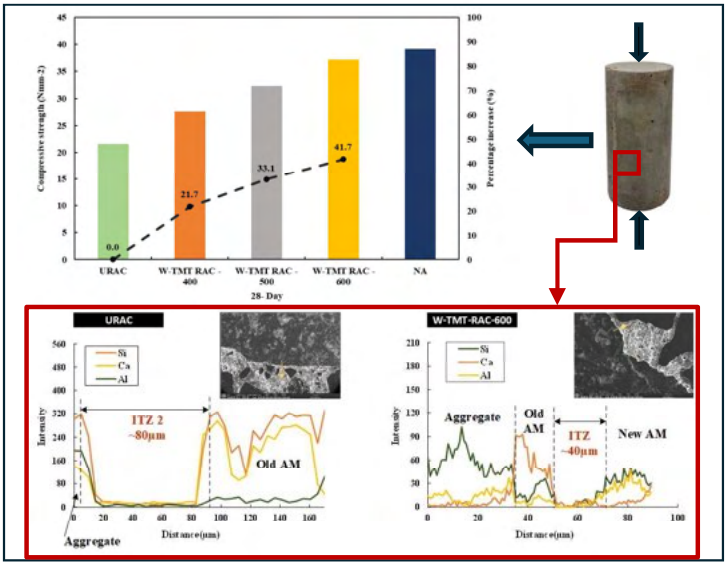


Fig 1:Compressive Strength and ITZ improvement

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Infrastructure Engineering Graduate Research Conference 2024

Design of high-strength concrete filled steel tubular columns under nonuniform fires

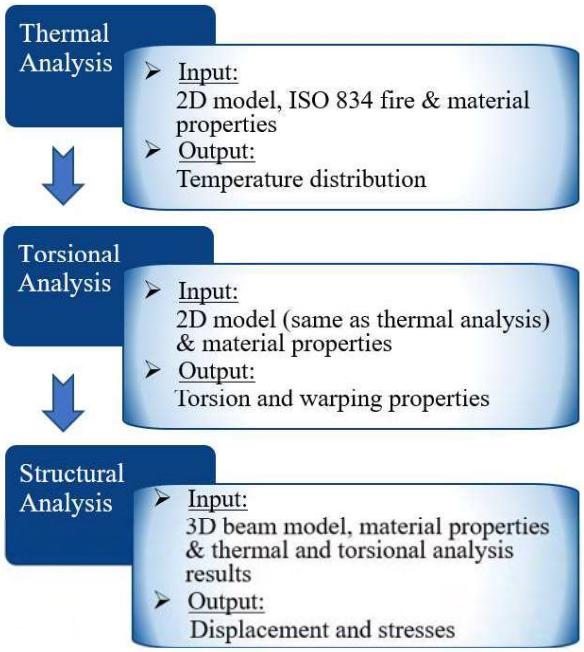
Name: Lalita Lama
Email: lalital@student.unimelb.edu.au
Supervisors: Prof. Huu-Tai Thai, Prof. Tuan Ngo
Discipline: Structural Engineering

INTRODUCTION

Concrete-filled steel tubular (CFST) columns are widely used due to their high load-bearing capacity, ductility, and fire resistance. The use of high-strength materials in CFST columns has been extensively studied and is increasingly adopted in structures, as it allows for smaller element sizes, greater strength, and maximises internal space. Non-uniform fire conditions, often caused by column alignment with walls, can affect fire performance differently than uniform fire conditions. Despite considerable research has focused on CFST columns with normal-strength materials under uniform fire, very limited studies have explored the performance of high-strength CFST columns under non-uniform fire conditions. The study addresses this gap by validating finite element models against experimental data, followed by parametric analysis to evaluate key factors such as concrete strength, steel strength, fire scenario, load ratio and length. The study also assesses the tabulated design method for CFST columns under fire as outlined in EN 1994-1-2 and AS/NZS 2327:2017, extending the evaluation to high-strength materials.

METHODOLOGY

This study utilises finite element modelling using SAFIR software to assess the fire performance of CFST columns. The analysis process is outlined in the flowchart below:



RESULTS & DISCUSSION

The study reveals that fire resistance decreases as load ratios increase and more sides are exposed to fire. In intermediate columns, higher-strength concrete was found to improve fire resistance under three- and four-sided fire exposure. For slender columns, steel strength contributed positively to fire resistance. However, the tabulated design method is found to be non-conservative for slender columns under certain conditions. Further experiments are needed, as most existing research focuses on the CFST columns with normal-strength materials exposed to uniform fire. Future studies should aim to refine the design tables by addressing existing limitations and flaws.

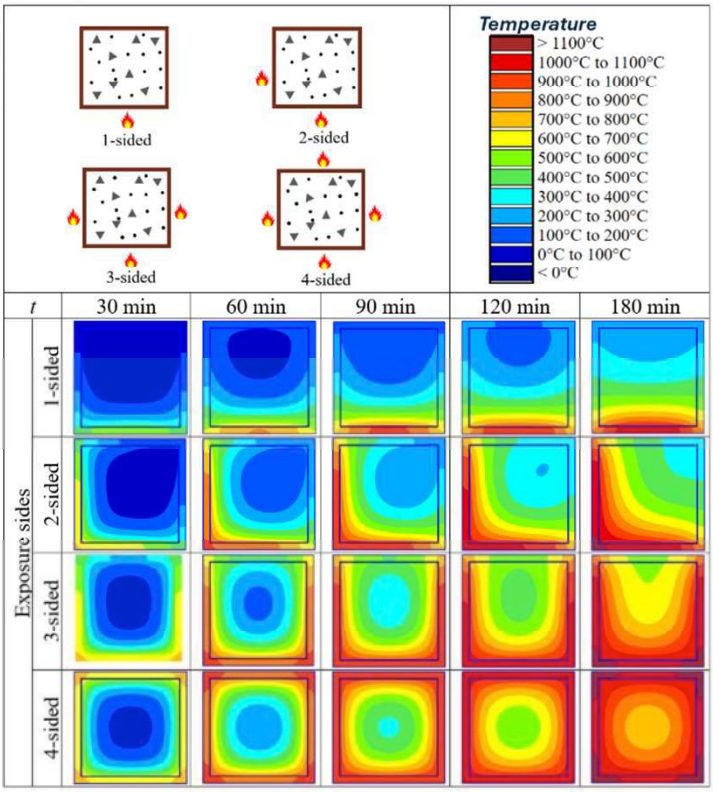


Fig.1. Temperature distribution profile at the cross-section

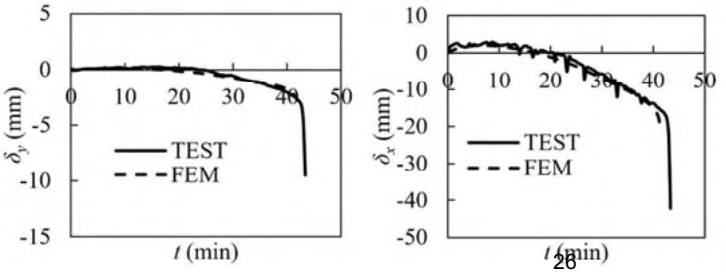


Fig 2. Comparison of vertical and horizontal displacement

Development of Waste Wood Composites for Load-bearing Engineered Wood Products

Name: Isuri Tamura Amarasinghe
Email: iamarasinghe@student.unimelb.edu.au
Supervisors: Prof. Priyan Mendis, Dr. Tharaka Gunawardena, Dr. Shanaka Baduge, Dr Benoit Belleville
Discipline: Structural Engineering

INTRODUCTION

The Global timber consumption is expected to reach over 500 million m^3 by 2030 (FAO, 2021). However, due to deforestation, illegal logging and climate change induced disturbances, there is a severe global timber shortage. On the other hand, there rises an issue of the increasing wood waste in landfills. Use of recycled wood to create engineered wood products is a sustainable solution to these issues and can improve resource efficiency in the construction industry.

Engineered wood products are sheet-like products made by combining fibres, veneers, and particles bonded with adhesives and pressed under heat. Wood waste can be collected, sorted, treated and dried to create panels, which utilizes wood waste that otherwise goes to landfills. It is important to understand how different wood waste types and mixes affect the mechanical and physical properties of the final composite and how we can optimise these parameters to fabricate a final product that is structurally sound.

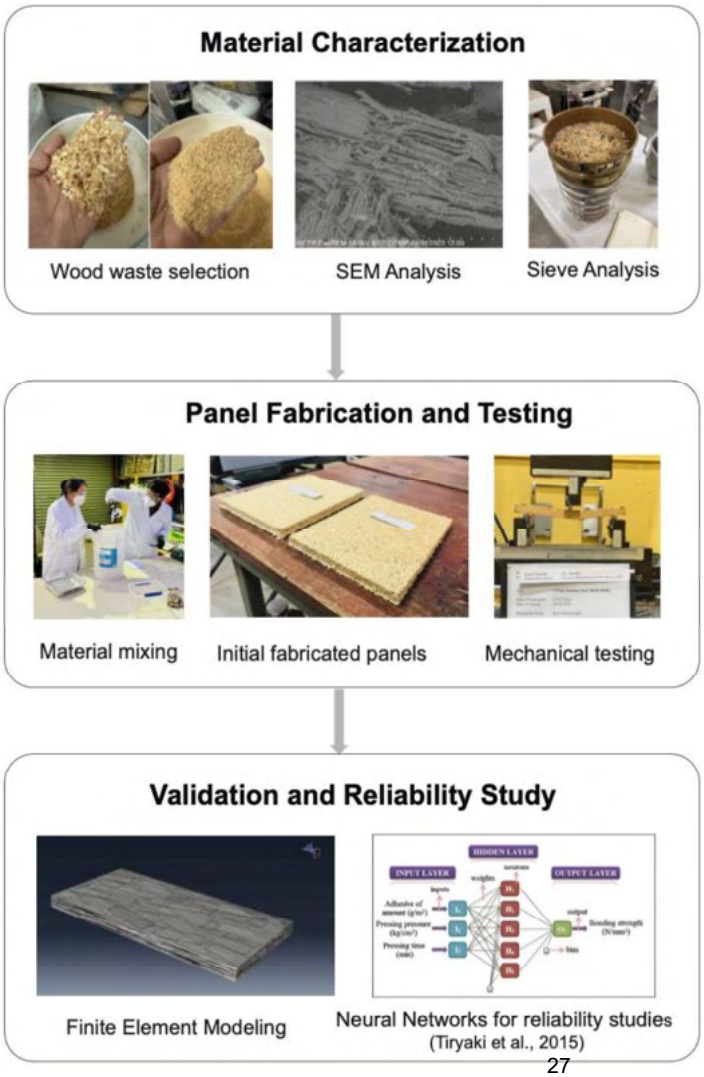
METHODOLOGY

For the initial trials, three types of sawmill residues including wood waste, wood flake and sawdust were collected from a local sawmiller, and the material properties including moisture content, density and particle size distribution were measured. The timber waste were dried at 80°C for 24 hours before mixing with the adhesive thoroughly. The adhesive-treated timber was loaded into the mold and pre-pressed using a laboratory press at 0.9 MPa. The mold was then removed and heat and pressure was applied to the mat at 180 °C until the desired thickness was achieved. The pressed particleboards were then conditioned in a room at 20 °C and 65% relative humidity for 7 days.

The panels were then trimmed and cut according to the scheme given in AS 1859 and tested for various mechanical and physical properties including Modulus of Rupture (MOR), Modulus of Elasticity (MOE), compression strength, density, moisture content and thickness swelling.

RESULTS & DISCUSSION

Initial results show that using wood waste to fabricate engineered wood panels can be achieved, especially considering the achieved physical properties. However, a significant strength loss can be observed in the mechanical properties, particularly due to the discontinuity in the bonds between the particles and adhesive. It was observed that by using wood flake, that have a higher surface area as well as a higher percentage of adhesive (12%) the properties of the particleboard can be improved. Future work include the use of the "wet mix" process to fabricate these wood waste panels to achieve a homogenous mixture, as well as a parametric study of the different wood waste types and mixes.



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Infrastructure Engineering
Graduate Research Conference 2024

Numerical Analysis of Steel-Concrete Composite Shear Wall at Elevated Temperature

Name: Nav Raj Bhatt
Email: navraj@student.unimelb.edu.au
Supervisors: Prof. Huu Tai Thai, Prof. Tuan Ngo
Discipline: Structural Engineering

INTRODUCTION

Steel-concrete composite shear walls (SCCSWs) offer significant advantages in structural engineering, such as modularity and accelerated construction timeline. By stiffening steel plates with tie bars and pouring concrete between them, SCCSWs provide the benefits of both materials, resulting in lighter and thinner cross-section compared to traditional reinforced concrete (RC) walls. High-rise buildings face extreme loading conditions, such as fires, which can severely affect the structural integrity of SCCSWs. Without fire protection, the steel plates are directly exposed to high temperatures, leading to uneven temperature distributions, degradation of material properties, and potential buckling. This can cause failure at lower axial loads than what SCCSWs can withstand at ambient temperatures. To ensure the safety and sustainability of SCCSWs in modular construction, this research investigates their behaviour under fire using finite element (FE) analysis. Through parametric study the research evaluates the effects of load ratio, eccentricity, material strengths and fire exposure, providing critical insights into SCCSW performance under fire.

METHODOLOGY

Numerical models were developed using ABAQUS to predict the behaviour of SCCSWs under combined axial load and fire conditions, employing a sequentially coupled transient thermo-stress approach. The wall elements were discretised into eight-node linear brick elements to ensure precise representation. The accuracy of the FE results was validated against the existing fire test data (Wei et al., 2018). Following validation, an extensive parametric study was carried out to investigate the influence of various factors on the performance of SCCSWs under fire.

Thermal Analysis

- 3D elements
- ISO 834 curve
- Temperature distribution

Structural Analysis

- 3D elements
- Integrate heat transfer results
- Dynamic Impilcit solver
- Structural performance Displacements, stresses.

RESULTS & DISCUSSION

The study shows that the fire endurance of SCCSWs significantly decreases with an increase in load ratio and surface area exposed to fire. Under identical geometrical and fire conditions, and with same sectional load ratios, normal strength materials demonstrate superior fire resistance compared to the high strength counterparts. Additionally, the eccentricity of the applied load substantially reduces the fire performance of SCCSWs. For one-sided fire exposure, the most critical scenario occurs in short walls when the load is applied towards the exposed side. In contrast, for slender walls, the critical condition arises when the load is applied to the unheated side.

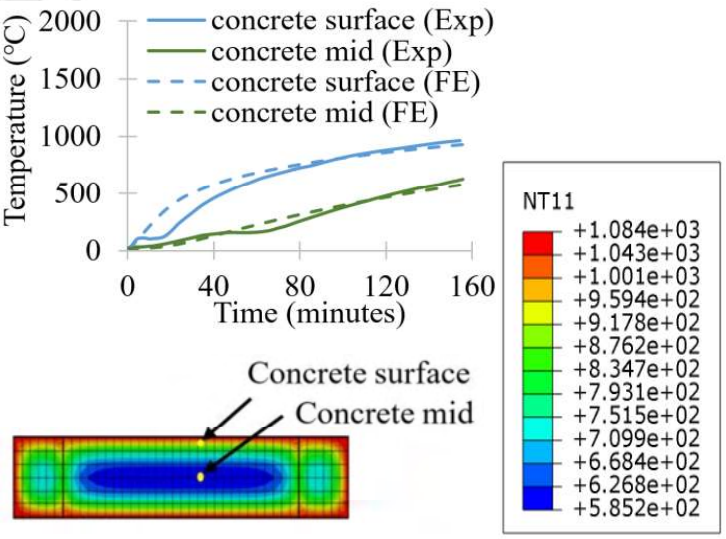

Fig. 1. FE-predicted vs Experimentally measured temperature distribution for wall SCW4

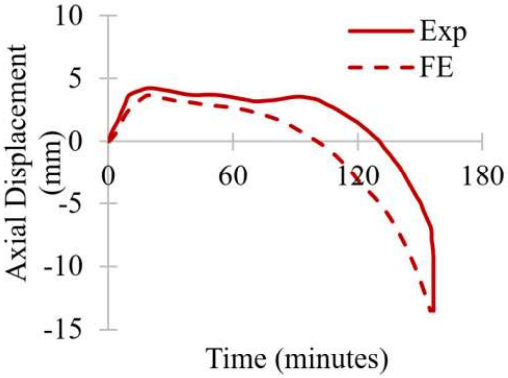

Fig.2. FE-predicted vs Experimentally measured axial deformation for wall SCW4

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A study on the durability of bamboo strips using the constant immersion method

Name: Nimisha Kattumunda
Email: nkattumunda@student.unimelb.edu.au
Supervisors: Prof. Tai Thai, Prof. Tuan Ngo, Prof. Damodar Maity
Disciple: Structural

INTRODUCTION

- Being a biomaterial, bamboo is subjected to degradation both inside and outside of the concrete, necessitating a thorough investigation of its durability before any structural applications.
- There exist a scarcity of research related to the long-term durability of bamboo.
- This study presents the experimental investigation for the evaluation durability of bamboo strips for up to a period of 125 days at ambient temperature in water and alkaline environments using the constant immersion test.
- The effect of epoxy Sikadur-32 LP coating on bamboo was assessed by comparing results with the non-coated samples and those kept at ambient conditions.
- The durability of the bamboo discussed through strength retaining capacity of the samples after the long-term exposure to the solutions.

RESULTS & DISCUSSION

- Contrary to the findings of Lima et al. who reported no significant changes in tensile strength and Young's modulus after 60 cycles of alternate wetting and drying in calcium hydroxide solution and tap water, our study observed a notable reduction in both tensile strength and modulus of elasticity after constant immersion in alkaline and water media for the stipulated time periods.
- The application of protective coating (Sikadur-32 LP) significantly enhances the strength-retaining capacity of bamboo compared to non-coated samples.
- It is noticed from the results of FTIR and XRD patterns that the chemical structure of bamboo remains intact. However, SEM micrographs reveal structural damages at the cellular level, indicating baboo undergoes structural degradation during constant immersion.

METHODOLOGY

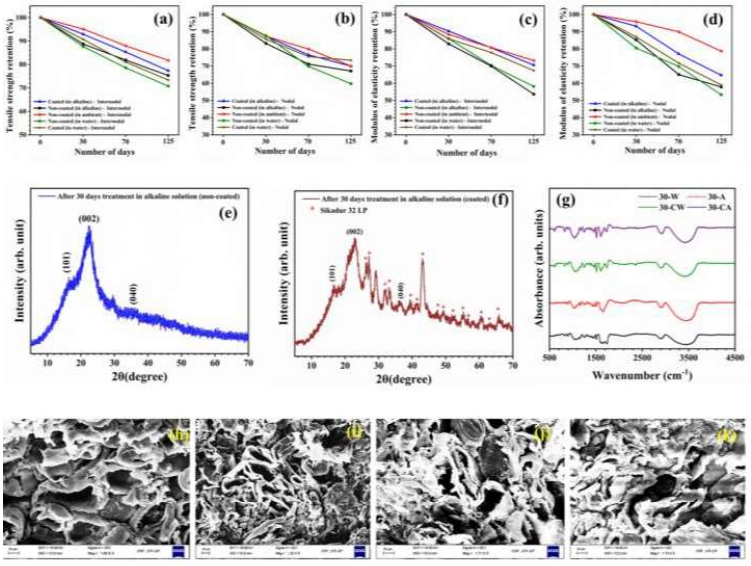

Figure: Percentage retention of tensile strength (a) internodal, (b) nodal; Percentage retention of modulus of elasticity (c) internodal, (d) nodal; X-ray diffractograms of (e) non-coated and (f) Sikadur-32 LP - coated bamboo (g) FTIR spectrum of bamboo after constant immersion for 30 days in different media (W- water, A- alkaline, CW- coated water, CA- coated alkaline); SEM micrographs of bamboo after 125 days (h) Sikadur-32 LP-coated-alkaline, (i) non-coated-alkaline, (j) Sikadur-32 LP-coated-water, and (k) non-coated-water solutions.

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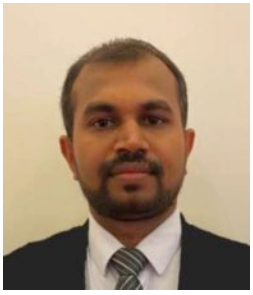
Impact of Progressive Dataset Expansion on CNN Performance in Plastic Waste Sorting



Name : Nuwan Dewapurage
Email : ndewapurage@student.unimelb.edu.au
Supervisors : Dr Shanaka Baduge, Prof Priyan Mendis, Prof Shanika Karunasekera
Discipline - Structures

INTRODUCTION

In modern solid waste recycling, computer vision-based methodologies have become increasingly popular for sorting plastic materials which employs advanced image processing algorithms to automate the sorting of items based on their visual characteristics. The effectiveness of these systems rely on the quality, visual features, and quantity of the training dataset being used. In deep learning methods, model performance is largely determined by the ability of dataset to represent real-world conditions rather than the quantity of dataset. This insight challenges the conventional one-size-fits-all approach emphasizing the need for a tailored evaluation of diversity and relevance of dataset. Our study analyses these factors in the context of waste plastic recycling in Australia demonstrating that high-quality and diverse datasets are crucial for improving model performance and optimizing waste plastic sorting practices in solid waste recycling.

METHODOLOGY

A comprehensive survey was conducted to identify and classify post-consumer waste plastic types and associated residues leading to the creation of a case-specific database. This database comprises of 25,000 waste plastic images accompanied by 67,741 annotations which were compiled for supervised model training in the recycling process. The dataset was organized into eight progressively larger sub-datasets to examine the impact of increasing training dataset size on the performance of Convolutional Neural Networks (CNNs) for waste plastic sorting tasks. Rather than starting training from scratch, we utilized transfer learning and trained a total of 72 models across three different You Only Look Once (YOLO) architectures: small, medium, and large. Each architecture was trained using batch sizes of 16, 32 and 64, respectively. To evaluate model performance, we employed mean Average Precision (mAP) particularly focusing on the area under the precision-recall curve which offers a balanced measure of both classification accuracy and localization precision.

RESULTS & DISCUSSION

The results indicate that increasing the size of the training dataset leads to significant improvements in mean Average Precision (mAP) and demonstrates a positive correlation between the volume of training data and model performance. To better understand the model's behaviour with additional data and to inform decision-making and resource allocation, we employed a logarithmic function to fit the mAP curve as illustrated in the figure 1. The overall accuracy of the model was approximately 35% with certain categories achieving accuracy rates exceeding 70%. However, some categories experienced lower performance levels which negatively impacted the overall accuracy. Contributing factors to this reduced accuracy include variability in the quality of post-consumer plastics, similarity in features among categories, contextual challenges specific to industrial settings and insufficient data availability for certain categories. These findings underscore the need for further investigation into more advanced machine learning techniques with effective detection capabilities of solid waste plastics.

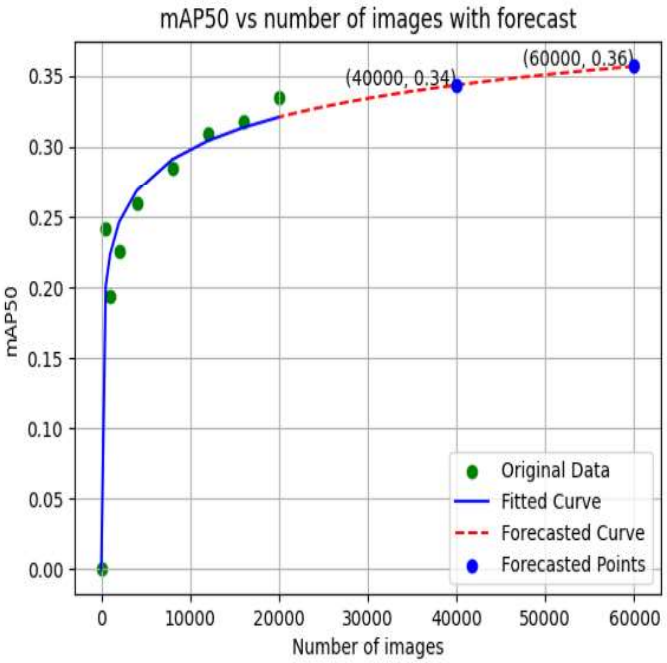


Fig 1 Learning curves of mAP with forecast

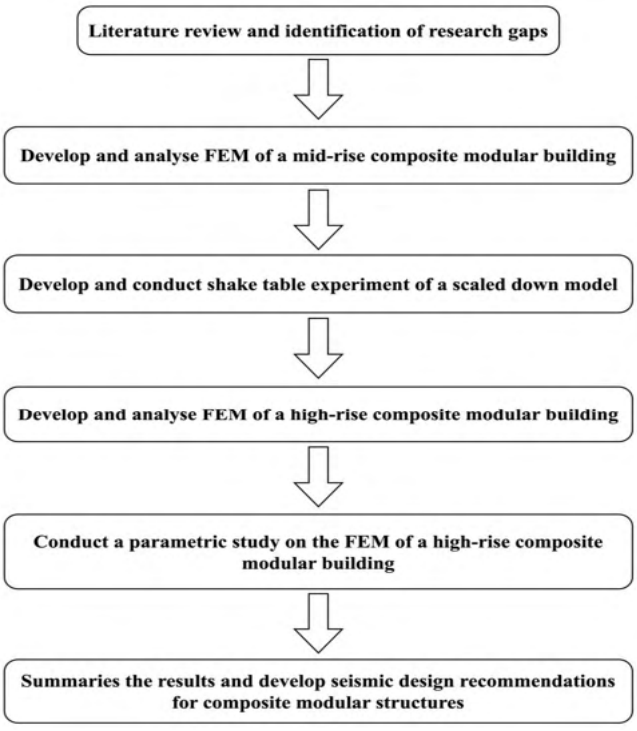
Seismic performance and earthquake design of composite modular buildings

Name: Omar Morsy
Email: omarahmedmoh@student.unimelb.edu.au
Supervisors: Prof. Huu-Tai Thai, Dr. Elisa Lumantarna
Disciple: Structural

INTRODUCTION

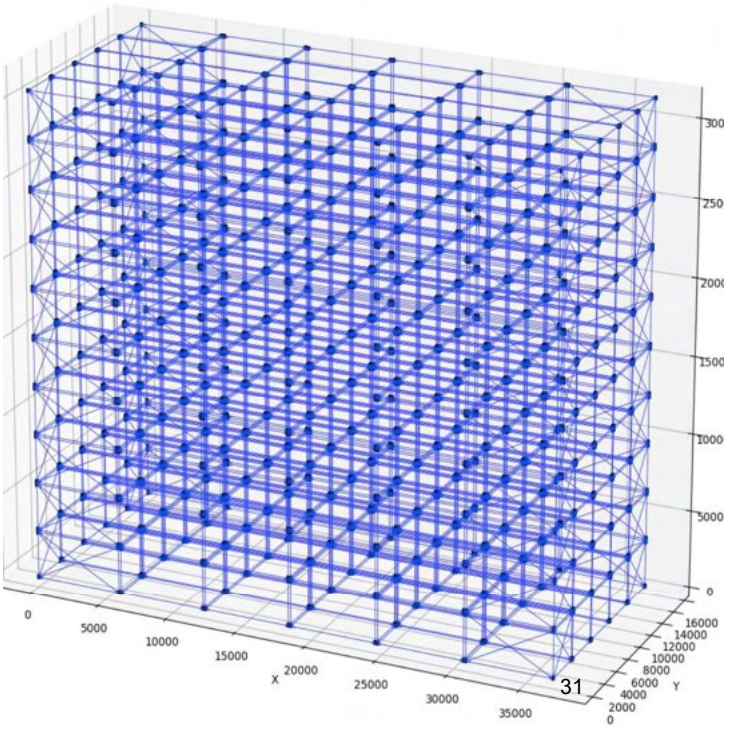
Modular construction provides advantages in terms of speed and quality of construction but brings along its unique structural response during earthquakes, considering the discontinuity at module interfaces. Most of the modular buildings are made from steel; however, its limitations have sparked off an interest in composite materials such as concrete-filled steel tube columns and composite shear wall systems for seismic resistance. It is worth noting that the current scarcity of research and design standards on modular buildings require further studies regarding their seismic performance, especially of those with composite elements, which have not been investigated up to this time. The key research aims include the influence composite elements have on seismic performance of modular buildings, applicability of current seismic design standards to composite modular structures, and accuracy or the limitation of the finite element modelling techniques for seismic response prediction of modular buildings. These investigations are crucial in ensuring safety and efficiency of modular buildings in earthquake zones.

METHODOLOGY



RESULTS & DISCUSSION

This study's current findings underscore the seismic resilience of mid-rise composite modular buildings incorporating concrete-filled steel tube columns, particularly in low-to-moderate seismicity regions. Nonlinear time-history analyses showed that the structure would remain within the life-safety limits even when subjected to amplified ground motions, suggesting potential for safe performance in higher seismic zones. The Australian Standard were found to underestimate key seismic performance parameters of composite modular buildings, highlighting the need for expanding the current design provisions. These findings are in good agreement with previous studies on steel modular buildings and confirm robust seismic performance of modular buildings. Future research include incremental dynamic analysis to study the seismic performance of high-rise composite modular buildings and the development of refined seismic design parameters. The current limitations include the focus on one 10-storey composite modular building and two hazard levels. However, the present results provide new insights into seismic performance of composite modular buildings, facilitating their wider adoption.



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Circular and Sustainable Prefabricated Structural Insulated Panel (SIP) System

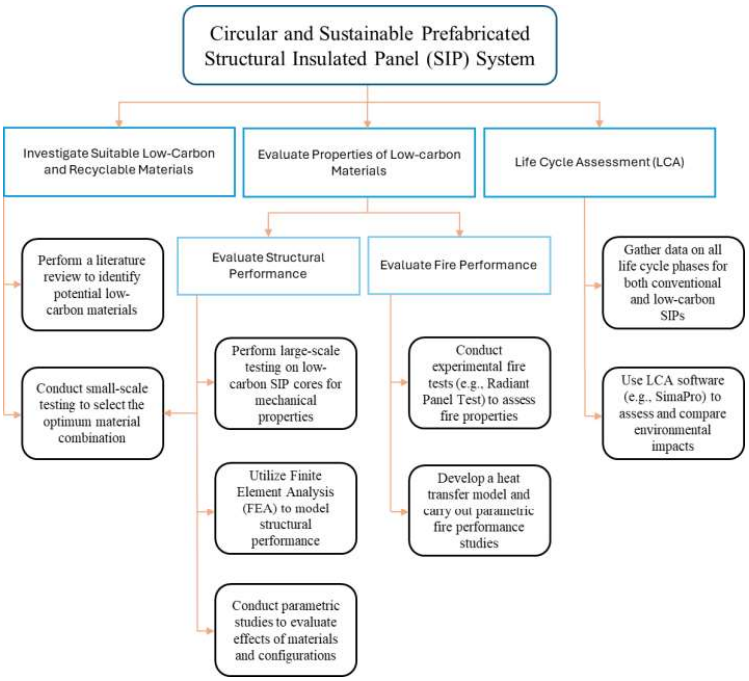
Name: Rannulu Nipun De Zoysa
Email: dezoysar@student.unimelb.edu.au
Supervisors: Dr. Shanaka K. Baduge, Dr. Sadeep Thilakarathna, A/Prof. Xuemei Liu
Discipline: Structural Engineering

INTRODUCTION

The construction industry is a major contributor to global carbon emissions and waste. This research project aims to address these challenges by developing a circular and sustainable Structural Insulated Panel (SIP) system, integrating low-carbon, recyclable, and bio-based insulation materials. The goal is to achieve superior thermal efficiency while minimizing environmental impact, supporting the Net Zero 2050 goals by reducing carbon emissions across the building life cycle.

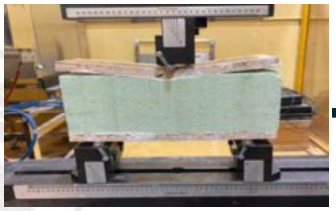
The use of conventional insulation materials in SIP systems, such as expanded polystyrene (EPS), has significant environmental drawbacks, including non-recyclability and high carbon footprints. This project explores alternative low-carbon insulation materials, including recycled polyethylene terephthalate (rPET) and bio-based Mycelium, which align with circular economy principles. These materials offer the potential to significantly reduce the environmental impact of SIP systems, contributing to the global transition towards Net Zero by 2050.

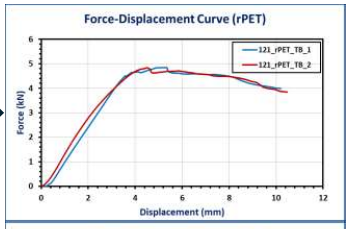
METHODOLOGY

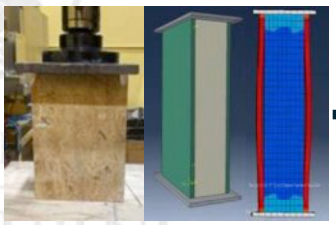


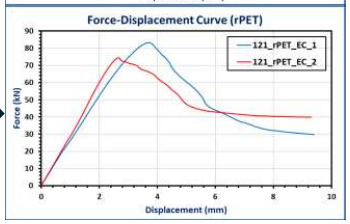
RESULTS & DISCUSSION

- Small-scale structural tests, including three-point bending and edgewise compressive tests, demonstrated that SIP samples with rPET cores exhibited significantly higher strength compared to conventional SIPs with EPS insulation. Also, finite element model in development stage, will undergo parametric studies after validation.

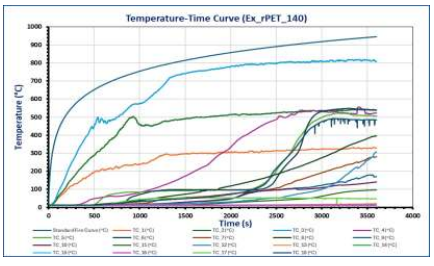




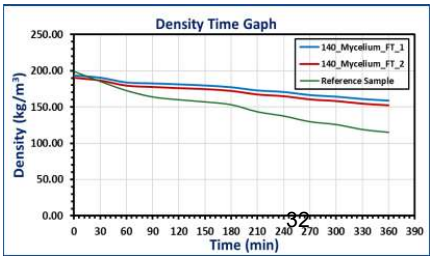




- In the Radiant Panel Test, SIP panels with rPET cores showed superior thermal performance over EPS. There was no significant temperature increase on the unexposed surface of SIPs with rPET insulation, whereas EPS-based SIPs exhibited significant temperature rise.



- Lab-made Mycelium samples, formed into large blocks, have achieved a reduced density of around 100kg/m³, suggesting potential for integration into SIP manufacturing. However, further testing is required.



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Design and Manufacturing Process Optimisation in Timber Prefab Housing

Name: Sasindu Samarawickrama
Email: sasindu.samarawickrama@student.unimelb.edu.au
Supervisors: Dr Tharaka Gunawardena, Prof Priyan Mendis
Discipline: Structural Engineering

INTRODUCTION

Timber prefab housing has emerged as a key innovation in the construction sector due to the growing demand for sustainable and efficient housing. These systems consist of pre-fabrication of structural elements such as timber components and panels in a controlled environment which enhances environmental sustainability and the efficiency of building practices. The Australian housing market is currently dealing with a pressing need, as projections indicate that the construction of 1.2 million new dwellings over the next five years is necessary to accommodate population growth and urbanisation (FWPA). This research focusses on the optimisation of the design and manufacturing processes in the timber prefab housing sector, a critical area that has not undergone significant research which attempts to improve the overall efficacy and sustainability of prefab timber housing by improving the integration of advanced design techniques and manufacturing automation, thereby addressing the gaps in streamlined design and production methodologies.

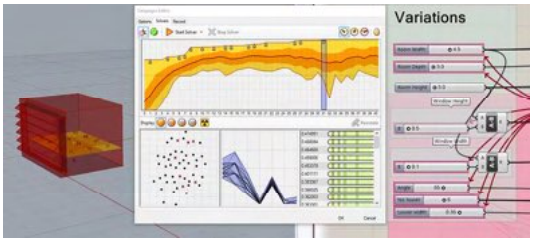
DISCUSSION

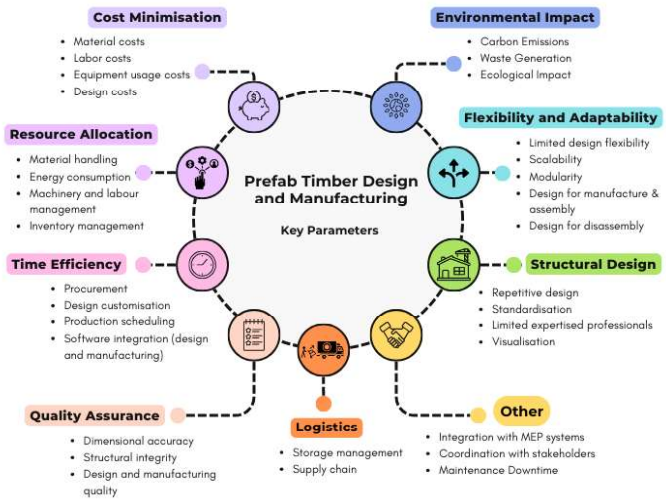
This study highlights key challenges in the timber prefab housing industry, including the need for improved efficiency and sustainability in design and manufacturing practices. The problems include the integration of advanced computational methods and the adaptation to emerging technologies such as artificial intelligence (AI) and multi-objective optimisation. This project proposes the development of a framework that employs digital tools and optimisation methods to improve production efficiency and minimise environmental effect. Future study needs to focus on real-world trials and collaborations with industry stakeholders that validate the proposed structure and improve its components based on practical feedbacks and technical progress.

METHODOLOGY

Optimising timber prefab housing involves a comprehensive review of current industry practices alongside an investigation of innovative design and manufacturing technology. We utilise artificial intelligence (AI) for design optimisation along with multi-objective optimisation techniques to enhance production processes, employing parametric modelling tools and digital fabrication technologies to significantly minimise waste and production time while maintaining high standards of quality and customisation. This comprehensive approach guarantees that designs are both optimal and practically applicable in real-world situations.

Rhinoceros + grasshopper





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Characterisation and Double-Sided Pullout Study of Recycled Flowline Steel Fibres

Vito Nathaniel Lokito – vlokito@student.unimelb.edu.au
Supervisors:
Dr. Elisa Lumantarna – elu@unimelb.edu.au
Dr. Massoud Sofi – massoud@unimelb.edu.au

INTRODUCTION

The growing demand for construction materials has led to innovations such as steel fibre reinforced concrete. However, inflated costs and environmental concerns remain as obstacles that cannot be ignored. On the other hand, decommissioning plans for offshore facilities in Australia presents a new opportunity for the potential recovery of vast amounts of waste steel. With both factors in mind, an upcycling initiative has been proposed to repurpose the recovered steel into recycled steel fibres.

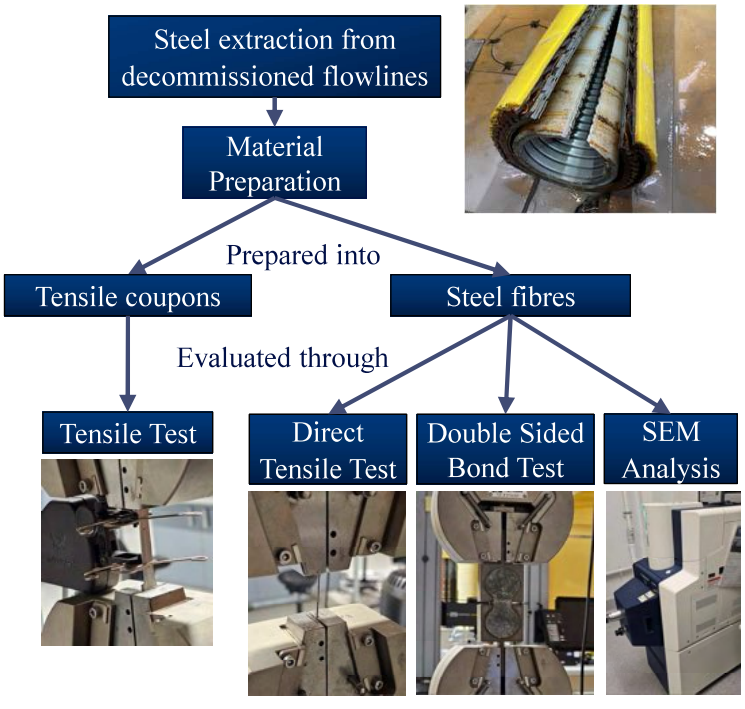
(Hughes, 2021)
https://www.oedigital.com/news/486187-baker-hughes-tackles-flexible-pipe-stress-corrosion-cracking

https://www.civilengineeringforum.me/applications-of-steel-fiber-reinforced-concrete/

Therefore, how effective will the fibres be? This study evaluates the performance of the recycled steel fibres through characterisation and double-sided pullout tests.

METHODOLOGY

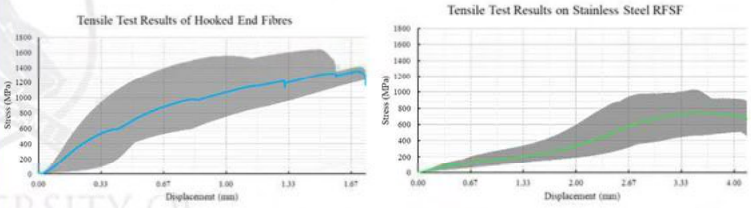
The flowchart representing the characterisation and pullout evaluation methods could be observed below:



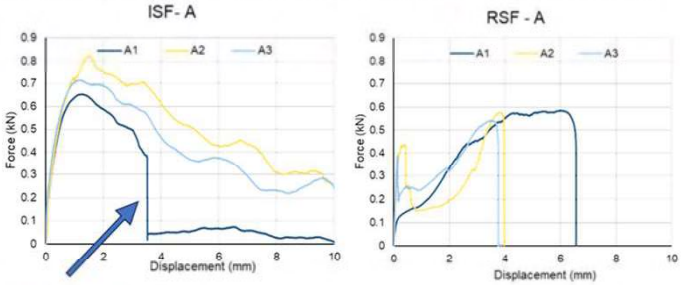
RESULTS & DISCUSSION

The steel layers extracted from decommissioned flowlines led to the production of two novel prototype recycled steel fibres: recycled stainless steel fibres and recycled carbon steel fibres.

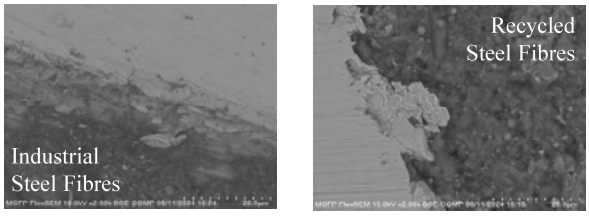
Tensile testing demonstrated the mechanical properties of the extracted prototype steel fibres, and a distinct difference against typical industrial fibres could be seen.



The unique stress-strain behaviour of the recycled fibres resulted in different double-sided pullout results, such as *delayed peaks and rupture dominated failure behaviours.*



SEM analysis showed the presence of beneficial surface roughness that leads to improved bond behaviour



In conclusion, this study showed the potential performance of recycled flowline steel fibres. Notably, distinct pullout performance was observed due to the improved bond or anchorage behaviour, although these improvements were limited by lower mechanical properties. This aligns with SEM analysis results. Nonetheless, initial findings suggest a promising future for this new pathway of recovered steel wastes upcycling. Future research will focus on evaluating the performance of flowline RSF reinforced concrete.

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Missing Data Imputation for Structural Health Monitoring Using Modified WGAIN-GP

Sumit Saha
sahass@student.unimelb.edu.au
Supervisors: Prof. Tuan Ngo, Dr. Siddhesh Godbole
Department: Infrastructure Engineering

INTRODUCTION

Problem: Structural Health Monitoring (SHM) ensures safety and performance through real-time virtual replicas of physical structures. However, missing data from sensor malfunctions or transmission failures can undermine the accuracy of SHM systems. Deep learning models like LSTM and VAE address this but struggle with continuous data loss, especially at high missing rates.

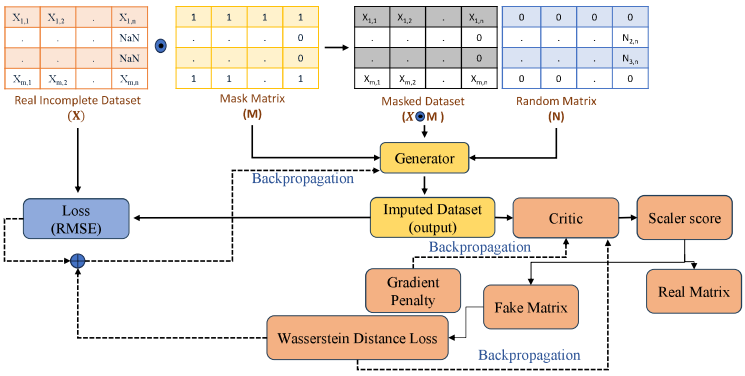
Proposed Solution: We introduce Modified Wasserstein Generative Adversarial Imputation Network with Gradient Penalty (MWGAIN-GP) to recover missing sensor data in both time and frequency domains.

Key Feature: Utilizes the stability of Wasserstein GAN with gradient penalty, eliminating the need for a hint matrix.

Validation : Tested on acceleration datasets, MWGAIN-GP shows superior performance over existing GAN-based models, especially in high missing data scenarios.

Performance: MWGAIN-GP consistently provides better recovery and enhanced structural condition assessments for SHM.

METHODOLOGY



To apply the proposed MWGAIN framework in both the frequency and time domains, following steps are required:

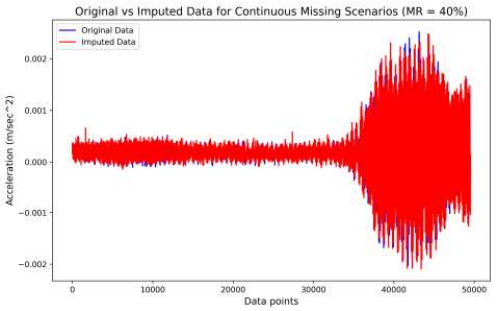
(a) Synthetic omissions are introduced into the original dataset.
(b) Next, the complete dataset is split into training and testing sets, and both sets are normalized.
(c) Normalized training datasets are used into the architecture and train the generator through the adversarial process.
(d) Test dataset is fed into the trained generator and impute the datapoints for both discrete and continuous missing data.
(e) Finally, renormalization technique is used to get the order sensor data.

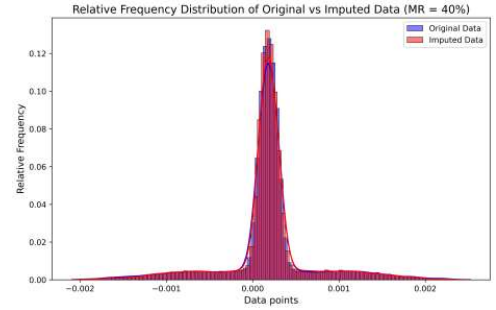
RESULTS & DISCUSSION

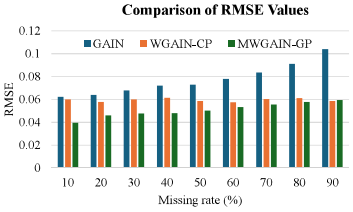
Evaluation Method: Missing data was simulated using the MCAR (Missing Completely at Random) mechanism. Missing rates ranged from 10% to 90%, covering both **discrete and continuous missing data scenarios**.

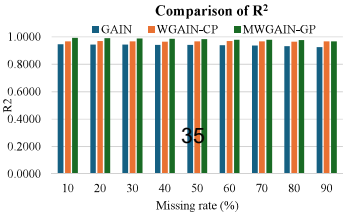
Framework Performance: MWGAIN-GP was tested against two state-of-the-art GAN-based imputation models: **GAIN and WGAIN-CP**. Real-world datasets from the LUMO steel mast were used, covering both time and frequency domains.

Key Results: MWGAIN-GP outperforms other two imputation frameworks across all performance metrics. Achieved lower root mean square error (**RMSE**) and higher coefficient of determination ($\mathbf{R^2}$). Demonstrated **consistent superiority even at higher missing** data rates. Ensures greater stability and improved imputation quality.







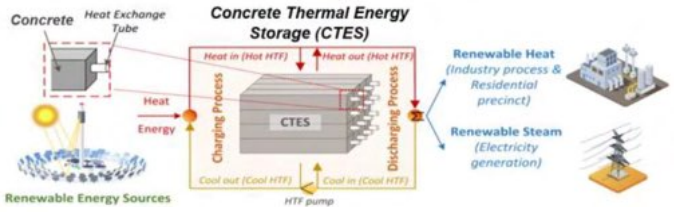


High-Temperature Stability of Geocrete for Thermal Energy Storage

PhD: Nghia P. Tran
Email: trannp@student.unimelb.edu.au
Supervisors: Prof. Tuan Ngo, Dr. Tuan Nguyen
Discipline: Structural Engineering

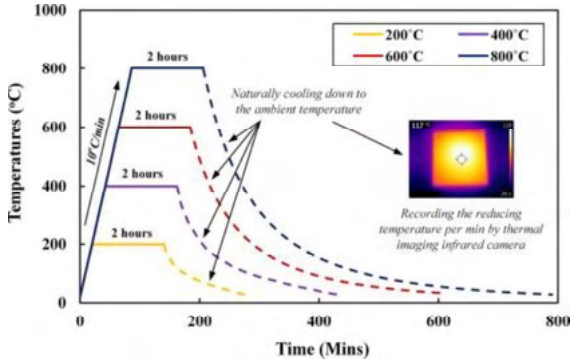
INTRODUCTION

- Driven by climate change and rising energy demands, the global shift towards clean, renewable energy is accelerating. Advanced energy storage technologies are crucial for supporting this transition. Concentrated solar plants with thermal energy storage (TES) systems offer a solution to renewable energy's intermittency. Concrete is proving to be an effective, low-cost TES medium. Improving the thermal performance of concrete is key to enhancing TES system efficiency.
- This study focus on developing an innovative Geocrete. A comprehensive investigation will be conducted to provide insight into the reaction mechanisms, microstructure, and pore structure of innovative Geocrete with enhanced thermal stability.



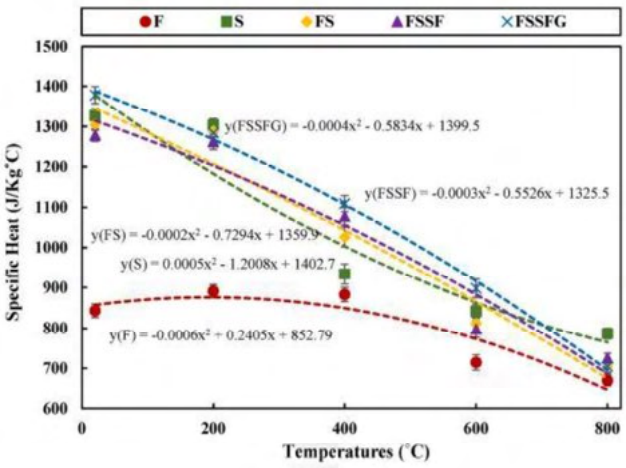
METHODOLOGY

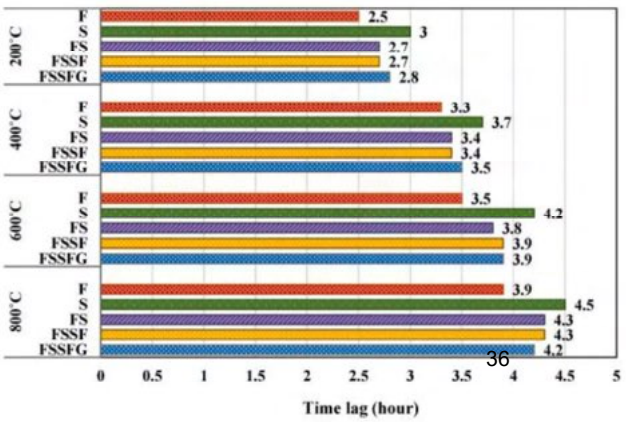
- Besides the specimen cured at ambient, other AAM samples were heated to 200 °C, 400 °C, 600 °C, and 800 °C. Once the target temperature was reached, it was maintained for 2h to ensure uniform heating. A thermal digital camera recorded the naturally cooling process, providing data to estimate the thermal lag.
- Residual strength, thermal properties, microstructure, pore structure were characterised through visual observation, TGA, XRD, SEM/EDS and X-ray μCT after high temperature exposure to 200–800 ◦C.



RESULTS & DISCUSSION

- When exposing to elevated temperatures, high heat and build-up vapour somewhat establish a hydrothermal condition inside AAM pastes, which promotes further geopolymerisation and hydration. This phenomenon facilitates the strength enhancement upon exposure to 400 ◦C, where the FSSFG obtains a 28-day strength of approx. 100 MPa.
- Specific heat capacity (Cp) of AAM tends to decline upon elevated temperature exposure. The AAM paste with 0.1% GNPs can achieve relatively high Cp value of approx. 1400 J/KgºC at ambient condition.
- High Si/Al and Ca/Si ratios associated with high strength but low thermal stability. Low Na/Al and Na/Si ratios also correlate to intensive cracking.
- Increasing temperature exposure proportionally correlates to a higher fraction of crystalline phases formed and a longer duration of heat energy storage.





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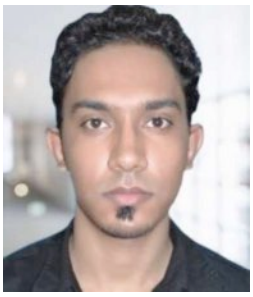
Infrastructure Engineering
Graduate Research Conference 2024

An Investigation Of Different Anchorage Systems For CFRP Bars Bonded Internally To Timber Beams

Hafedh Al-Mashgari
Email: halmashgari@student.unimelb.edu.au
Supervisors: Assoc Prof. Xuemei Liu, Dr. Tuan Ngyuen
Discipline: Structural



INTRODUCTION

In the recent years, the inclusion of mass timber in the construction industry has predominantly been relied on softwoods which classified as less durable due to lower stiffness. The main aim of this research is to propose an innovative strengthening technique utilizing Carbon fiber reinforced polymer (CFRP) bars to increase the timber stiffness and overcome the shortcomings of using mass timber production (MTP) in construction. The most critical challenge encounters the application of FRP materials in the construction industry is the occurrence of premature debonding between the structural element surface and the strengthened FRP system. This project investigates the behaviour of timber beams strengthened with CFRP bars with three different anchorage systems to prevent premature debonding. .

METHODOLOGY

Three different anchorage systems will be considered in this work: Internally bonded reinforcement on grooves with (i) embedded end by 90°; (ii) with embedded end by 45°; (iii) with the addition of mechanical anchorage system (MAS): two steel plates and anchor bolt as a clip to fix the CFRP rod to timber (Fig. 1-3)

Figure 1: CFRP bar bent by 45 degree

Figure 2: CFRP bar bent by 90 degree

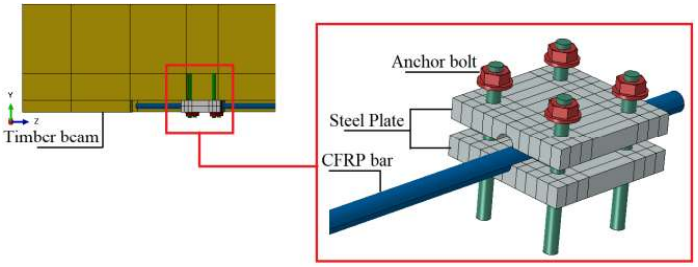


Figure 3: CFRP bar with MAS

RESULTS & DISCUSSION

- The use of FRP bar with MAS allowed the ultimate load to increase by 54.89 % compared to unreinforced timber beam, while increment of 63.4 % and 43.59 % were recorded for timber beams reinforced with Embedded-45 degree and Embedded-90-degree CFRP bars respectively (Fig. 4)
- Fig. 5 and Fig. 6 demonstrate the different debonding mechanism of the reinforced beams. At the time of failure, the maximum tensile strength of the anchorage CFRP rods was approximately 70%, while for the case of conventional NSM system did not exceed 40 % of its ultimate proved the effectiveness of the current anchorage system

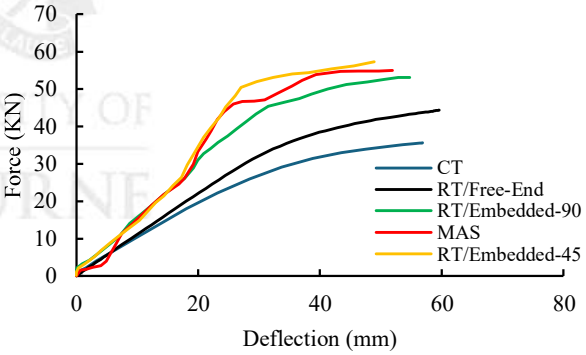


Figure 4: Load vs. Deflection curve

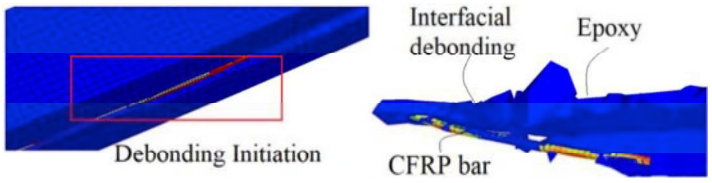


Figure 5: Interfacial deboning of Free-End CFRP

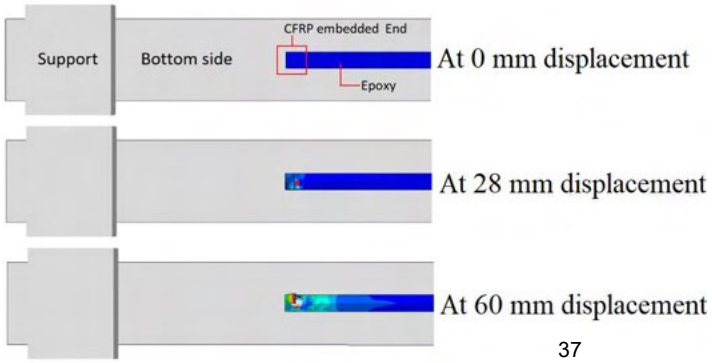


Figure 6: Interfacial deboning of CFRP with anchorage

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A Physics-informed Neural Network Framework for Laminated Composite Plates

Name: Weixi Wang
Email: weixiw1@student.unimelb.edu.au
Supervisor: A/Prof Tai Thai
Discipline: Structure

INTRODUCTION

The use of machine learning in the field of structural engineering is becoming more common. However, the high dependence of traditional purely data-driven models on the size and quality of the database has posed challenges to the practical application of machine learning. Applying physics-informed machine learning can achieve accurate predictions while reducing the need for extensive input data. This study developed a Physics-Informed Neural Network (PINN) framework to predict the bending behaviours of laminated composite plates. In this framework, the Classic Laminated Plates Theory (CLPT) is adopted as the physical constraint, and the loss function is formulated based on the energy method. The comparisons of the machine learning prediction results with the CLPT analytical solutions and Finite Elements Method (FEM) results revealed that the PINN framework can achieve satisfactory bending behaviour predictions, potentially serving as a promising alternative.

Keywords: physics-informed machine learning; artificial neural network; classical laminated plate theory; bending

METHODOLOGY

- Sample and input point coordinates in input layer
- Apply activation function to obtain displacement field
- Get strain and stress based on constitutive equations
- Design loss function based on equilibrium equations
- Minimize model loss to approximate the exact solution

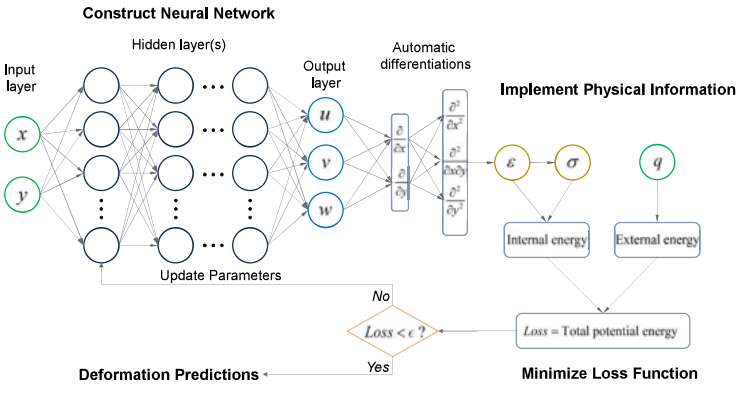
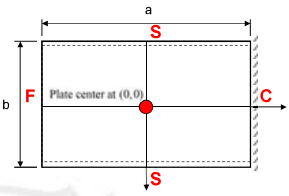


Figure 1. The flow chart of the PINN framework

RESULTS & DISCUSSION

This framework uses the total system potential energy as the loss function. By employing hard constraints to ensure the neural network outputs consistently satisfy the BCs.



$$Net'_w(x,y) = Net_w(x,y)\times\left((x+a/2)^2(x-a/2)^2(y+b/2)\right)$$
$$Net'_u(x,y) = Net_u(x,y)\times\left((x+a/2)(x-a/2)(y+b/2)\right)$$
$$Net'_v(x,y) = Net_v(x,y)\times\left((x+a/2)(x-a/2)\right)$$

Figure 2. Hard constrains for a rectangular laminated plate with FSCS boundaries

Apply the framework to predict laminated plates bending behaviours and evaluate its predictive performance across three dimensions: load cases, laminate lay-ups, and boundary conditions.

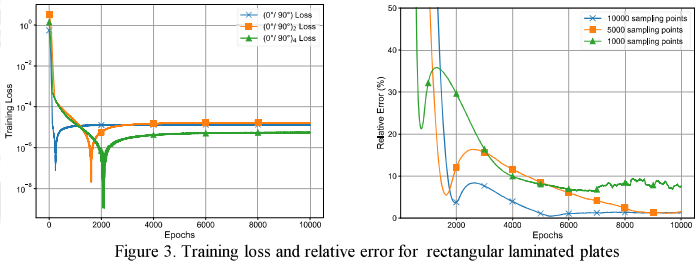


Figure 3. Training loss and relative error for rectangular laminated plates

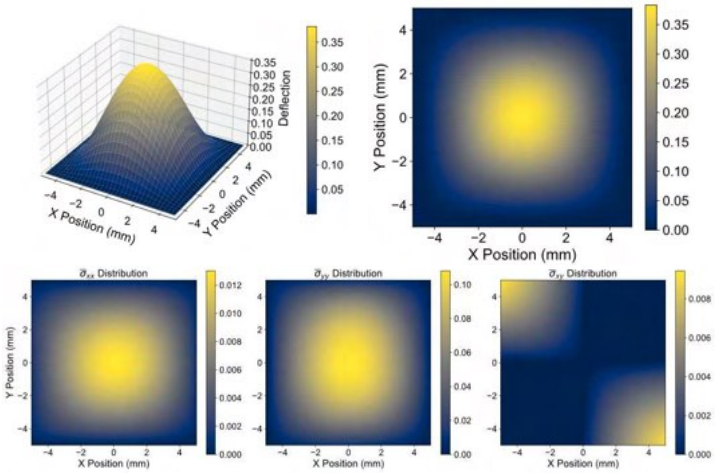


Figure 3. Deformation and stress distribution predictions for a (0°/90°) laminated plate

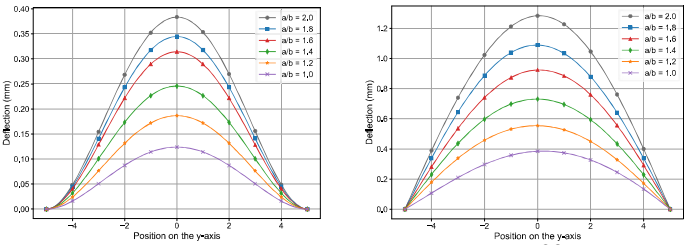


Figure 3. Deflection predictions for (−45°2/0°2/45°2/90°2)s laminated plates with different aspect ratios

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 02 – Morning session- Geotechnical Engineering

Session chair: Dr Samintha Perera

Presentation title	Presenter
Field Testing and Numerical Modelling of Battered Minipile Systems	Alberto Escobar
Arrangement of shared anchors and distribution of force system	Bin Yan
Numerical modelling of pullout of suction bucket under varying pullout rates	Debiprasad Bhakta
Integrated Modelling of the Mooring System for Floating Wind Turbines	Yanyan Guo
Integrating Physics-Informed Neural Networks with Transfer Learning for Modelling Turbidity Currents and Sediment Transport	Farid Fazel
An Elasto-Viscoplastic Soil Constitutive Model for Crashworthiness Evaluation of Barrier Piles	Fatemeh Safari Honar
Plasticity Analysis of Drag Anchor Installation Considering the Integrated Mooring System	Hong Zhu
Early Detection of Internal Erosion in Earth Dam	Sanjit Kumar Bhattarai
Three-dimensional plate anchor uplift behaviors in sand	Zhenyu Liu
The role of the Particle Size Distribution in the thermo-volumetric response of dry sands	Luis Villegas Negrette
Multi-Scale Investigation of Mechanical and Hydrological Performance of Permeable Concrete Pavement	Zohreh Fakhar Shakeri
Performance analysis of H2 production system using hot sedimentary aquifer geothermal	Maryam Hamlehdar

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 02 – Afternoon session- Geotechnical Engineering

Session chair: Chair: Dr Philip Christopher

Presentation title	Presenter
Mapping Microannular Voids Formation on Existing Wellbore Cement for Underground Hydrogen Storage	Amirthan Thirukumaran
Numerical assessment of ground heat exchangers performance in a pit lake environment	Mauricio Carcamo Medel
Impact of Sample Preparation on Erosion and Post Erosion Mechanical Behaviour of Gap-Graded Soils	Meysam Mousavi
Numerical modelling of suction caissons under cyclic loading	Nazish Ullah
Soil-Structure Interaction Framework for Monopiles in Sand under Cyclic Loading	Olgu Orakci
Smart Offshore Site Investigation Using Free-Fall Penetrometers	Parviz Tafazzoli Moghaddam
Assessing Caprock Integrity for Underground Hydrogen Storage in Depleted Gas Reservoirs	Pramod Dilshan
Installation of helical pile in clayey soil	Zeliang Li
Large Deformation Modelling: a numerical approach in offshore geotechnics	Ran Tu
The influence of OWT installation process on the monopile foundation behaviour	Shen Xie
Fluid Inertia Effect on Flow Through Fracture Intersections	Amila Vimukthi Edirisinghe
Influence of Fluid Rheology on Fluid Flow in Natural Fracture Network	Mai Cuong Bui

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Field investigation of single and group minipiles under vertical loadings

Name: **Alberto Escobar**
Supervisors: Prof. G. Narsilio, A/Prof. M. Disfani, Dr. S. Mondal, Dr. A Mehdizadeh
Discipline: Geotechnical Engineering

INTRODUCTION

- Minipiles are driven hollow steel piles with a diameter of 80mm or less, usually at an inclined or batter angle. They have been introduced in the construction industry in recent times. Their main use is to support lightweight residential buildings. As there is a difference in the capacity of a single minipile and a minipile group, several field investigations have been done to have a better understanding of the behaviour of minipiles and minipile groups under vertical loadings.
- This research aims to study the load-displacement curves of single minipiles and minipile groups under vertical loadings. Minipiles with inclination of 28° and 0° have been selected for this study. The field investigation was carried out at the Melbourne University Dookie campus, consisting of alluvium cohesive soils. The loading tests were done according to ASTM standards D1143 and D3689, as quick loading tests.

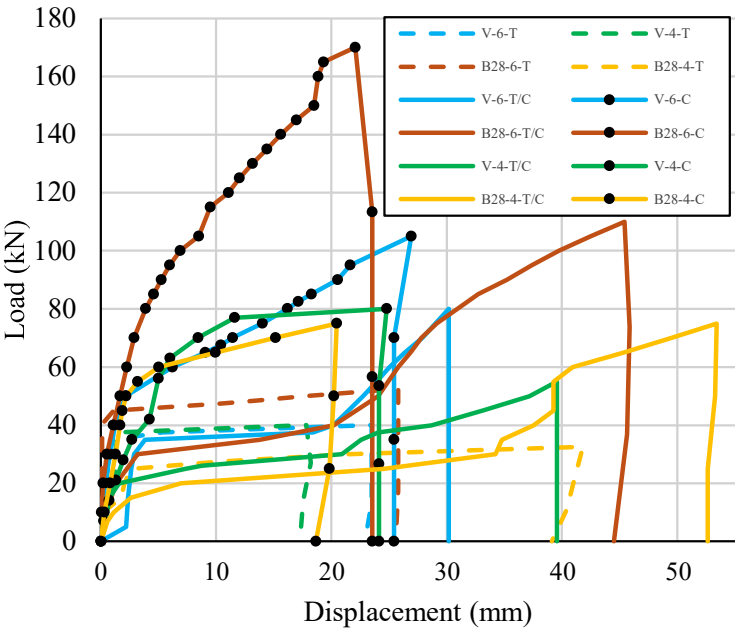
METHODOLOGY

- The testing schedule is shown in the table below:

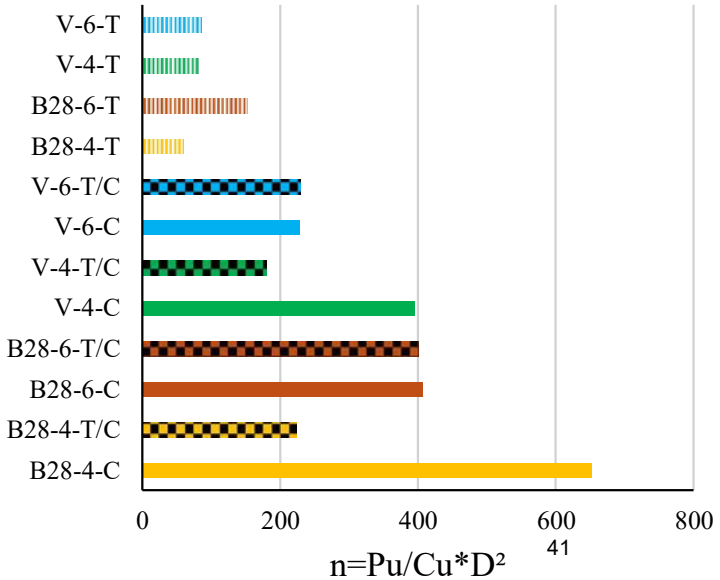
Type	Item	Cap dimension (squared, mm)	# of Piles	Angle of Batter (°)	Test
Group	B28-4-C	200	4	28	Compression
Group	B28-6-C	250	4	28	Compression
Group	V-4-C	200	4	0	Compression
Group	V-6-C	250	6	0	Compression
Group	B28-4-T/C	200	4	28	Tension + Compression
Group	B28-6-T/C	250	6	28	Tension + Compression
Group	V-4-T/C	200	4	0	Tension + Compression
Group	V-6-T/C	250	6	0	Tension + Compression

RESULTS & DISCUSSION

- It can be seen that groups with battered (B28) minipiles have a much higher capacity under compressive loadings, whereas groups with vertical (V) minipiles do not exhibit this difference in capacity.



- After a simplified normalisation (n) of the results, it can be seen that the efficiency of minipile groups varies depending on the angle of inclination of the minipiles and the number of minipiles in a group. This behaviour is more pronounced under compressive loadings.



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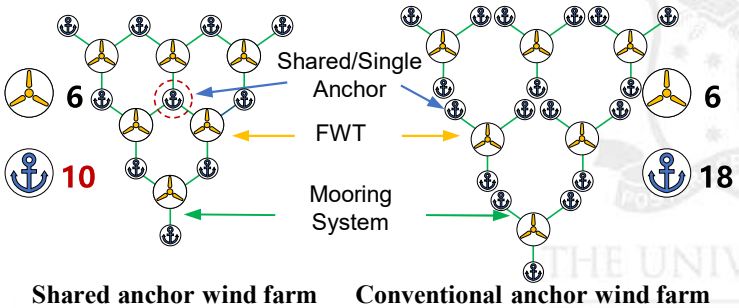
Arrangement of shared anchors and distribution of force system

Name: Bin Yan
Email: byya1@student.unimelb.edu.au
Supervisors: Prof. Y. Tian, Dr. Y. Wang
Disciple: Geotechnical

INTRODUCTION

Offshore wind energy is rapidly growing, with 10.8 GW of new capacity added in 2023 alone. A significant portion of the costs associated with floating wind turbines (FWTs) comes from their foundations, accounting for over 37% of total project expenses. To address this challenge, shared-anchor turbine designs have emerged as a promising solution to reduce foundation costs. However, these systems are subjected to complex multidirectional loads, making the analysis and understanding of their intricate load interactions a formidable task.



Shared anchor wind farm **Conventional anchor wind farm**

Fig. 1 Comparison of shared-anchor and conventional anchor wind farm arrangements

METHODOLOGY

- Analysis of Loads on FWT
- Developing a Mechanical Model

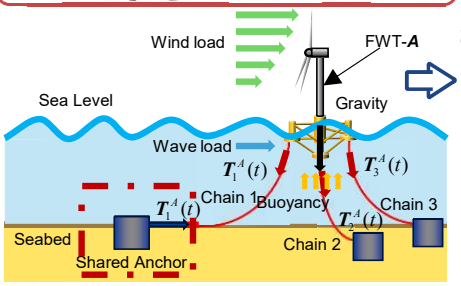


Fig. 2 Load analysis of shared anchors and floating wind turbine system

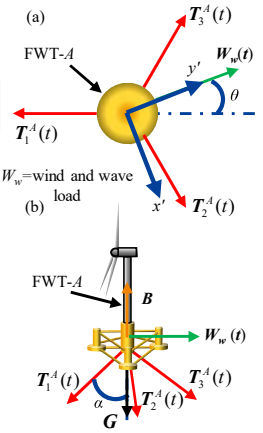


Fig.3 Simplified model of loads

- Establishing the Force Balance Equation

$$\begin{cases}\sum F_{x'}=0\\ \sum F_{y'}=0\\ \sum F_z=0\end{cases}\Rightarrow\begin{cases}(T_1^A\sin(\theta+\pi)+T_2^A\sin(\theta+\pi/3)+T_3^A\sin(\theta+5\pi/3))\sin\alpha=0\\ (T_1^A\cos(\theta+\pi)+T_2^A\cos(\theta+\pi/3)+T_3^A\cos(\theta+5\pi/3))\sin\alpha+W_w=0\\ T_1^A\cos\alpha+T_2^A\cos\alpha+T_3^A\cos\alpha+G-B=0\end{cases}\quad\text{Eq. 1}$$

- Shared Anchor Loads Considering Phase Differences

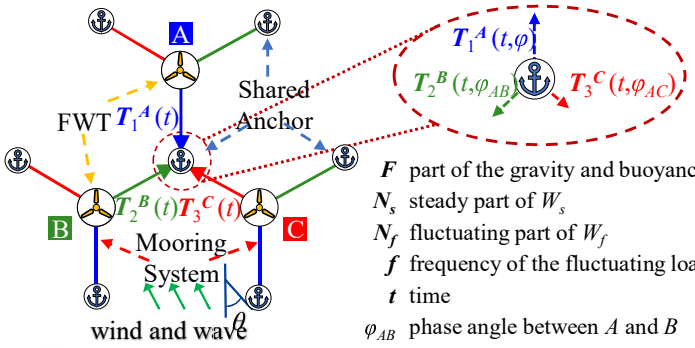


Fig. 4 Shared anchors subject to loads from different chains

RESULTS & DISCUSSION

- Load Model of the Shared Anchor

The influence of ***phase angle***

$$\begin{cases}T_1^A(t)=F+N_s\cdot\cos(\theta)+N_f\cdot\cos(\theta)\cos(2\pi\cdot f\cdot t)\\ T_2^A(t)=F+N_s\cdot\cos(\theta-2/3\pi)+N_f\cdot\cos(\theta-2/3\pi)\cos(2\pi\cdot f\cdot t+\varphi_{AB})\\ T_3^A(t)=F+N_s\cdot\cos(\theta-4/3\pi)+N_f\cdot\cos(\theta-4/3\pi)\cos(2\pi\cdot f\cdot t+\varphi_{AC})\end{cases}\quad\begin{cases}F=\frac{1}{3\cos\alpha}(B-G)\\ N_s=\frac{2}{3\sin\alpha}\cdot W_s\\ N_f=\frac{2}{3\sin\alpha}\cdot W_f\end{cases}\quad\text{Eq. 2}$$

- Effect of Wind and Wave Direction on Load Type

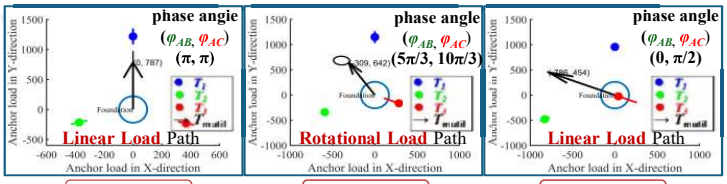


Fig. 5 Load path types on the shared anchor for different wind and wave directions

- Effect of Phase Difference φ on Load Type (θ=30°)

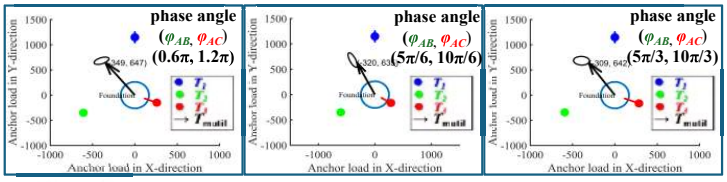


Fig. 6 Load path types on the shared anchor for different phase angle (θ=30°)

Conclusions

- ☐ The proposed model can be used to calculate the loads on the shared anchor.
- ☐ Both the wind & wave direction and the phase difference could influence the load path types on the shared anchor.
- ☐ A well-designed shared wind farm can significantly reduce the loads on the shared anchor.

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Numerical modelling of pullout of suction bucket under varying pullout rates

Name: Debiprasad Bhakta
Email: debiprasad.bhakta@student.unimelb.edu.au
Supervisors: A/Prof. Shiaohuey Chow, Dr. Anamitra Roy
Discipline: Geotechnical Engineering

INTRODUCTION

- Suction buckets are gaining popularity as offshore foundation due to its easy and environment friendly installation and decommissioning process
- In multi-jacketed configuration, the bucket on the windward side is subjected to tension loading owing to "push-pull" action and is critical
- The fabric related anisotropy affects behaviour of sand in tensile and compressive loading (Miura et al., 1986)
- SANISAND-F model incorporates both inherent and evolving fabric anisotropy
- The implementation of SANISAND-F model for boundary value problem is scarce
- This study investigates –
  - The pullout behaviour of suction buckets for varying pullout rates considering different drainage conditions
  - The change in fabric orientation in different drainage conditions during loading

METHODOLOGY

- **Finite element model details:**
  - Axisymmetric model prepared in Abaqus 2020
  - SANISAND-F constitutive model to capture behaviour of UWA fine silica sand
  - Validated against centrifuge test data performed by da Silva Pereira et al. (2023)
  - Different pullout rates have been applied

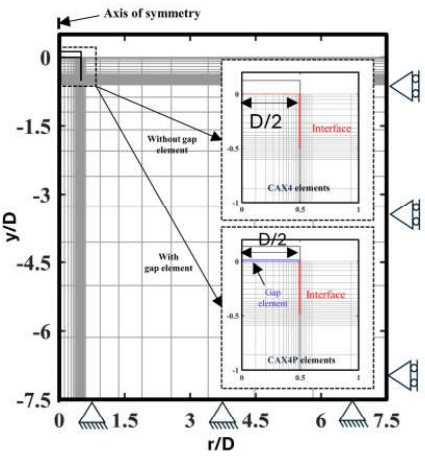

Figure 1: Model details in Abaqus

RESULTS & DISCUSSION

- Simulated result matches well with centrifuge test data

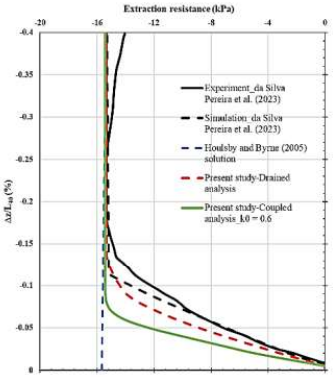

Figure 2: Extraction resistance vs displacement

- For lower pullout velocity, drained boundary condition prevails and soil around the skirt provides resistance

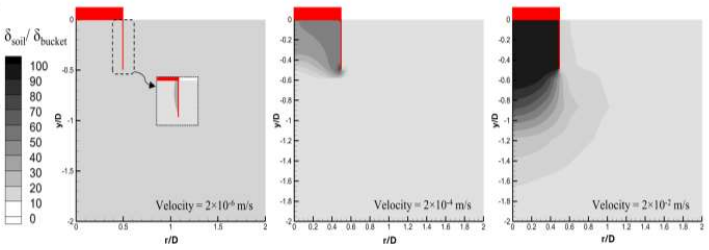

Figure 3: Displacement contours

- For higher pullout rate, partially drained or undrained condition arises. Soil inside and/or surrounding bucket gets involved and moves with bucket. Generated suction reaches bottom of the bucket. Capacity is greater compared to drained case.

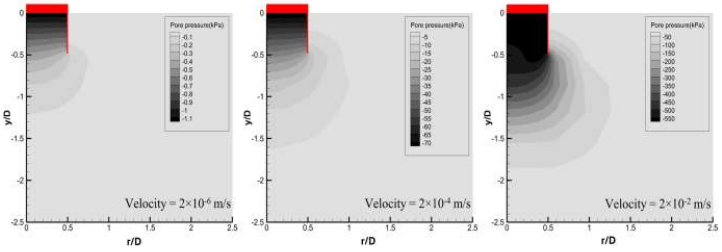

Figure 4: Pore pressure contours

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[2] da Silva Pereira, F., Bienen, B., & O'Loughlin, C. D. (2023). Mind the gap–an experimental study on the need for grouting suction buckets in sand under vertical cyclic loading. Géotechnique, 1-16.

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Integrated Modelling of the Mooring System for Floating Wind Turbines

Name: Yanyan Guo
Email:yaguo6@student.unimelb.edu.au
Supervisors: Prof. Yinghui Tian, Dr. Wenlong Liu
Disciple: Geotechnical Engineering

INTRODUCTION

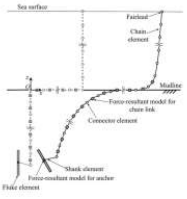
Offshore floating facilities, floating wind turbines, rely on mooring systems to securely anchor them at designated locations. These mooring systems consist of an anchor embedded in the seabed, connected to an anchor chain (within the soil) and a mooring line (attached to the floating vessel or platform). However, current mooring system analyses typically focus only on the mooring line segment suspended in water, while simplifying the embedded chains and anchors as fixed points or springs at the seabed. This simplification overlooks the detailed interactions between all components of the system, leading to a lack of comprehensive methods for modeling the entire mooring system, including suspended mooring lines, embedded chains, and anchors. This research aims to study the installation process of drag anchors, the mechanism between tangential resistance and normal resistance, and perform multi-chain system analysis based on the existing UoMMoor program. Besides, a new, efficient approach to simulate the chain model in the mooring system will be developed, which will be coupled with OpenFAST to enable a comprehensive analysis of the mooring system and wind turbines.

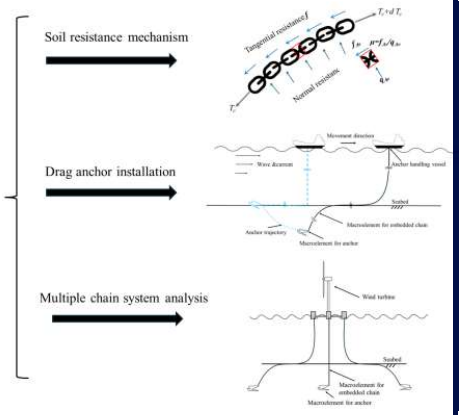
METHODOLOGY

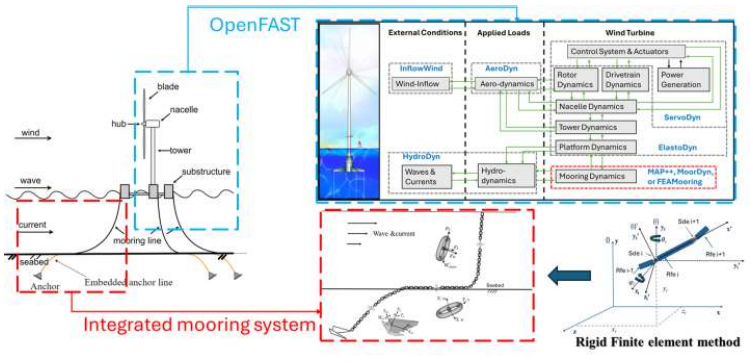
UoMMoor uses force-resultant model (macroelement) to describe the coupled soil resistance to embedded chain. **(Wenlong et al. 2024)**

Soil resistance yield surface equation for chain:

$$F=\left(\frac{|N_t|}{N_{t\max}}\right)^{\gamma}+\left[\left(\frac{|N_n|}{N_{n\max}}\right)^{\eta}+\left(\frac{|N_\tau|}{N_{\tau\max}}\right)^{\gamma}\right]^{\frac{\gamma}{\eta}}-1=0$$



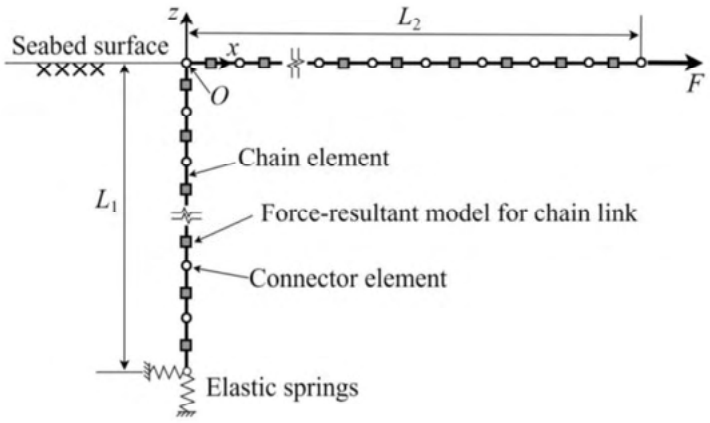


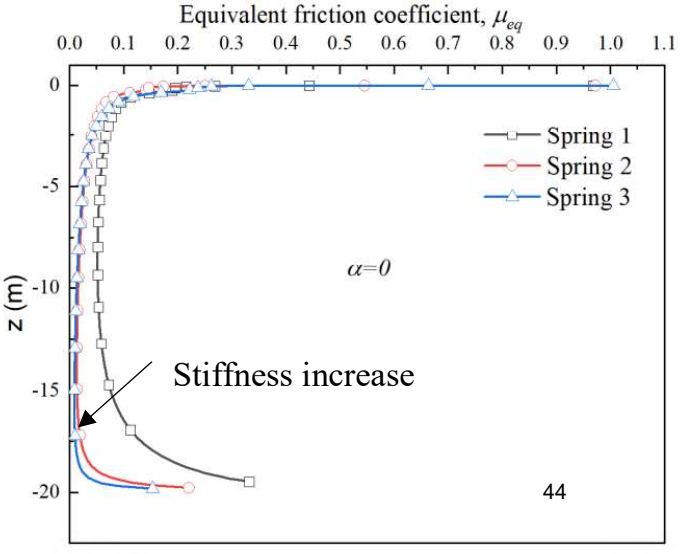


RESULTS & DISCUSSION

To study the effect of the anchor stiffness on the mobilisation of the tangential soil resistance to the anchor chain, this study used two linearly elastic springs to model the anchor for the purpose of simplification. The stiffness of the vertical and horizontal springs is set to be proportional to the elastic stiffness of the force resultant model for plate anchor. Tian et al(2019). evaluated the dimensionless elastic stiffness along the sliding and normal directions of plate chain.

The equivalent friction coefficient μ_{eq} varies with the embedment depth, indicating, the coupling of the soil resistances to anchor chain. Comparing the 3 cases, the increase of anchor stiffness resulted in smaller Cases tangential soil resistance along the anchor chain. Thus, to accurately estimate the capacity of a mooring system, it is necessary to treat the anchor and chain as an integrated system.





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Infrastructure Engineering
Graduate Research Conference 2024

An Elasto-Viscoplastic Soil Constitutive Model for Crashworthiness Evaluation of Barrier Piles

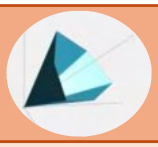
Name: Fatemeh Safari Honar
Email: fsafarihonar@student.unimelb.edu.au
Supervisors: Dr. N. Yousefpour, Prof. N. Lam, Dr. J. Perera
Discipline: Geotechnical Engineering

INTRODUCTION

The nonlinear dynamic interaction between soil and pile is a crucial factor in determining the performance of roadside piled-barrier systems during vehicle collisions. Previous studies have primarily focused on the structural aspects of these systems in numerical crash test models, with less attention given to the influence of soil on barrier performance. To achieve a more reliable and optimal design of soil-embedded piles subjected to impact loads, appropriate soil constitutive model is required that can aptly capture the relevant physics during such extreme loading. Existing soil models in LS-DYNA often exhibit overly stiff or overly soft behaviour in road safety applications. In this study, we introduce a modified soil model (DVP-Impact model). This nonlinear soil constitutive model is developed with a small number of parameters requiring calibration and can address the current gap in existing models, capturing strain softening and strain rate effects, critical in soil-pile behaviour under impact. The results of full-scale crash simulations using proposed soil model demonstrate the superiority of the proposed soil model for scenarios involving soil-pile interaction under impact loading.

METHODOLOGY

A critical review of the state of practice of the most common constitutive soil models for simulating piled barriers in LS-DYNA

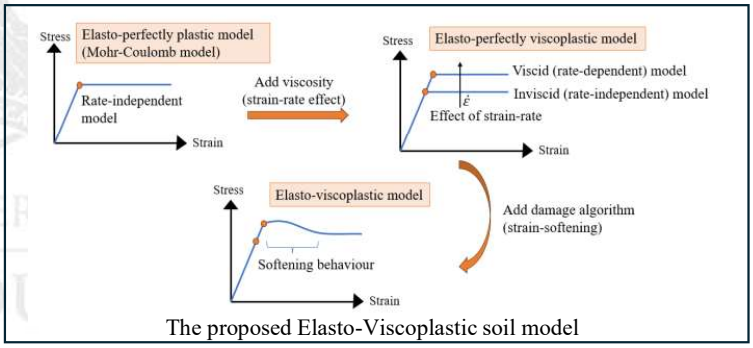


Developing a modified soil model to properly capture strain rate effect and strain softening

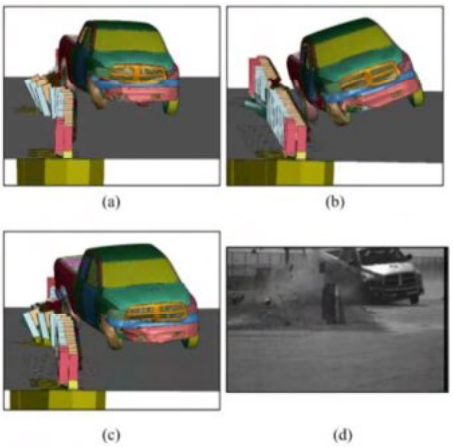
Implementation and validation of proposed soil model in full-scale crash simulations and comparison with existing soil models in LS-DYNA

RESULTS & DISCUSSION

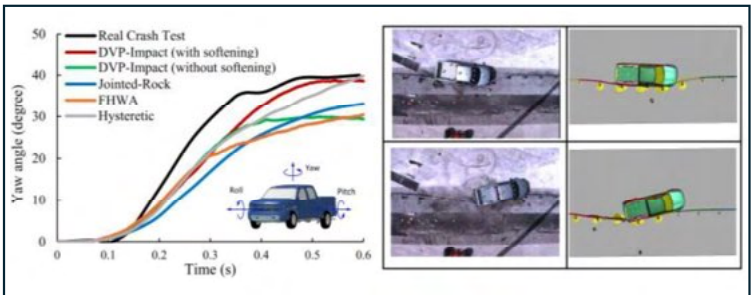
The aim has been to introduce a modified soil model with a balance between advanced features and the number of parameters (needing calibration) for roadside safety barrier systems under vehicle impact. Incorporating such a soil model can result in more realistic crashworthiness simulations of piled barriers, leading to more optimal and cost-effective design of piles. The proposed model was validated through several single-element triaxial tests and full-scale crash simulations. The proposed soil model has shown great potential to be used as a viable simple nonlinear model for pile impact simulations for barrier crashworthiness evaluations.



The proposed Elasto-Viscoplastic soil model



Vehicle model in crash simulations using a) Jointed-Rock; b) FHWA; c) proposed model; d) real test



Validation and comparison of the proposed soil model using real crash test and existing soil models

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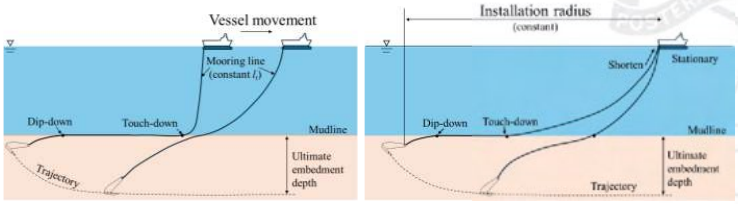
Plasticity Analysis of Drag Anchor Installation Considering the Integrated Mooring System

Name: Hong Zhu
Email: honzhu2@student.unimelb.edu.au
Supervisors: Prof. Y. Tian, Dr. S. Maitra, Prof. M. Cassidy, Dr. N. Boylan
Disciple: Geotechnical

INTRODUCTION

- Drag anchors have been widely used for mooring mobile offshore drilling units. With the rapid expansion of offshore wind, the demand for reliable mooring systems that can handle the extended service life and higher operational loads of floating structures has increased. A key challenge in the deployment of drag anchors for these applications lies in the invisibility and uncertainty of anchor installation trajectory, which involves complex interaction between the seabed, anchor and mooring line.
- This research presents an improved plasticity analysis method to predict the anchor drag-in trajectory by incorporating the integrated response of the entire anchor-mooring line system.



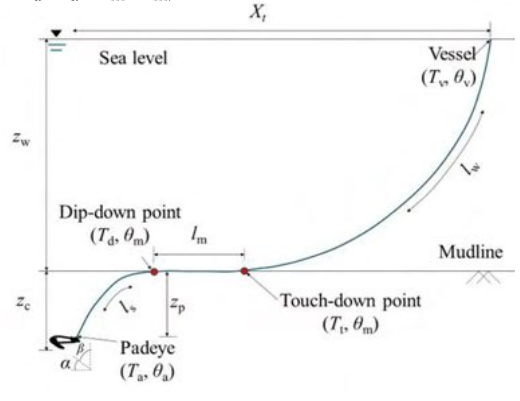
METHODOLOGY

- **Mooring line:** Use Forward Euler to iteratively solve governing equation for embedded line in soil. Use catenary equation to solve for suspended line in water.

Governing equation

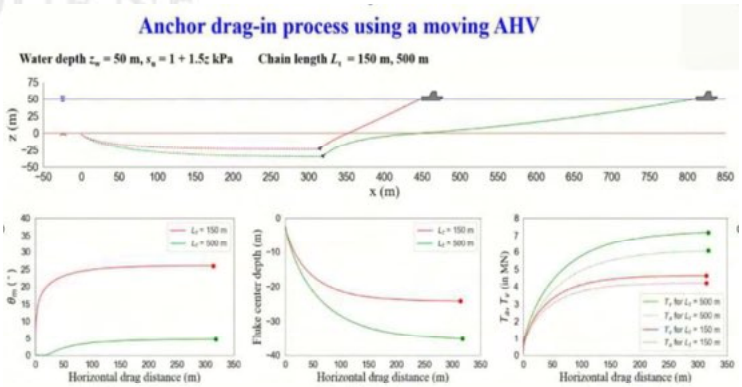
$$\frac{dT}{dl} = F + w\sin\theta\,; \qquad T\frac{d\theta}{dl} = -Q + w\cos\theta$$

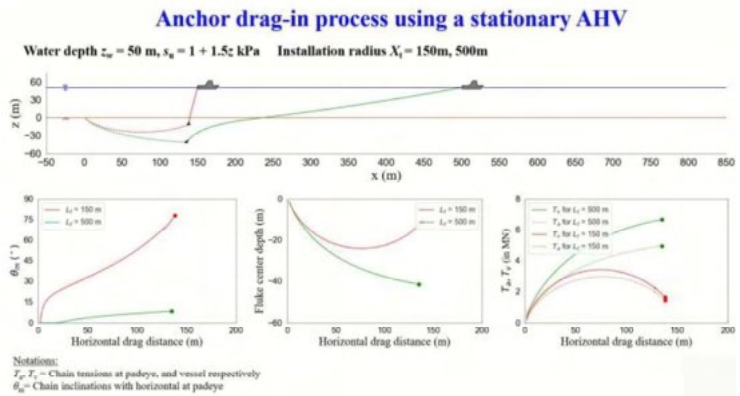
- **Anchor motion:** Plasticity analysis method: yield envelope and associated flow rule. Iteratively solve for T_a, θ_a, L_m, θ_m.



RESULTS & DISCUSSION

- A novel predictive method named **Plasticity Analysis for Integrated Mooring System (PAIMS)** is proposed.
- The model can be adjusted to model two installation modes: **fixed-length** and **fixed-point**. The accuracy was validated against the field test and a comparison was made between two installation modes: fixed-point installation requires smaller operation area while has higher requirement on the anchor installation vessel's draft. Limited chain length leads to shallower embedment depth using fixed-point installation compared with fixed-length.
- **PAIMS** not only models drag anchor installation but is also versatile for various scenarios, including the keying process of SEPLAs, multi-mooring line systems, and the kinematic behaviors of drag anchors and SEPLAs under extreme loading conditions.





Early Detection of Internal Erosion in Earth Dam

Name: Sanjit Kr. Bhattarai,
Email: sanjitkumarb@student.unimelb.edu.au
Supervisor: Dr. Negin Yousefpour, A/Prof. Mahdi Miri Disfani

INTRODUCTION

Earth dams, including embankments, dikes, and levees, are essential for irrigation, flood control, hydropower, and water supply but are vulnerable to internal erosion. This erosion occurs when fine soil particles are transported by seepage through cracks, excessive pore water pressure, or unstable soil gradations, often progressing undetected until a breach occurs. Current geophysical monitoring methods focus on seepage detection rather than early internal erosion. This study explores continuous passive monitoring techniques to detect early signs of internal erosion. Using a small-scale dam model with passive seismic sensors, fibre optics, and piezoelectric transducers, the research captures low-frequency micro-seismic events at the initiation of internal erosion, followed by high-frequency acoustic waves during its progression. Seismo-acoustic data are processed to identify erosion initiation, offering a novel approach for early detection.

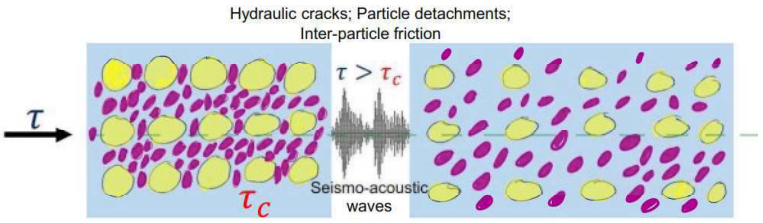
RESULTS & DISCUSSION

Flow-dependent parameters generally have a better ability to detect changes than material-dependent methods (Johansson, 1997; Sjodahl et al., 2019).

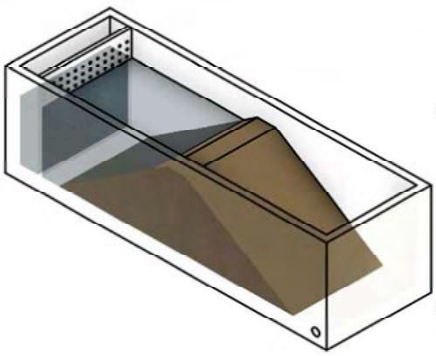
Internal erosion events are observed to produce acoustic emissions in the range of 10 kHz to 45 kHz (Smith & Dixon, 2018; Ming et al., 2021). In a small-scale earth dam model, AI methods using deep neural autoencoders process seismic sensor data to detect internal erosion by identifying patterns and anomalies (Planès et al., 2016; Belcher et al., 2016; Ozelim et al., 2022; Yousefpour & Fazel Mojtahedi, 2023).

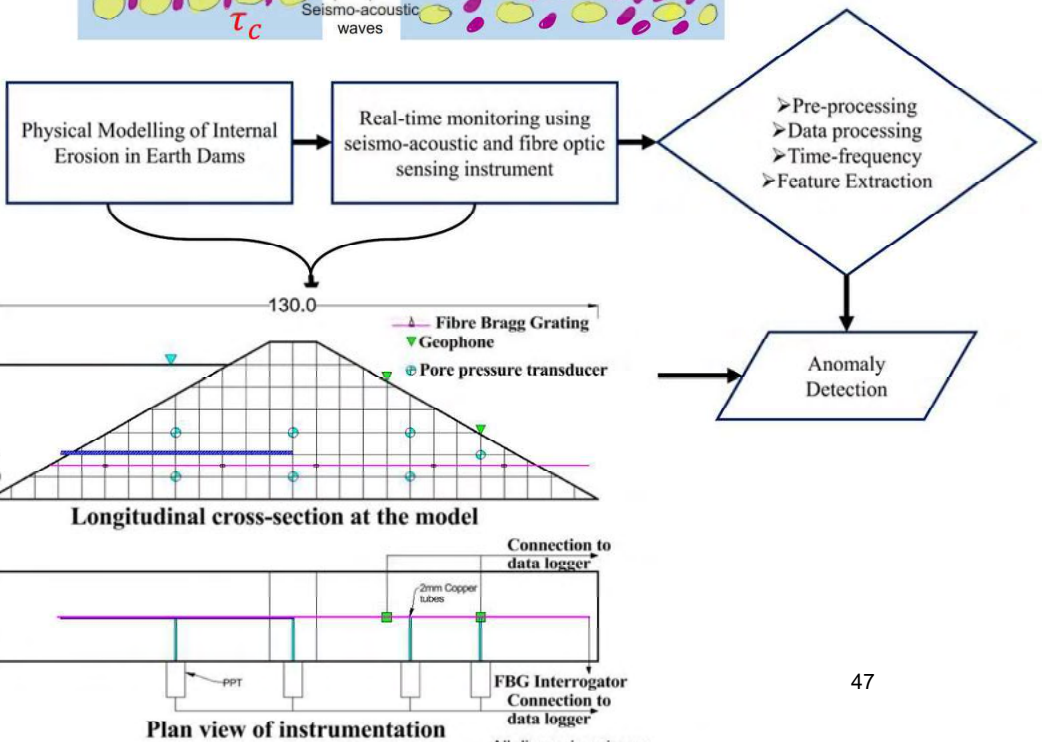
Convolutional Autoencoder algorithm with seismic data collected through the large-scale physical modelling of concentrated leak erosion could identify early signs of internal erosion (Yousefpour & Fazel Mojtahedi, 2023).

HYPOTHESIS



METHODOLOGY





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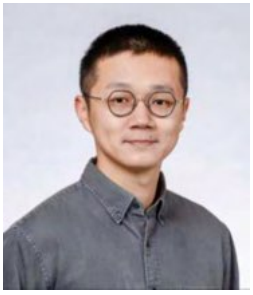
Towards predicting three-dimensional plate anchor uplift behaviors in sand with NorSand model



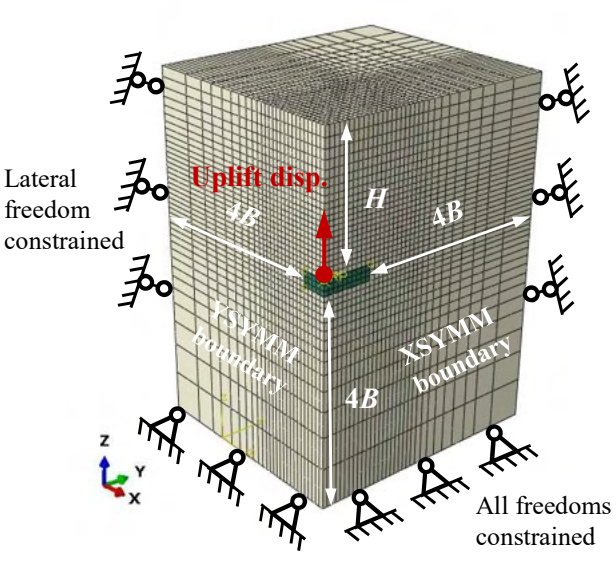
Name: Zhenyu Liu
Email: zhenyu.liu6@student.unimelb.edu.au
Supervisors: A/Prof. Shiao Huey Chow, Prof. Yinghui Tian, A/Prof. Mason Ghafghazi
Discipline: Geotechnical Engineering

INTRODUCTION

- Plate anchors offer an attractive mooring solution for floating energy devices. However, existing numerical studies on plate anchor capacity in sand mainly considered strip anchors instead of more commonly used rectangular anchors.
- One main reason is that three-dimensional (3-D) simulations with advanced soil models consume much higher computational resources, which in turn raises higher requirements for convergence and efficiency of the adopted constitutive model and its numerical implementation.
- In this study, the uplift capacity of a horizontal rectangular anchor in sand was investigated through 3-D finite element (FE) analysis. The critical state-based model NorSand was implemented in FE package Abaqus/Standard, and several modifications were made to improve convergence and efficiency. The FE model was first validated against experimental data. Then, a parametric study was conducted to reveal 3-D failure mechanisms of rectangular anchors in sand.

METHODOLOGY

- 3-D FE model set-up in Abaqus/Standard

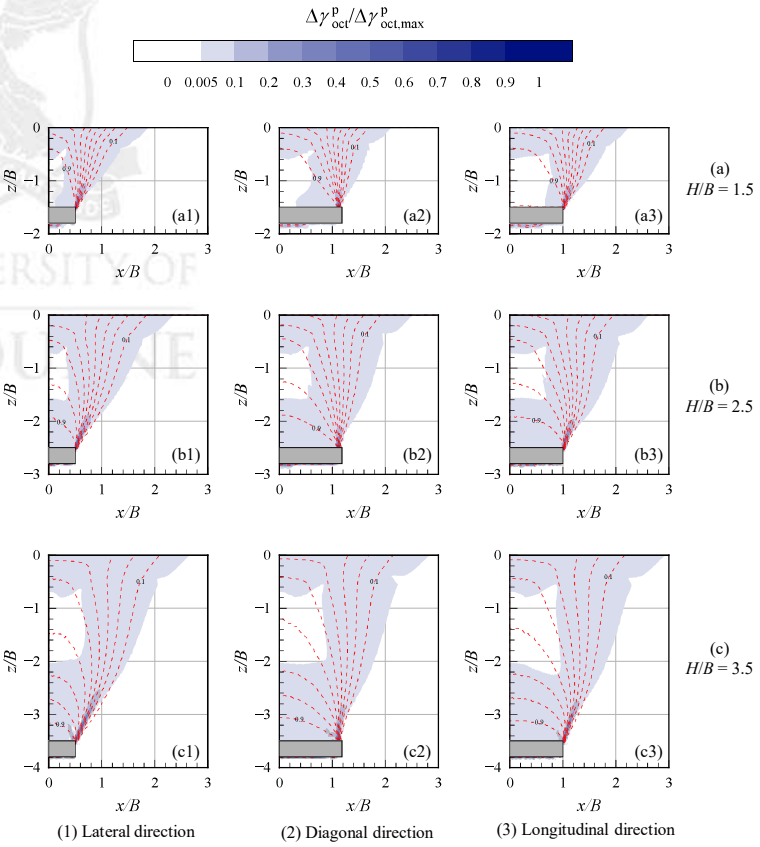


Quarter-anchor FE model

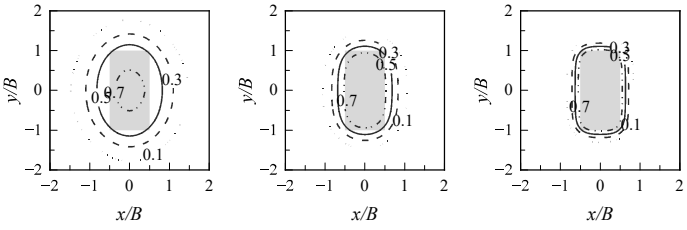
RESULTS & DISCUSSION

- Parametric study program and results

Relative density, R_D (%)	Effective unit weight, γ (kN/m^3)	Embedment ratio, H/B (-)	Normalised mobilised displacement, δ_m/B (%)	Simulated anchor factor, $N_{\gamma,num}$ (-)
70	10.25	1.50	3.0	2.69
		2.50	5.5	4.02
		3.50	9.27	5.76
45	9.86	1.50	3.52	2.44
		2.50	6.50	3.60
		3.50	12.03	5.13



Normalised plastic shear strain increment contours contrasted against normalised deformation contours at peak capacity (R_D = 70%)



Typical plan views of normalised deformation contours at different depths at peak capacity (H/B = 1.5, R_D = 70%)

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Evaluating the role of the Particle Size Distribution in the thermo-volumetric response of dry sands

Luis Villegas Negrette
villegasl@student.unimelb.edu.au
Supervisors: Prof. Guillermo Narsilio, Prof. Dr. Raul Fuentes
Discipline: Geotechnical Engineering

INTRODUCTION

- **Observations** on the **thermo-volumetric response on sands are conflicting**. Experimental findings indicate expansion, contraction, or a combination of both upon heating.
- **Recent** investigations have **identified critical factors** influencing this behaviour. **Heating rate**, **materials-boundary interaction** ratios, **calibration** procedures, **repeatability**, and **sensors capabilities**; are reported as the key variables.
- The **most recent** experimental **studies** on **dry sands** have demonstrated a **consistent response**. Materials with varying relative densities and particle shapes, subjected to different **heating** amplitudes and confining pressures, exhibit **expansion**, while **irreversible deformations** develop upon **cooling**.
- Although it is well established that the number of contacts controls the stability of the particle assembly; the influence of **particle size distribution** on the **magnitude** of these **expansive/contractive** responses is **underexplored** for **sands**.

METHODOLOGY

- **Four*** distinct dry **sands** are tested under **temperature-controlled oedometric conditions**. Volumetric deformations (axial strain, ε_a) of **three** poorly-graded (**SP**) and **one** well-graded (**SW**) sand specimens are monitored. The specimens are subjected to vertical stress (σ_v) of 100 and 800 kPa and **five** thermal cycles (TC) of 50 °C (soil temperature variation, ΔT) as indicated in **Fig 1**.

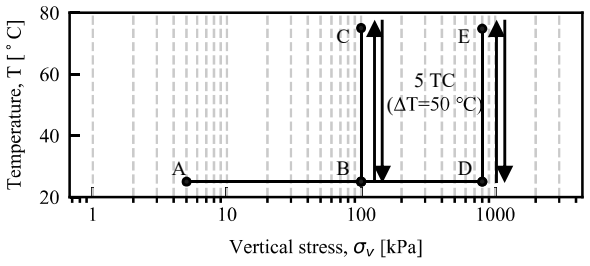


Fig 1. Soil vertical stress-temperature path.

***Note:**
K: Karlsruhe sand;
AWG: Well Graded, AInt: Intermediate, AC: Coarse Aachener sand.

RESULTS & DISCUSSION

- **Independent** of the **particle size distribution,** dry **sand expands** upon **heating** and **irreversible deformations** accumulate upon **cooling** (refer to **Fig 2**), with most of these deformations being contractive. **This confirms recent experimental findings**.
- The use of the **soil's classification system** appears inadequate for inferring the magnitude of **thermo-volumetric** deformations. **No** significant **differences** are noticed between **poorly-** and **well-graded sands in this study**.
- **Sands** with a **broader particle size distribution** exhibit **larger contractions** upon **cooling** (compare Coefficient of Uniformity, **Cu**, in **Table 1**), and its magnitude is **stress dependent**.

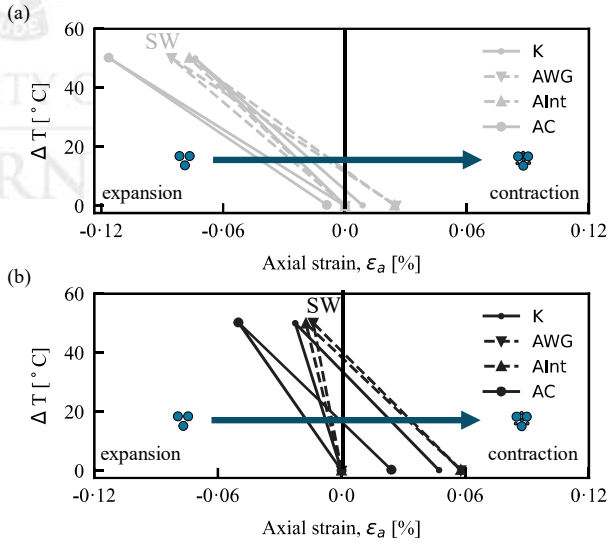


Fig 2. First thermal cycle, volumetric deformation at (a) 100 kPa, (b) 800 kPa.

Table 1. Material properties **.

Material	Void ratio, e			Gs	d50 [mm]	Cu	Cc
	min ***	initial	max ***				
K	0·71	0·74	1·16	2·64	0·14	2·2	0·9
AC	0·59	0·71	0·91	2·65	1·42	1·6	0·9
AInt	0·57	0·58	0·87		0·68	3·4	1·2
AWG	0·47	0·50	0·80		0·64	7·2	1·3

*** Minimum and maximum void ratio determined following DIN 18126

****Note:**
e: void ratio; Gs: Specific Gravity, d50: mean particle size, Cu: Coefficient of Uniformity, Cc: Coefficient of Curvature.

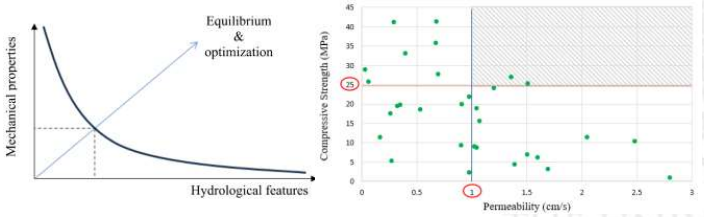
Infrastructure Engineering Graduate Research Conference 2024

Multi-Scale Investigation of Mechanical and Hydrological Performance of Permeable Concrete Pavement

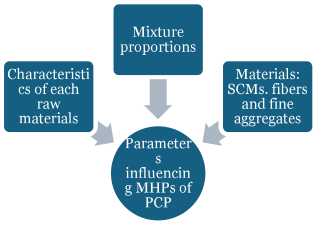
Zohreh (Venus) Shakeri
zfakharshake@student.unimelb.edu.au
Dr Rackel San Nicholas, A/Prof. Mahdi Miri Disfani
Geotechnical Engineering/ Civil Engineering

INTRODUCTION

- Although permeable concrete pavement (PCP) plays a crucial role to mitigate surface runoff and urban heat island (UHI) phenomenon, its application has been limited to areas with light traffic loads due to low load bearing capacity and lack of flexibility.
- To overcome this issue, a lot of investigations have been conducted to make a balance between mechanical and hydrological properties (MHPs), and few have achieved a compressive strength of more than 25 MPa and permeability of more than 1 cm/s.

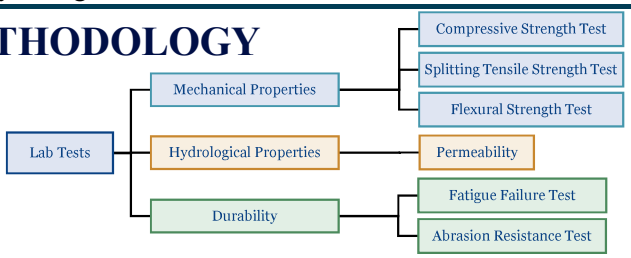


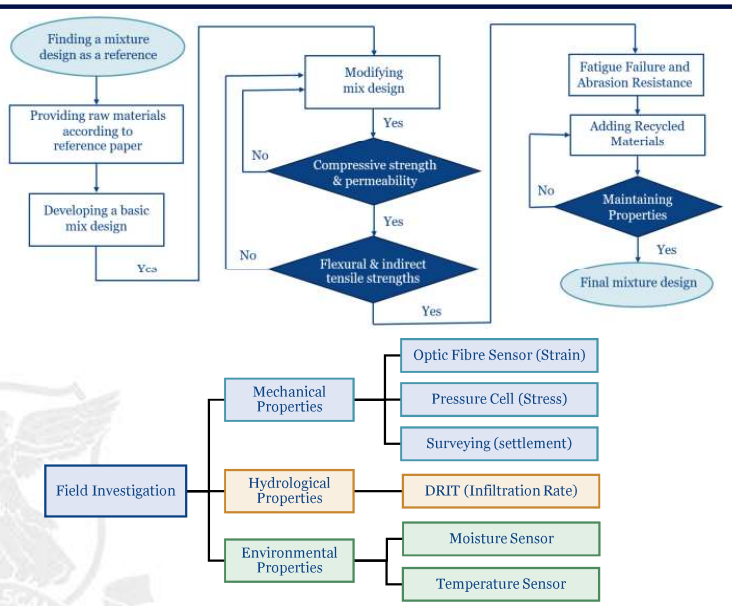
- The parameters influencing MHPs of PCP through developing its mixture design have been investigated by previous studies. However, most investigations have independently assessed the impact of effective factors and there is a lack of comprehensive study of such factors and their interaction.



- Although conducting field investigations provides insights into the performance of PCP under actual conditions, most studies have not extended their research to field experiments. The structural design of PCP through numerical simulation have been rarely investigated.
- The main aim of this research is Deep understanding of the performance and behaviour of pervious concrete to develop a PCP mix design, meeting mechanical and hydrological criteria to bear traffic loads.

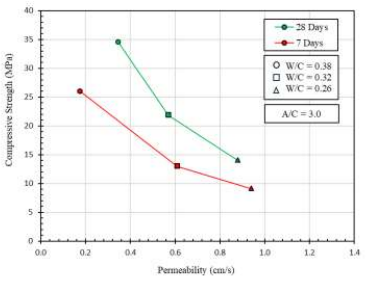
METHODOLOGY

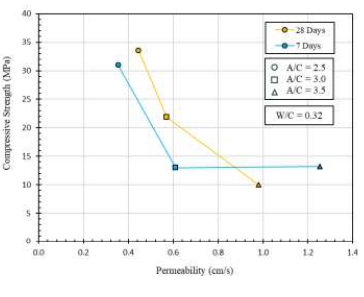


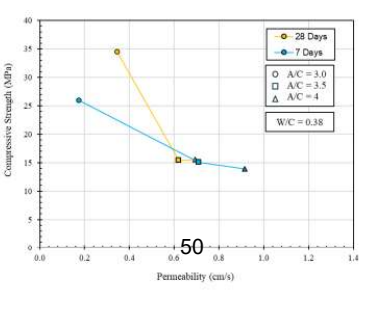


RESULTS & DISCUSSION

As W/C increases, the compressive strength increase, in contrast to conventional concrete. In mixtures with lower water to cement ratios, the hydration process is constrained due to inadequate water availability for complete cement reaction. As the W/C increases, the extra water allows for more complete hydration of the cement, leading to a denser matrix with stronger internal bonds. Additionally, increasing A/C causes an increase in permeability and a reduction in compressive strength, for both water to cement ration of 0.26 and 0.38. Anyway, a compressive strength of 13.2 MPa and permeability of 1.26 cm/s have been reached for the W/C of 0.32 and the A/C of 3.5.







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Infrastructure Engineering Graduate Research Conference 2024

Performance analysis of H_2 production system using hot sedimentary aquifer geothermal

Name: Maryam Hamlehdar
Email: mhamlehdar@student.unimelb.edu.au
Supervisors: Prof. Guillermo Narsilio, Dr. Nikolas Makasis, Dr. Graeme Beardsmore
Discipline: Geotechnical Engineering

INTRODUCTION

- **Systematic** assessment of **geothermal-based** hydrogen production systems requires modelling **variations** in geothermal **temperature** over time.
- This factor impacts **system performance** throughout the **reservoir's lifespan**, yet it is often **overlooked** in the literature.
- Existing studies primarily focus on **modelling above-ground** components, leaving gaps in reservoir performance assessment.
- Some numerical models of underground geothermal reservoirs explore the **effect of geothermal design parameters** on production temperature and system performance.
- However, these studies typically focus on **aquifer modelling** alone, overlooking thermal interactions between wellbores and the **surrounding ground layers.**

METHODOLOGY

- **A hybrid numerical** model, combining the **underground reservoir** with the **above-ground** components, is used for the **long-term** performance analysis.
- A validated **full geometry 3D finite element** model (Fig 1) for a doublet geothermal system, encompassing **wellbores** and the **ground mass**, is developed.

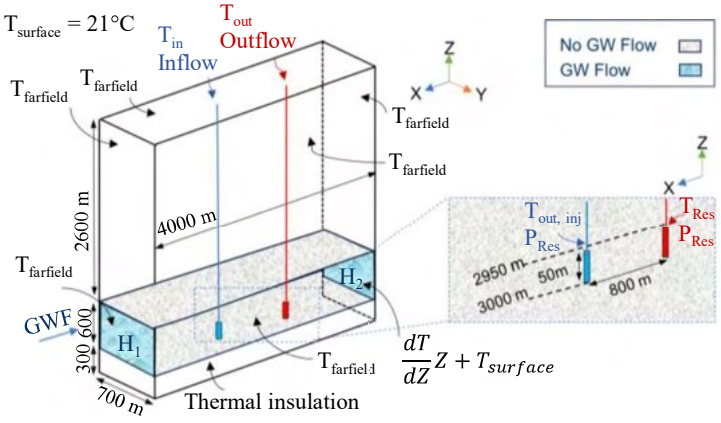

Fig 1. Geometry and boundary conditions of model

RESULTS & DISCUSSION

- Temperature difference between the **two models** shows that the **temperature gap** across the **production well** significantly impacts both the hydrogen cost and rate.
- **Bottomhole temperature** from the **aquifer** model is significantly higher than the wellhead temperature from the **full geometry** model, and it gradually decreases as the system operates (Fig 2).
- Over 30 years, the temperature difference across the production well, ranging from **7.3°C** to **1.4°C**, led to **variations** in hydrogen production **rates** from **19.3%** to **4%** and **cost differences** from **12% to 9%** (Fig 3).

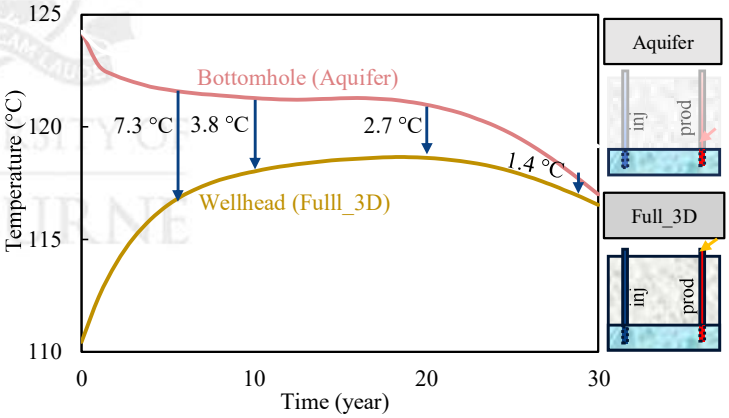

Fig 2. Heat loss across the production well

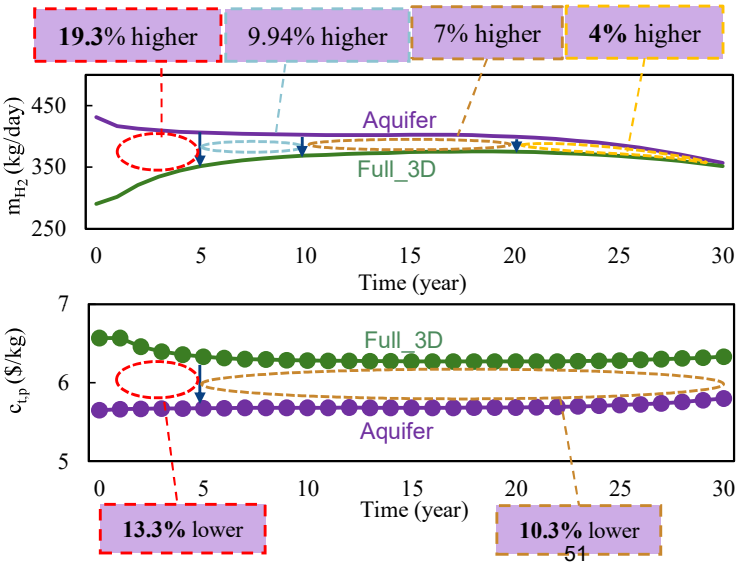

Fig 3. Heat loss effect on the system performance

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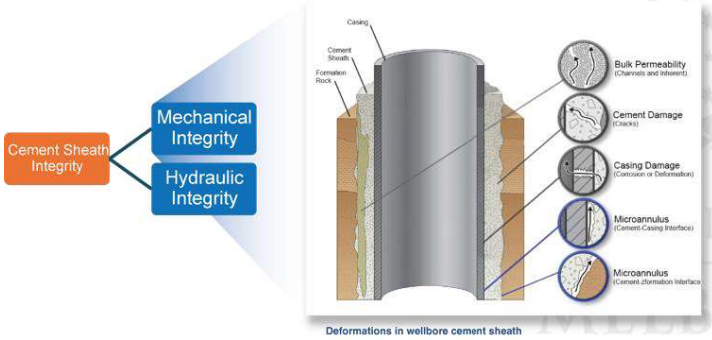
Infrastructure Engineering Graduate Research Conference 2024

Mapping Microannular Voids formation on Existing Wellbore Cement for Underground Hydrogen Storage

Amirthan Thirukumaran
amirthan.thirukumaran@student.unimelb.edu.au
Dr. Samintha Perera, Prof. Stephan Matthai, Dr. Rack San Nicolas & Prof. Ranjith Pathegama
Geotechnical Engineering Group

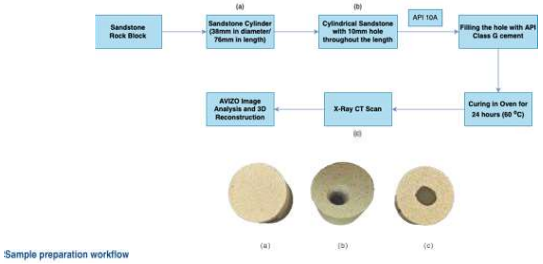
INTRODUCTION

Depleted gas reservoirs are a promising candidate for hydrogen storage due to their relative abundance, long exploration history and experience operators have. However, the successful utilization of depleted reservoirs requires an in-depth knowledge of how the existing wellbore completion technology, especially cement sheath integrity, fare for hydrogen storage. Microannuli formation are a result of poor cement bonding or debonding between cement and casing as well as cement and formation, and this can be either immediately after the cementing operations or due to the continuous injection-withdrawal cycles. This work presents a novel method to map and quantify the microannular voids along the cement-rock interface.

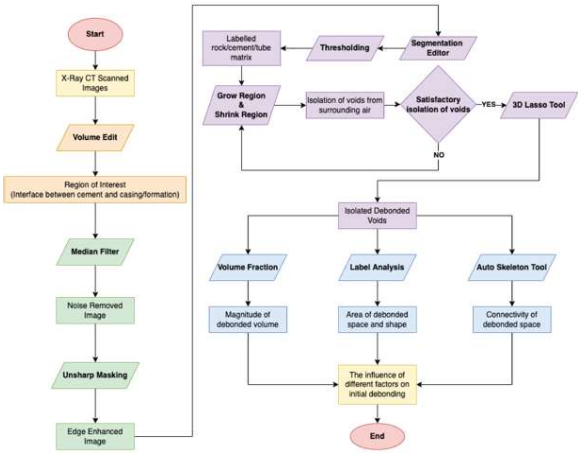


Deformations in wellbore cement sheath

METHODOLOGY



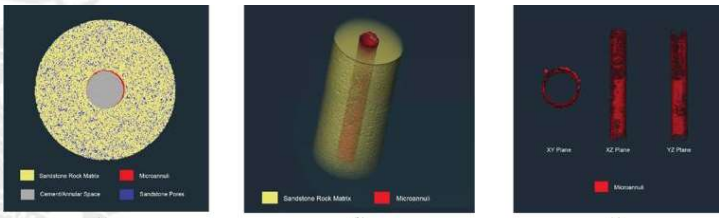
Sample preparation workflow



AVIZO workflow

RESULTS & DISCUSSION

It can be clearly seen that the micro annular voids are present throughout the length of the sandstone specimen. Based on the determined volumetric values, the Piles creek sandstone specimen has a porosity of 23.35%. The micro-annuli percentage is calculated as the ratio between the volumetric values of micro-annuli and annular space. The calculation revealed a micro-annuli percentage of 7% for the current curing condition.



Visualization of micro-annuli in AVIZO - (a) segmented segmented CT image; (b) micro-annuli observed through the length of the specimen; and (c) separated micro-annuli observed through perpedicular planes

Feature	Volume (mm³)
Rock Matrix	69,183.53
Rock Pores	16,155.57
Cement (annular space)	5,850.87
Micro-annuli	415.61

CONCLUSIONS

- The estimation of microannular voids highly depend on the resolution of the scanned images. Higher resolution, in other words, smaller voxel sizes lead to accurate estimation and mapping of the microannular voids.
- The debonding was observed throughout the length of the specimen.
- The test must be repeated with shale samples.
- The effect of subsurface geochemistry on microannular voids can be studied by saturating the samples under different representative geochemical environments and then examining the changes in microannular voids through similar procedure.

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Numerical assessment of ground heat exchangers performance in a pit lake environment

Mauricio Carcamo Medel
m.carcamo@student.unimelb.edu.au
Supervisors: Prof. Guillermo Narsilio and Prof. Raul Fuentes (RWTH Aachen)
Discipline: Geotechnical Engineering

INTRODUCTION

- **Mine pit lakes**, formed from decommissioned open-pit mines, have the **potential** to be an **abundant source** of low-enthalpy **geothermal energy**.
- The mine **decommissioning phase** is an unprecedented **opportunity** to **embed** ground heat exchangers (**GHE**) in the pit lake basin before filling it with water.
- Basin-embedded **GHE performance** is expected to be significantly affected by **seasonal lake thermal dynamics**. Yet, **no studies** of GHE in deep water body basins, such as pit lakes, were found in the **literature**.
- We **assess** the **performance** of pit lake basin-embedded GHE using **two** numerical modelling **methodologies** of **varying complexity**. Both methodologies were implemented and validated using **2D** finite element (**FE**) models. A continuous residential thermal load (heating-dominated) is considered for a 5-year assessment.

METHODOLOGY

- The **model** geometry and properties are representative **of coal mines** found in **Victoria, Australia** (Fig 1a). The simpler model (**Case 1**) **only** considers heat transfer (HT) by **conduction**, while **Case 2** is a more complex model accounting for **turbulent** HT.
- The estimated **energy budget** by both methodologies is compared for varying **cover thicknesses** (Fig 1b).

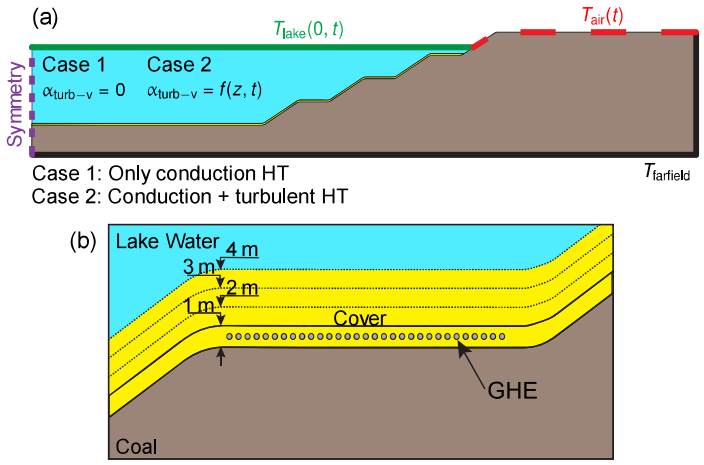

Fig. 1: (a) Model geometry and properties (b) Variation in cover thickness.

RESULTS & DISCUSSION

- Considering **turbulent heat transfer** (Case 2) is **vital** to correctly **estimate** the available **thermal energy** (Fig. 2). **Maximum difference** in energy budget occurs at 1.0 m cover thicknesses (**~280%** - Fig. 2).
- A **seasonal-stable** behaviour is observed for the carrier **fluid temperatures** for Case 2 (Fig. 3), highlighting the **lake** energy **renewal** potential.
- Additional **cover thickness** provides a **damping effect** for **maximum** carrier fluid **temperature** and **modifies** the **temporal occurrence** of temperature maximum/minimum (Fig.3). These **differences** could **impact** system **efficiency** and **costs**.

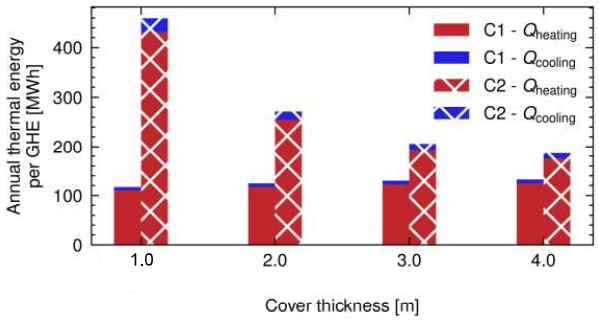

Fig. 2: Annual thermal energy budget for Case 1 (C1) and Case 2 (C2).

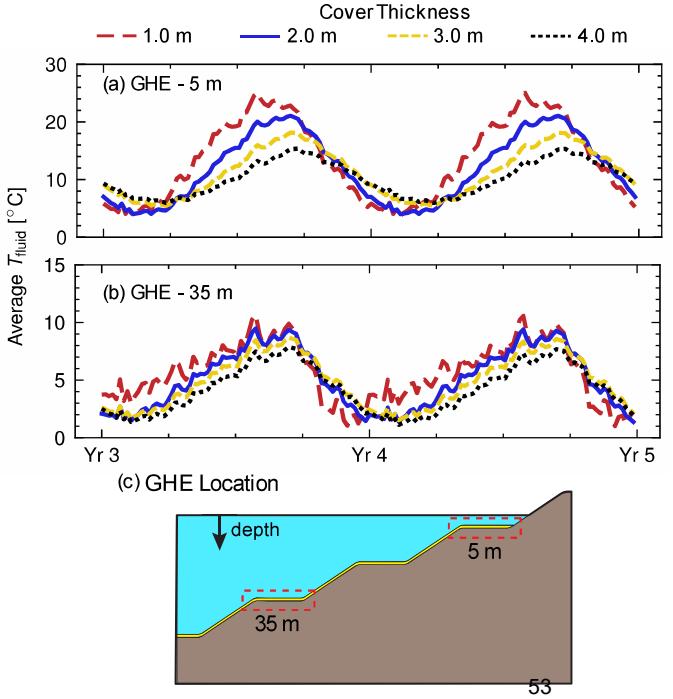

Fig. 3: Average carrier fluid over time for GHE at different pit depths for Case 2 (a) 5m. (b) 35 m. (c) Schematic of GHEs allocation.

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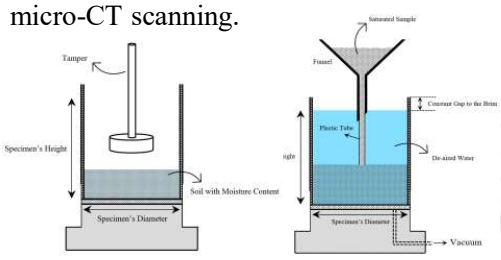
Impact of Specimen Preparation on Internal Stability of the Gap-graded Soils

Name: Meysam Mousavi
Email: m.mousavi@student.unimelb.edu.au
Supervisors: A/Prof. Mahdi Miri Disfani, Dr. Amirhassan Mehdizadeh
Discipline: Geotechnical Engineering

INTRODUCTION

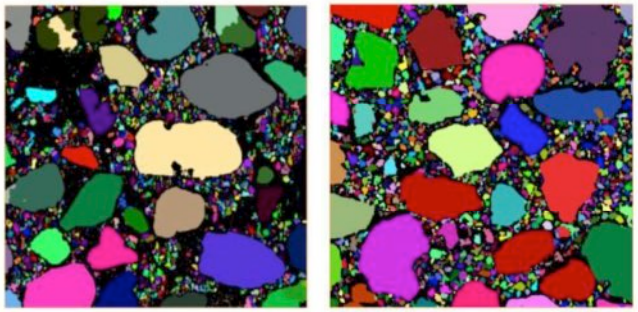
- The study aims to apply micro-CT scanning to gain a detailed and accurate understanding of the internal structure of gap-graded soils, which significantly affects their erosion behaviour.
- The soil specimens prepared by various techniques have different soil fabrics and hence, distinct characteristics.
- Two techniques of moist tamping (MT) and wet pluviation (WP) are employed to prepare the soil samples for this experiment. The results in terms of the erosion progress and residual fine contents are discussed, and the soil structure is investigated using micro-CT scanning.



Moist Tamping *Wet Pluviation*

METHODOLOGY

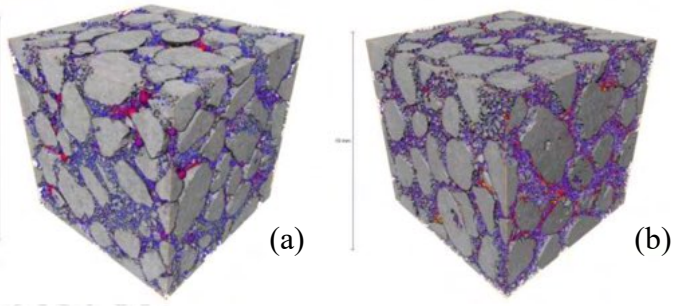
- Samples were prepared using moist tamping and wet pluviation techniques, with dimensions of 50 mm in diameter and 100 mm in height.
- Micro-CT scans were collected on full columns of sediment at a focussed region of interest scans enclosed within an 8.25×8.25×8.25 mm^3 section in the middle of sediment columns at 5.5 µm resolution.
- The segmentation implemented to allow differentiate between various components of the soil structure.



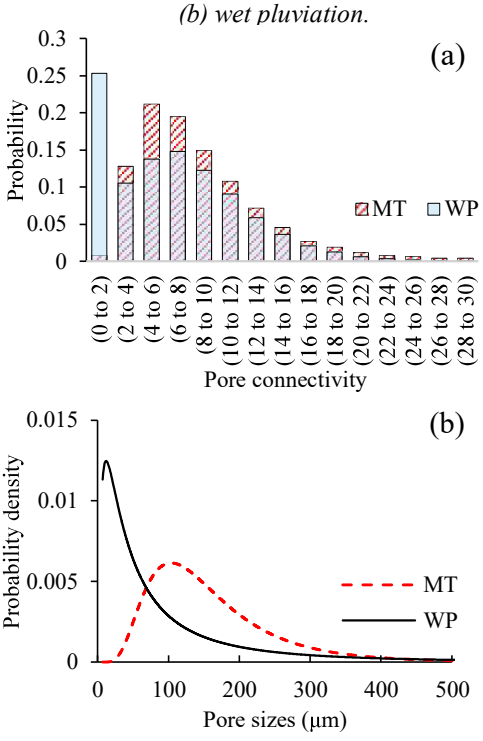
Moist Tamping *Wet Pluviation*

RESULTS & DISCUSSION

- WP samples had smaller, more isolated pores and shorter channel lengths compared to MT samples. The MT samples, with their larger and more connected pores, facilitated greater erosion.
- Fine particle segregation does not occur with the MT preparation method. This uniform distribution suggests that MT produces a more homogeneous sample.
- Heterogeneity across both the radius and height in WP samples, likely due to fine particle segregation during preparation.



Pore network connectivity in: (a) moist tamping and (b) wet pluviation.



Pores connectivity distribution and pore sizes log-normal distribution in: (a) moist tamping and (b) wet pluviation.

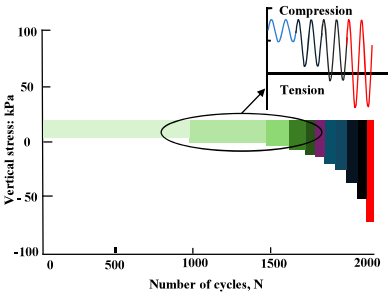
Joint Doctoral Project
THE UNIVERSITY OF MELBOURNE KU LEUVEN
Infrastructure Engineering Graduate Research Conference 2024

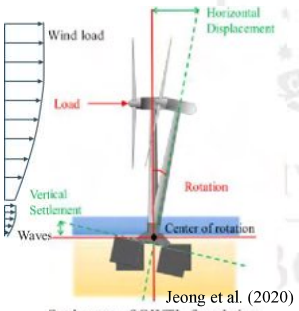
Numerical analysis of suction caissons in sand under cyclic loading: transition from compression to tension

PhD researcher: Nazish Ullah, nullah@student.unimelb.edu.au
Supervisors: A/Prof Shiaohuey Chow, Geotechnical Engineering
A/Prof Stijn François (KU Leuven, Belgium)
A/Prof George Anoyatis (KU Leuven, Belgium)
Dr. Anamitra Roy, Geotechnical Engineering

INTRODUCTION

- Offshore wind energy sources are vital in achieving the world's green energy goals.
- Suction caissons are an emerging foundation solution for Offshore wind turbines (OWT).
- The direction and magnitude of cyclic loading influence the suction caisson deformation response.
- This study employs numerical analysis to investigate the impact of load transition from compressive to tensile on suction caisson response.



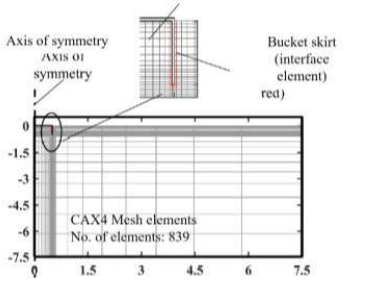


Jeong et al. (2020)
Settlement of OWT's foundation

METHODOLOGY

- **Finite element model:** SANISAND-MS model calibrated for UWA silica sand was used for numerical analysis performed using ABAQUS.
- **Model Setup:** Axisymmetric caisson model with a structured mesh using four-node linear quadrilateral elements (CAX4) for both soil and caisson.
- **Validation:** Model validated against centrifuge tests by Bienen et al. (2018), investigating the effect of compressive load cycles on the caisson's response in tension.
- **Parametric Study:** Investigated the effect of the number and amplitude of compressive cycles on the caisson's response to subsequent tensile cyclic loading.

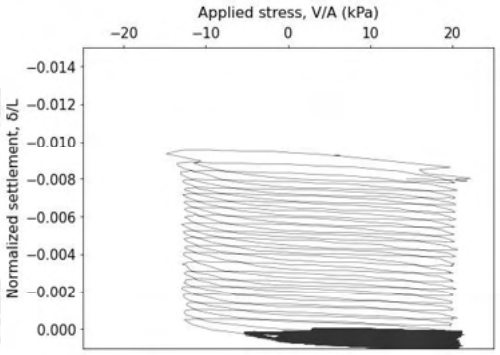
UWA centrifuge facility



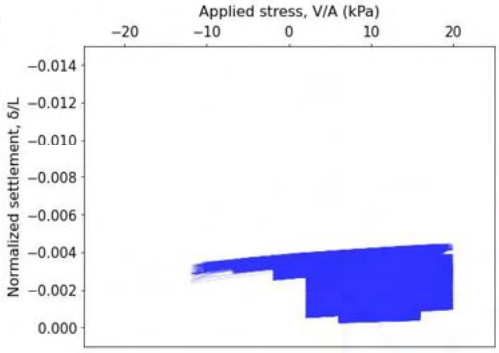
Model suction caisson and mesh details

RESULTS & DISCUSSION

- The SANISAND-MS model calibrated by Roy et al. (2024) for silica sand has been used to simulate the boundary value problem.
- The calibrated model has been used to predict the centrifuge test results conducted at 100g, as reported by Bienen et al. (2018).



Results of centrifuge tests (Bienen et al., 2018)



Results of FE analysis: Simulated centrifuge experiment

- Preliminary results show a qualitative comparison between the experimental and simulated results.
- Next element tests will be conducted under identical loading conditions to further corroborate the results of the numerical analysis.
- The scope of the study will be extended by investigating the suction caisson response in **calcareous sand**.

REFERENCE

[1] Bienen, Britta, et al. "Suction caissons in dense sand, part II: vertical cyclic loading into tension." Géotechnique 68.11 (2018): 953-967.
[2] Roy, A., et al. "Suction bucket performance in sand under vertical cyclic loading: Numerical modelling using SANISAND-MS." Computers and Geotechnics 173 (2024): 106497.

Joint Doctoral Project
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Monopile under lateral loading: centrifuge testing and numerical investigation

PhD researcher: Olgu Orakci, oorakci@student.unimelb.edu.au
Supervisors: A/Prof Shiaohuey Chow, Geotechnical Engineering
A/Prof Stijn François (external, KU Leuven)
A/Prof George Anoyatis (external, KU Leuven Brugge)

INTRODUCTION

The global push for renewable energy has increased offshore wind energy production. The REPowerEU Action Plan aims for 150 gigawatts by 2050, emphasizing the need for reliable offshore wind turbine (OWT) designs.

This study examines the lateral loading response of OWT monopiles in dense sand using the 50-g geo-centrifuge at TU Delft. Experimental results will be upscaled for comprehensive analysis. Numerical simulations in PLAXIS 3D range from basic to advanced soil models. By comparing experimental data and numerical analyses, this study aims to improve monopile foundation reliability in challenging offshore conditions.

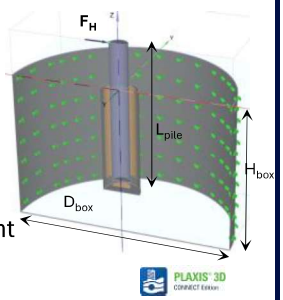
METHODOLOGY

This study uses a range of soil models, from the classical Mohr-Coulomb (MC) to advanced models like Hardening Soil (HS), Hypoplasticity with intergranular strains (ISHP), and NorSand. Soil parameters for GEBA sand are adopted from various studies.

The monopile and the soil bucket in the centrifuge model at 50-g are modelled and analyzed as an elastic steel plate and soil as 10-node tetrahedral elements, respectively via finite element analysis. Half of the foundation system is modeled for efficiency, with refined mesh around the pile.

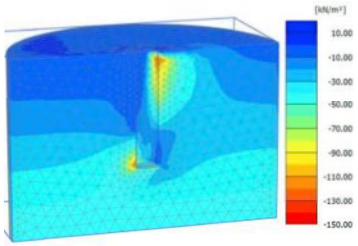
Staged analysis

K0 condition
Acceleration 50g via $\Sigma M_{weight} = 50$
Wished in Place
Loading up to 0.1D lateral displacement

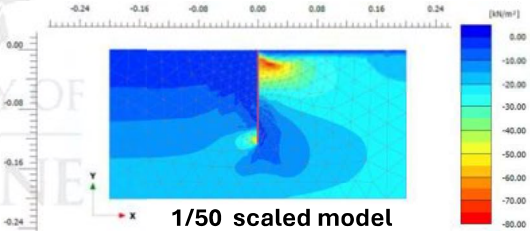


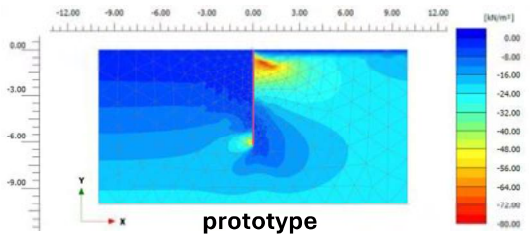
RESULTS & DISCUSSION

- Since model parameters are calibrated towards certain tests via different sets of parameters, the displacements are expected to be calibration-dependent although they share similar stress distribution in 3D as shown:

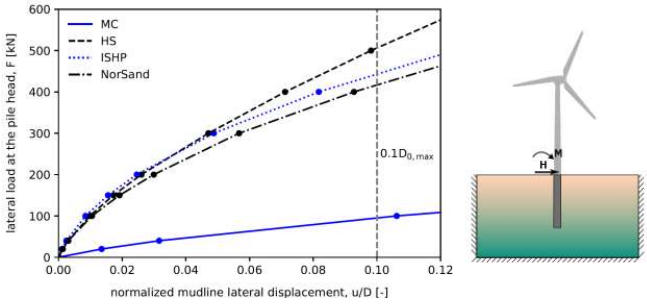


- Numerically, the 1/50 scaled model and the prototype have the same lateral response under monotonic loading in terms of stresses and displacements:





- Simulation results show quite close estimates of lateral load-displacement under the given loads:



- The experimental data will be compared with the predictions once the test results become available.

stay informed about the project's progress and access the scripts

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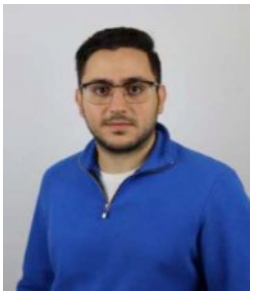
Bayesian Inference for Estimating Quasi-Static Tip Resistance from Free-Fall Penetrometer Data



Name: Parviz Tafazzoli Moghaddam
Email: ptafazzolimo@student.unimelb.edu.au
Supervisors: Dr. N. Yousefpour, Prof. S. Chow, Prof. M. Cassidy
Discipline: Geotechnical Engineering

INTRODUCTION

The estimation of seabed strength is crucial in geotechnical design. However, this process is impeded by significant costs and time constraints. In such cases, free-fall penetrometers (FFPs), offer feasible alternatives to constant rate penetrometers (CRP), like cone penetrometer tests. However, interpreting soil properties from FFP data involves substantial uncertainty. In this study, Bayesian inference is applied to evaluate empirical models developed for FFP in clay using comprehensive laboratory-paired test data. This dataset includes numerous FFP characteristics alongside static tip resistance (Fig. 1). Results show that unmeasurable parameters, such as the strain-rate coefficient (*SRC*) and drag coefficient (C_D) involve significant uncertainty. This underscores the importance of Bayesian inference, to optimize these parameters and improve the reliability of FFP data interpretation.

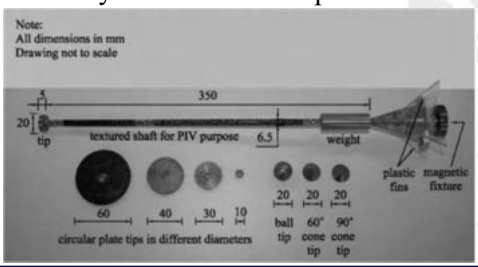


Fig. 1. Free fall penetrometer

METHODOLOGY

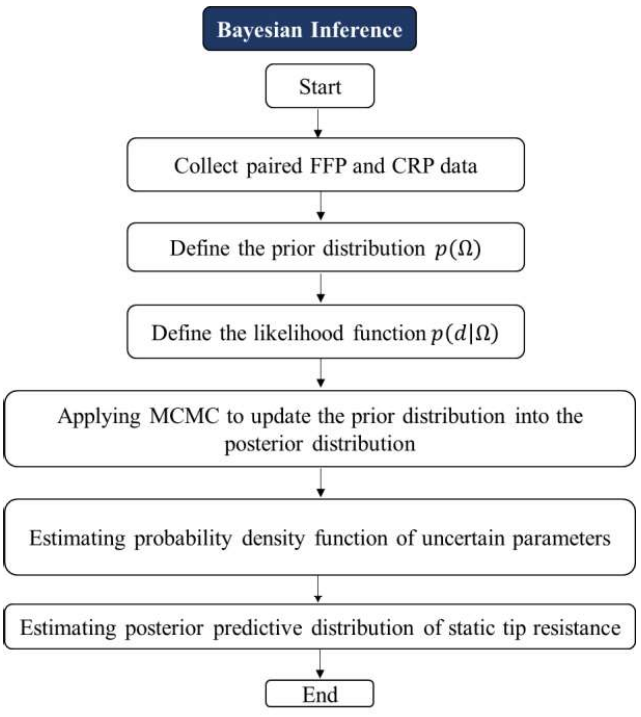


Fig. 2. Bayesian inference process

RESULTS & DISCUSSION

The results illustrate how integrating observed laboratory test data into the Bayesian inference process shifts the *SRC* from 0.2 (commonly adopted in former studies) to a posterior mean of 0.478 (Fig. 3). Moreover, after updating the model, the uncertainty in the *SRC* is reduced, with the standard deviation decreasing from 0.1 for the prior to 0.0096 for the posterior. Evaluating metrics such as R-squared and Mean Absolute Percentage Error (MAPE) demonstrates an improvement in prediction when using the posterior mean compared to the prior mean (Fig. 4 and Fig. 5). Furthermore, this approach not only enhances predictive accuracy but also captures both epistemic and aleatoric uncertainties inherent in the process (Fig. 5).

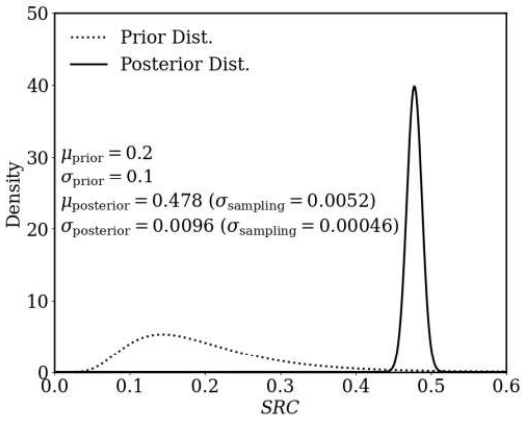


Fig. 3. Prior vs. posterior distribution

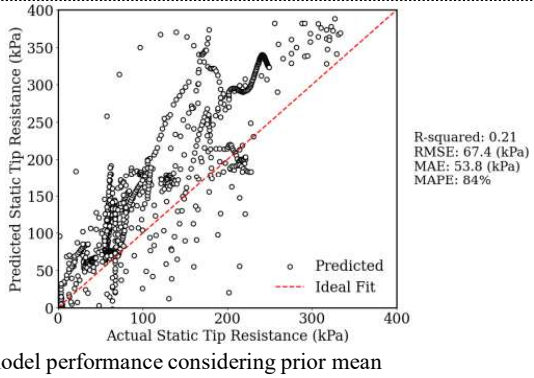


Fig. 4. FFP model performance considering prior mean

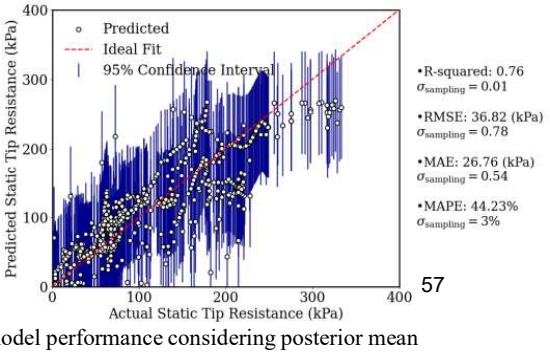


Fig. 5. FFP model performance considering posterior mean

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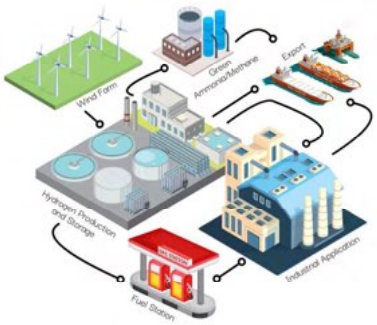
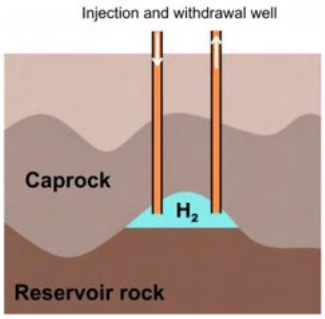
Assessing Caprock Integrity for Underground Hydrogen Storage in Depleted Gas Reservoirs

Name: Pramod Dilshan
Email: pranathungaa@student.unimelb.edu.au
Supervisors: Dr. Samintha Perera, Prof. Stephan Matthai, Dr. Saeed Salimzadeh
Disciple: Geotechnical

Introduction

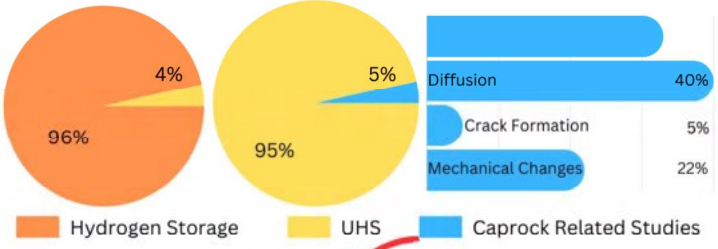




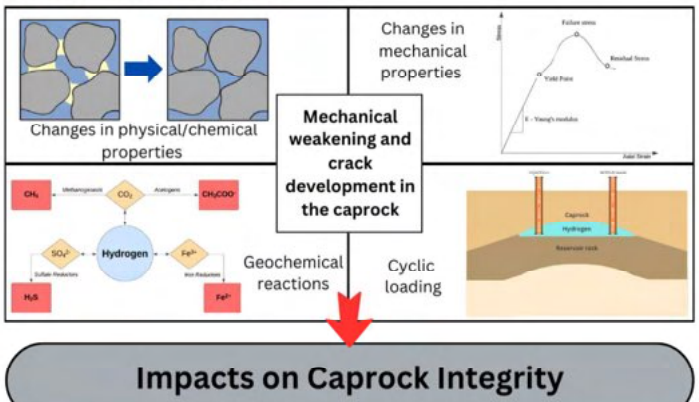
Hydrogen is emerging as a potential energy carrier for converting and storing excess renewable energy. Accordingly, underground hydrogen storage (UHS) in depleted gas reservoirs is a more viable solution due to its large capacity, cost-effectiveness, and existing infrastructure. The caprock, characterized by low porosity and permeability, is crucial to safely containing hydrogen in the subsurface storage. However, high-pressure injection, cyclic loading, and interactions with hydrogen can weaken the caprock, causing crack formation and increased permeation. This research explores caprock integrity in UHS, focusing on mechanical weakening, crack development, and hydrogen leakage mechanisms.

Research Gaps and Hotspots

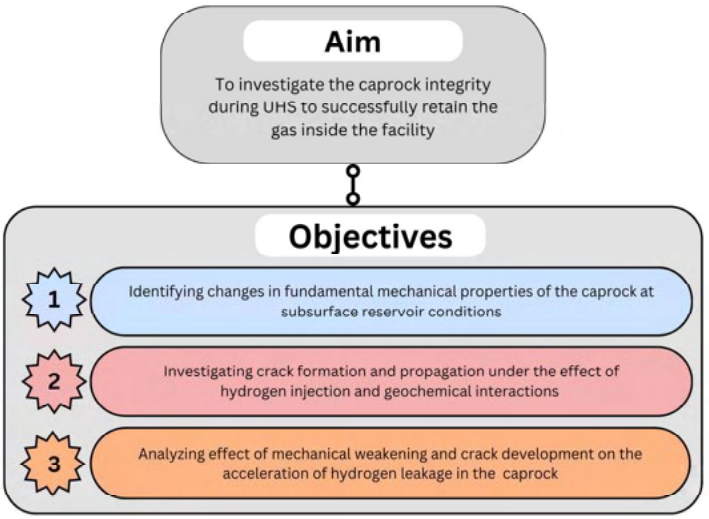
Overview of Existing Literature



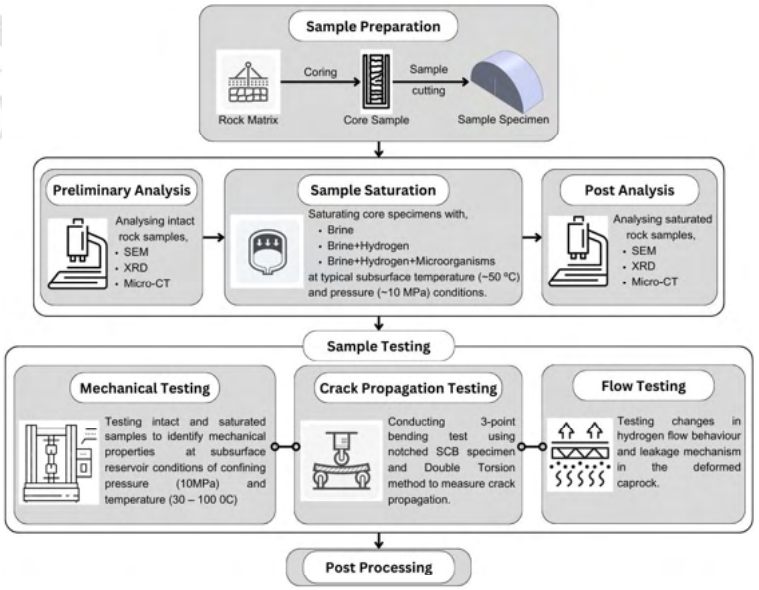
Research Hotspots



Purpose of the Study



Proposed Methodology



Conclusion

This research project focuses on the impact of mechanical property changes and crack formation in caprock on underground hydrogen storage. By examining multiple crack propagation mechanisms, the study aims to understand how these factors affect storage integrity. A combination of experimental methods including UCS, triaxial testing, double torsion technique, semi-circular bend testing, and core flooding testing will be utilized on shale samples saturated with hydrogen. Additionally, experimental findings will be validated numerically to assess hydrogen leakage mechanisms at a large scale.

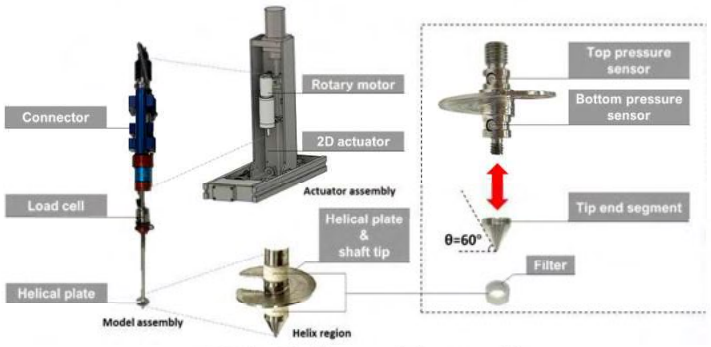
Installation of helical pile in clayey soil

Name: Zeliang Li
Email: zeliangl@student.unimelb.edu.au
Supervisors: Prof. Yinghui Tian; Dr. Shubhrajit Maitra; Prof. Mark Cassidy
Discipline: Geotechnical Engineering

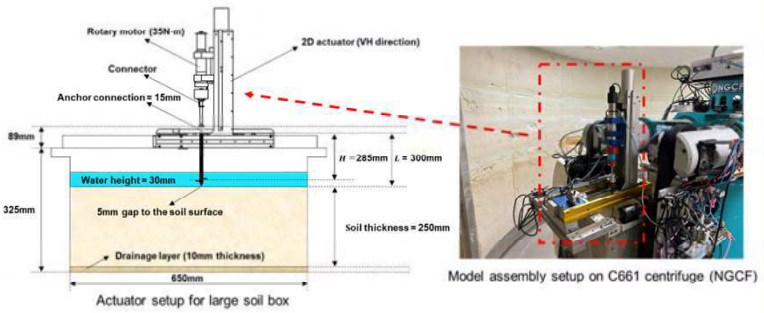
INTRODUCTION

- Helical piles are gathering growing attention for offshore engineering due to their avoidance of acoustic emissions inherent in pile installation and their capacity enhancement compared to driven piles. However, the installation requirements for these upscaled helical piles are still unclear and the impact of the installation process on its load-bearing performance remains to be investigated. Although previous research on sandy soils has suggested the potential for a reduction in installation force, investigations pertaining to clay substrates remain notably lacking. These uncertainties present challenges in terms of the application as offshore foundation system. In this presentation, the entire process of helical pile installation will be discussed from different perspectives.

METHODOLOGY

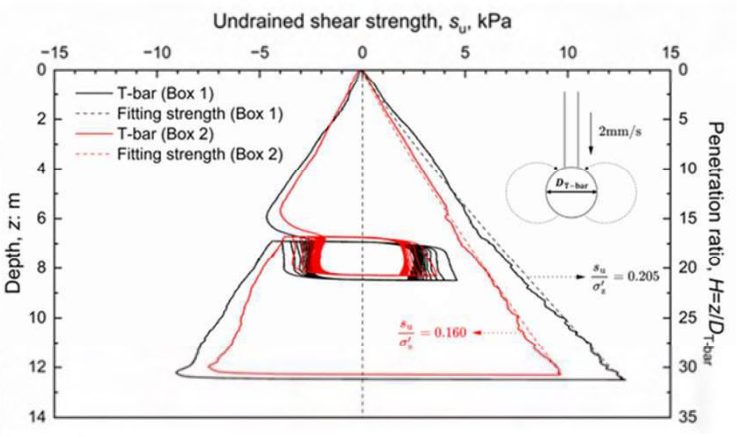


Helical pile model assembly

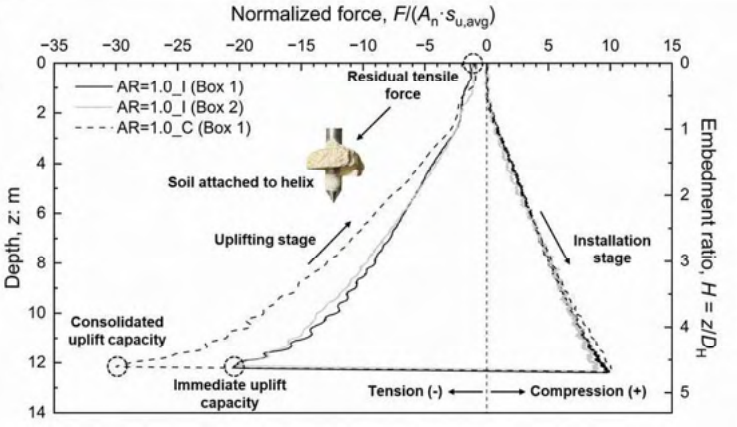


Centrifuge test setup

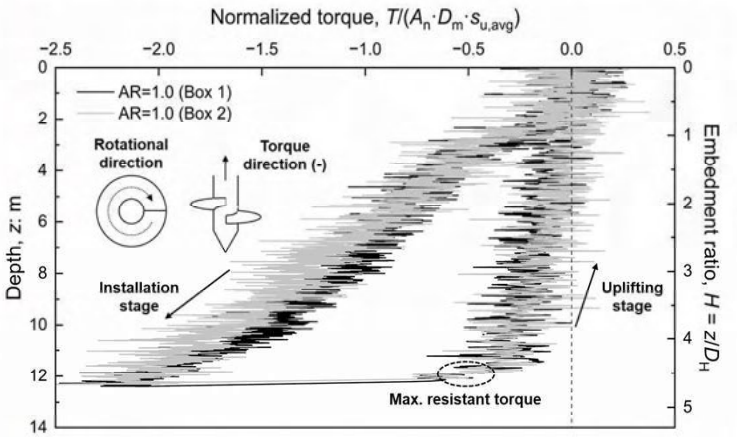
RESULTS & DISCUSSION



Soil strength profile



Normalized force response



Normalized torque response

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Large Deformation Modelling: a numerical approach in offshore geotechnics

Name: Ran Tu
Email: ratu@student.unimelb.edu.au
Supervisor: Prof. Yinghui Tian & Prof. Mark Cassidy
Disciple: Geotechnical engineering

INTRODUCTION

- Large deformation process is commonly encountered in offshore geotechnical applications, with typical examples including penetrometer penetration, anchor installation, spudcan preloading and pipeline laying and buckling. Numerical large deformation modelling still remains one of the most challenging aspects of computational geomechanics. Offshore engineers require reliable and accessible numerical approaches to simulate large deformation processes. The traditional Lagrangian finite element analysis is inadequate due to excessive mesh distortion. An efficient approach, Periodic Lagrangian Analysis with Mesh Reconstruction, is proposed to overcome the numerical difficulties, with clear demonstration of concept and implementation in this paper. And a new mapping algorithm is developed for the proposed numerical approach with focus on its accuracy and efficiency. Finally, the performance of the proposed approach is demonstrated by showcasing some of its applications in offshore geotechnics.

METHODOLOGY

- In large deformation finite element (LDFE) modelling, the large deformation process can be achieved by successively incremental analyses in which either periodically reconstructed mesh or undeformed background mesh is used in currently incremental analysis to replace the distorted mesh of the previously incremental analysis.
- To ensure continuity between successively incremental analyses, mapping variables (e.g. stress and material properties) from old mesh to reconstructed/background mesh is key to LDFE modelling.
- The newly proposed algorithm includes two key steps, namely neighbouring element recovery and local interpolation. Neighbouring element recovery serves to recover variables stored at integration points of the old mesh to element nodes of the old mesh. And variables, both recovered and inherently stored at element nodes of the old mesh, can be interpolated to element nodes or integration points of the new/background mesh via local interpolation

RESULTS & DISCUSSION

- The accuracy and efficiency of the proposed mapping algorithm are verified via element test.
- This paper proposed an efficient approach to overcome the numerical difficulties in large deformation FE modelling.
- Practical simulation examples are showcased to demonstrate the performance of the proposed numerical approach.

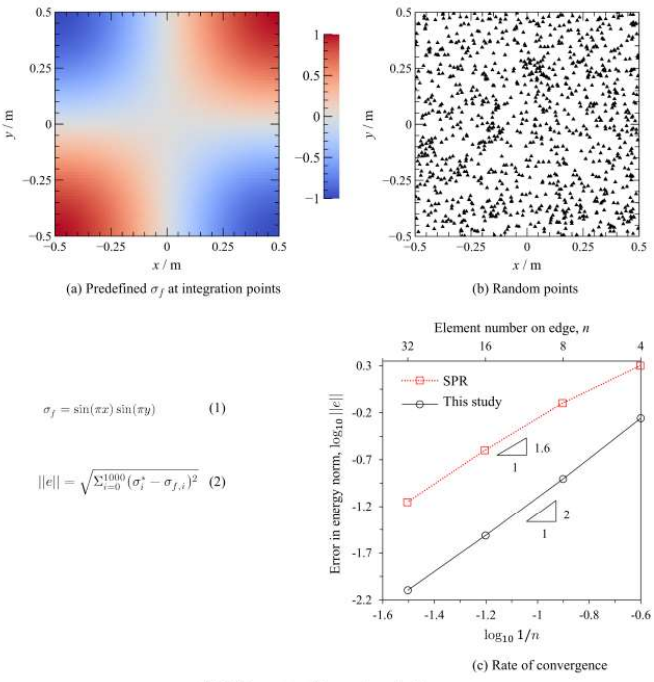

Fig.1 Element tests for mapping algorithm

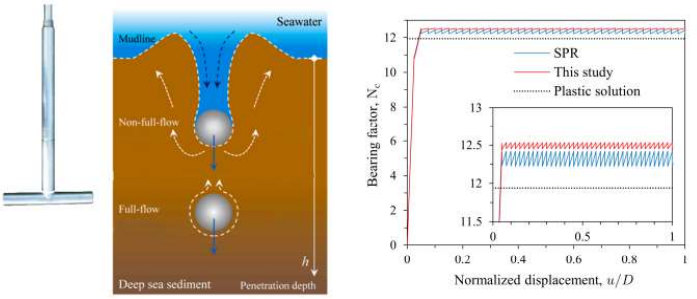

Fig. 2 Practical simulation example of T-bar

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The influence of OWT installation process on the monopile foundation behaviour

Name: Shen Xie
Email: shexie1@student.unimelb.edu.au
Supervisors: Prof. Y. Tian, Dr. Y. Wang, Dr. B. Atazadeh
Disciple: Geotechnic

INTRODUCTION

- Monopiles have emerged as a widely utilized solution for fixed offshore wind turbine foundations due to their operational simplicity and cost-efficiency. However, significant uncertainties remain regarding the soil failure mechanisms during the installation of superstructures on pre-existing monopile foundations.. Figure 1 describes the working process of the Offshore Wind Turbine (OWT) installation vessel.

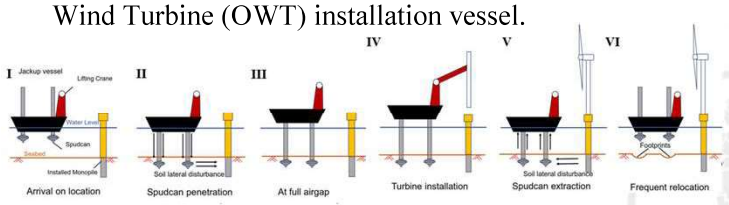


Fig. 1 Working process of the OWT installation vessel

- Two key issues to consider:

1.The impact of spudcan penetration on the lateral response of the nearby monopile. (step II)

2. Changes in the bearing capacity and stiffness of the soil around the monopile after spudcan-induced soil disturbance post-installation. (step VI)

METHODOLOGY

- Numerical simulation: The Smoothed Particle Hydrodynamics method (SPH) is a mesh-free computational technique used to simulate fluid dynamics and complex systems (as shown in fig.2). Unlike traditional grid-based methods, SPH represents the domain using particles that move with the fluid and interact through kernel functions. In this research, soil can be modelled as smoothed particles.

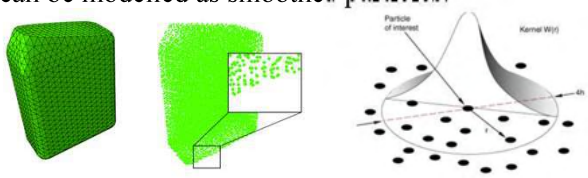


Fig. 2 SPH diagram

- Physical model test: a. The 1g test is a physical model test conducted under normal gravitational conditions (1g). b. The centrifuge test simulates geotechnical problems by increasing the gravitational force (typically up to 100g or more) using a centrifuge. This allows small-scale models to mimic full-scale stress conditions.

RESULTS & DISCUSSION

- Investigation of spudcan installation and its Influence on monopile: The spudcan model will be inserted at varying distances from the monopile, and strain gauge measurements will be used to record the resulting pile displacement and bending.

- Experimental investigation of the capacity and stiffness of monopile post-OWT installation: By inserting and withdrawing the spudcan model at different distances, various footprints will be created. Forces will then be applied using a load cell on either the same or the opposite side of the footprint

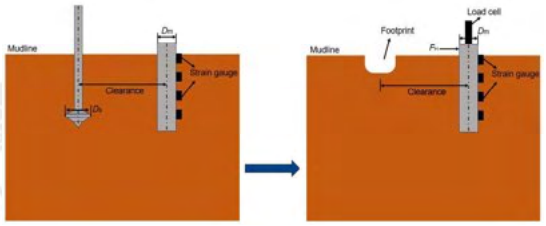


Fig. 3 Physical scaled model diagram

- Comparison for spudcan penetration analyses: The first phase of the study involves a comparative evaluation of three numerical methods for simulating spudcan penetration into the soil layer.

- Extensive parameter analyses for safe distance Determination: The numerical comparison, extensive parameter analyses will be conducted, guided by the results from initial physical model experiments.

- Final parameter analysis and load capacity-displacement curve Modeling: The study will focus on varying the footprint positions and applying lateral loads on both the same and opposite sides of the monopile.

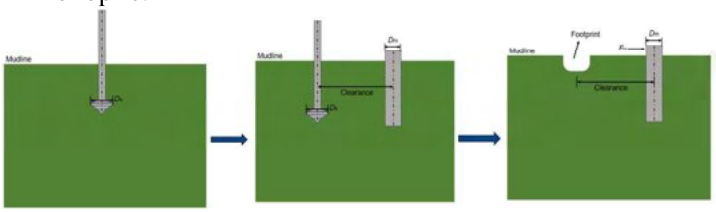


Fig. 4 Numerical simulation diagram

- Expected outcomes: 1. Conduct a preliminary analysis to assess the effects of spudcan installation on the monopile's lateral displacement and bending moments. 2.Establish safety guidelines for spudcan proximity to monopile foundations. 3. Develop a simplified load capacity-displacement curve model to understand the monopile's performance and lateral load.

Fluid inertia effect on flow through fracture intersections

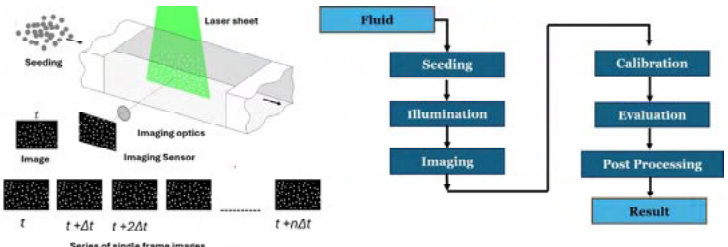
Name: Amila Edirisinghe
Email: edirisinghea@student.unimelb.edu.au
Supervisors: Dr. M.S.A. Perera, Prof. S.K. Matthai, Dr. E.Goudeli, Prof. D. Elsworth
Discipline: Geotechnical Engineering

INTRODUCTION

- Fracture networks are critical pathways for fluid transport in both natural environments (e.g., groundwater flow) and industrial applications (e.g., hydraulic fracturing, geothermal energy extraction).
- At fracture intersections, the behaviour of fluid flow becomes complex, and the impact of fluid inertia- especially at higher velocities-may significantly alter flow patterns.
- Traditional models often neglect this factor, leading to oversimplifications.
- There is still an ongoing need of high-fidelity experimental data of fracture flows to understand the complex interactions between fluid and the fracture geometry.
- This study aims to experimentally investigate the effect of fluid inertia on flow behaviour at a fracture intersection using Particle Tracking Velocimetry (PTV).

METHODOLOGY

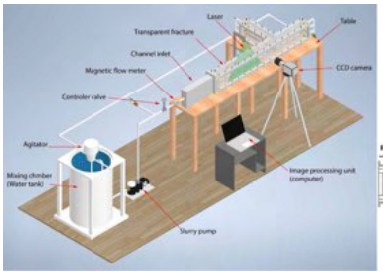
- 2D Particle Tracking Velocimetry (PTV)

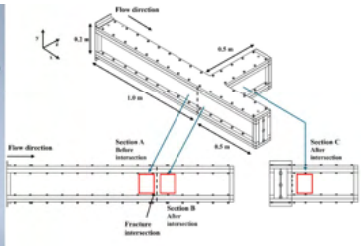


Measurement of fluid flow velocities at very fine temporal resolutions
Capture highly transient and turbulent phenomena in more detail

- Experimental Setup

Hele-Shaw type laboratory fracture intersection model

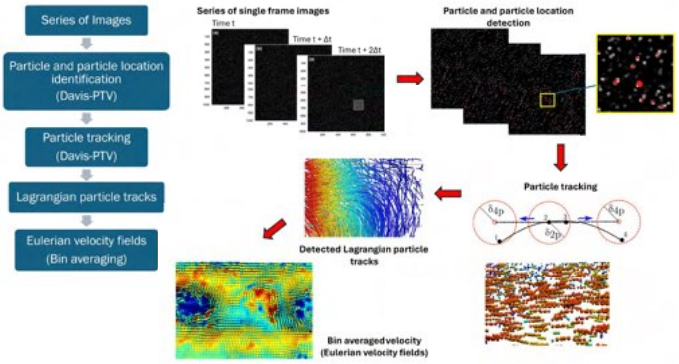




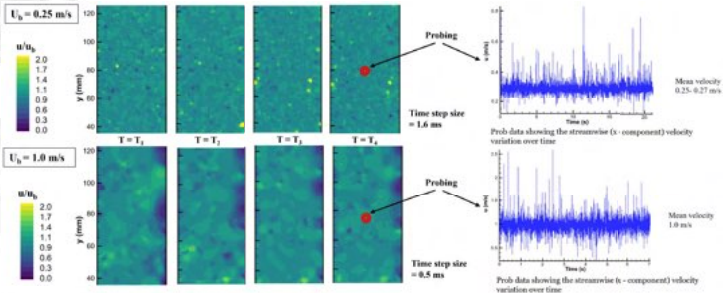
Flow channel and the area of interest for measurements

RESULTS & DISCUSSION

- PTV Image Processing

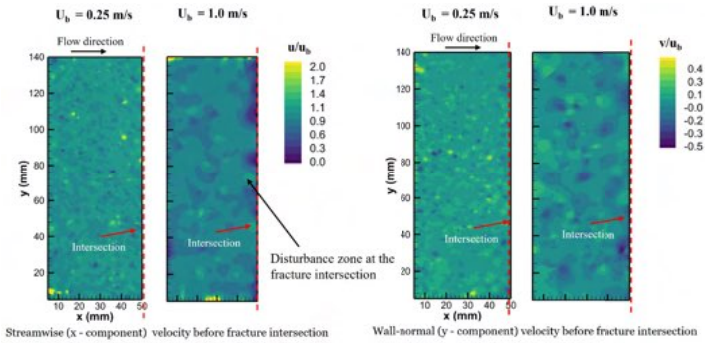


- Transient flow behaviour: Streamwise velocity fluctuations



Variation of instantaneous streamwise velocity (x component) with time captured before the fracture intersection

- Formation of the disturbance zone at the fracture intersection



Streamwise (x - component) velocity before fracture intersection
Wall-normal (y - component) velocity before fracture intersection

Streamwise (u) and wall-normal(v) velocity before the fracture intersection

CONCLUSIONS

- Flow within the fractures show a transient behaviour even for relatively low flow velocities
- Fracture intersections become dominant factor for the unsteady flows
- Preliminary results of this study confirms that the steady flow assumption is not valid for high velocity fracture flows

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Influence of Fluid Rheology on Fluid Flow in Natural Fracture Network

Name: Cuong Bui
Email: cuongb@student.unimelb.edu.au
Supervisors: Prof. Stephan Matthai, Dr. Samintha Perera
Discipline: Geotechnical Engineering

INTRODUCTION

Transport of non-Newtonian fluids through natural fracture networks is relevant to many geophysical phenomena (e.g., magma flow, groundwater movement) and frequently prompted by subsurface engineering activities (e.g., drilling process, enhanced oil recovery, hydraulic fracturing). Yet, rheologically non-Newtonian behaviour and its effects are overlooked by fracture-flow studies that rely on the Newtonian viscosity assumption. Moreover, flow computations for fracture networks remain scare, owing to difficulties in dealing with non-linear partial derivative terms on complex geometries. This work aims to investigate and analyse the impact of polymer rheology on the fluid flow across a statistically representative millimetre (mm)-aperture fracture network, comparing and contrasting it with Newtonian fluid flow. A wide range of network influxes is employed to examine the interplay between fluid rheology and fluid inertia effect, providing a comprehensive understanding of how non-Newtonian fluid properties influence flow distribution in complex geological structures.

METHODOLOGY

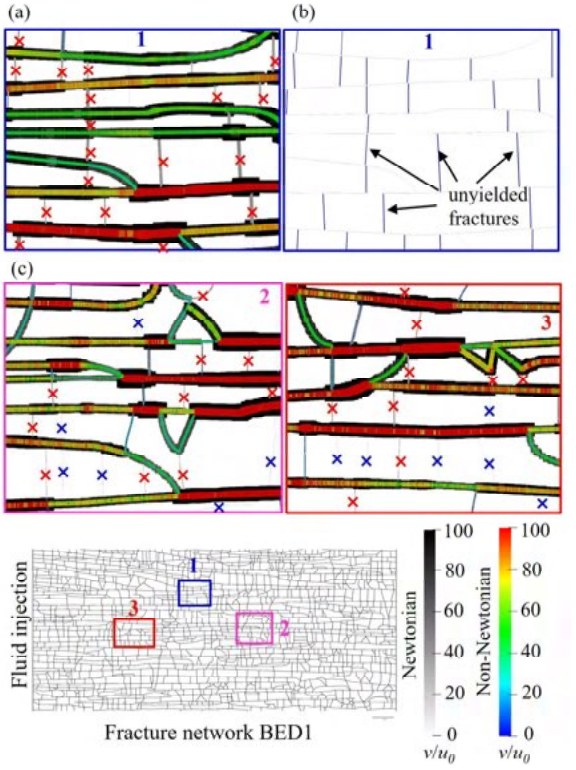
The Navier-Stokes equation (NSE) was approximated using the Finite Volume Method (FVM) on the realistic fracture network BED1, mapped in the southern Bristol Channel coast, UK [Belayneh and Cosgrove, Geol. Soc. Spec. Publ. 2004]. This heterogeneous system comprises thousand of arbitrarily-shaped mm-aperture fracture segments and intersections. A steady-state solver utilising the Reynolds-averaged Navier-Stokes (RANS) with the shear-stress transport (SST) k-ω model is used to simulate fracture flow across broad range of injection rates (u_0 = 10^{-6} – 10^{-1} $m^3m^{-2}s^{-1}$).

The rheological properties of Carbopol polymer gel, including yield stress (τ_0=1.88 Pa) and shear-thinning (n=0.42) behaviour as characterised by Mossaz et al. [Mossaz et al., J Non-Newton. Fluid 2012] were adopted for our non-Newtonian fluid flow simulations. These features are modelled using the Herschel-Bulkley-Papanastasiou approach. For comparison with Newtonian fluid flow, we used an equivalent (plastic) viscosity (μ=K=1.46 Pa s).

RESULTS & DISCUSSION

Fluid rheology alters the flow partitioning at all fracture influxes. At low rates, the yield stress effect forces the fluid flow in main fractures by causing serious rigid blockage in side branches. At high rates, fluid inertia takes into place since shear-thinning reduces viscous forces, preventing fluid distribution into short fractures and creating circulation wakes in fracture intersections.

The Newtonian viscosity assumption overestimates the network-wide average velocity by neglecting complex viscosity variations across fractures. At low injection rates, it underestimates the velocity variation range because it does not account for the reduced effective fracture volume due to the yield stress effect.



Comparison of flow partitioning between non-Newtonian and Newtonian injections into fracture network BED1 at (a) u_0 = 10^{-6} (low rate) and (c) 10^{-2} $m^3m^{-2}s^{-1}$ (high rate). (b) Formation of unyielded fractures at u_0 = 10^{-6} $m^3m^{-2}s^{-1}$. (×) denotes pathways inactive with non-Newtonian but active with Newtonian viscosity; (×) indicates branches ignored by both.

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Detecting internal erosion in gap-graded soils using CFD-DEM and Convolutional Autoencoder

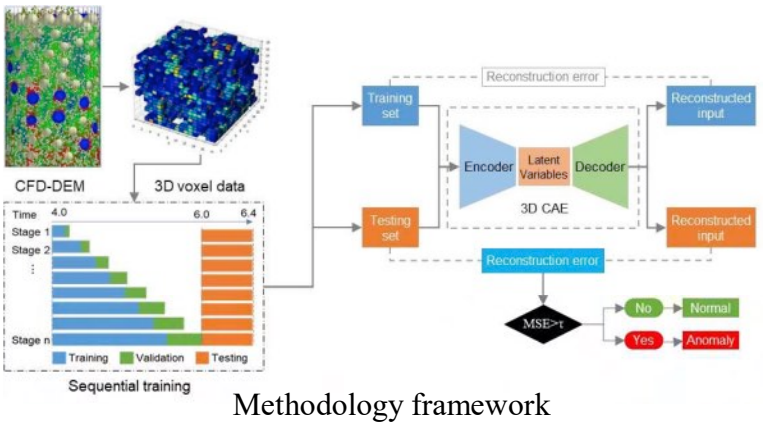
Name: Jie Qi
Email: jie.qi@student.ujnimelb.edu.au
Supervisors: Guillermo Narsilio Wenbin Fei, Negin Yousefpour, Mahdi Disfani
Discipline: Geotechnical Engineering

INTRODUCTION

- This research focuses on understanding **internal erosion** in gap-graded soils at the particle scale, which poses significant risks to water-retaining structures like earth dams.
- The study couples the Discrete Element Method (DEM) with Computational Fluid Dynamics (CFD) to simulate internal erosion in gap-graded soil samples, extracting **particle-scale** parameters such as contact forces, particle velocity, and fluid velocity.
- Multidimensional tensors of particle-scale data are constructed to train Deep Learning models, specifically **Autoencoder** models with 3D Convolutional Neural Networks (CNN), to identify subtle erosion patterns and anomalies.
- The findings reveal how mesoscale particle behaviours, such as motion and contact forces, lead to macroscale erosion. The research may help develop AI-based monitoring systems for **early detection** and risk mitigation in dam safety.

METHODOLOGY

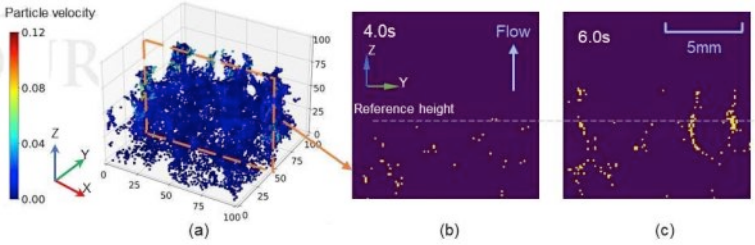
- The **CFD-DEM** model simulates internal erosion in gap-graded soil, driven by a hydraulic gradient from the bottom to the top.
- A **voxelization algorithm** is developed to convert particle-scale data into 3D tensors, capturing the spatial distribution of particles.
- The machine learning framework incorporating **Convolutional Autoencoder** and sequential training strategy, detects anomalies using 3D tensors as inputs.



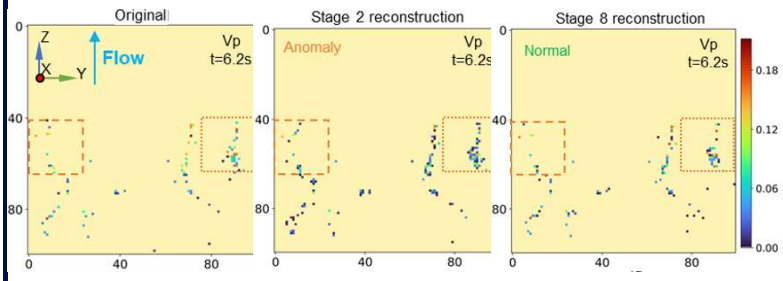
Methodology framework

RESULTS & DISCUSSION

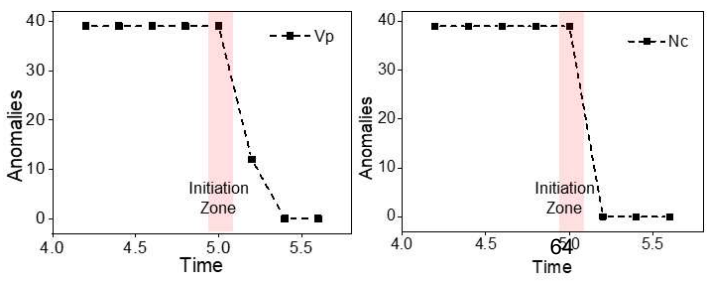
- The CFD-DEM model successfully simulates the suffusion process, capturing **particle-scale** interactions and fluid flow patterns during internal erosion.
- The voxelization algorithm effectively captures detailed particle **migration** and erosion **paths**, providing high-resolution data on the spatial distribution of eroded particles.
- Convolutional Autoencoder (CAE) models successfully recognize particle data **patterns** and detect **anomalies** related to erosion progression.
- The **initiation** point of internal erosion is detected by the CAE model through the number of anomalies at different erosion stages, highlighting its effectiveness in monitoring the progressive stages of internal erosion.



(a) Fine particle migration



(b) Data reconstruction



(c) Anomaly detection

Infrastructure Engineering
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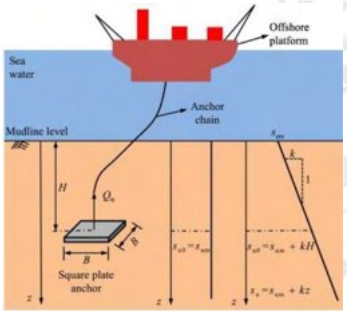
Geotechnical behavior of plate anchors in clay under rapid loading

Name: Quanzhen Chen
Email: quanzhen.chen@student.unimelb.edu.au
Supervisors: Prof. Yinghui Tian, Dr. Yifa Wang, Prof. Mark Cassidy
Discipline: Geotechnical Engineering

INTRODUCTION

The growing demand for floating offshore wind energy necessitates advancements in anchoring solutions. To reduce foundation costs in this rapidly evolving sector, it is essential to improve the accuracy of anchor capacity predictions and exploit previously untapped capacity sources. One such source is the suction force generated beneath anchors, which is often neglected in traditional anchor design for oil and gas facilities due to high uncertainties and estimation challenges. This study employs finite element analysis to examine the contribution of soil-anchor interface tension (originated from suction) on anchor capacity under both uniaxial and combined normal, sliding, and rotational moment loadings. The findings highlight the critical impact of interface tension on the anchor capacity, offering valuable insights for engineers in anchor design.

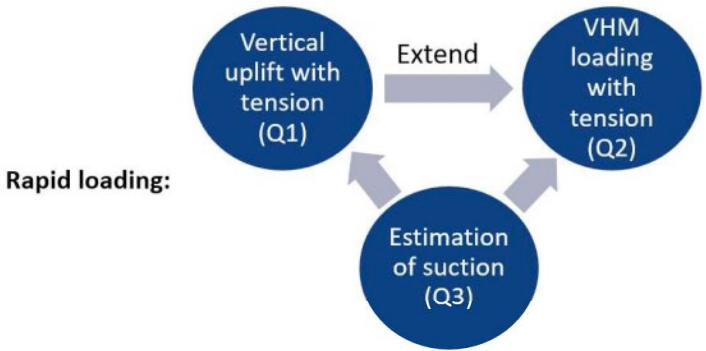


METHODOLOGY

1) Vertical uplift of plate anchors:
Total stress analysis with a user-defined model of the interface.

2) Plate anchors under combined normal (V), sliding (H), and rotational moment (M) loadings:
Total stress analysis with a user-defined model of the interface.

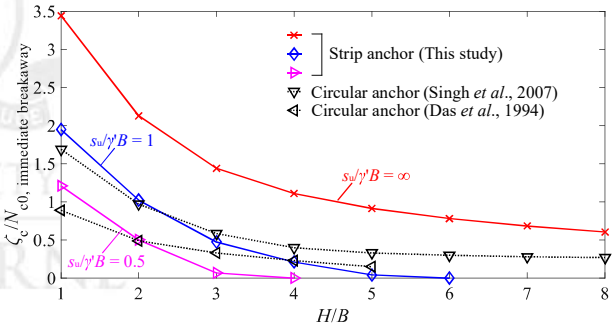
3) Estimation of suction:
Coupled pore fluid diffusion and stress analysis based on Biot's consolidation theory.



RESULTS & DISCUSSION

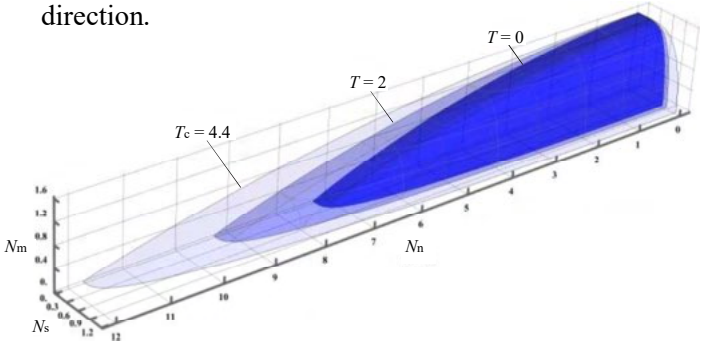
1) Vertical uplift of plate anchors:

- An increase in interface tension results in an evolving failure mechanism from the extremes of immediate breakaway to no breakaway conditions;
- The anchor capacity is a superposition of tension factor on the pullout capacity factor of the immediate breakaway case but limited to the no breakaway capacity;
- The soil overburden pressure has a suppression effect on the interface tension effect.



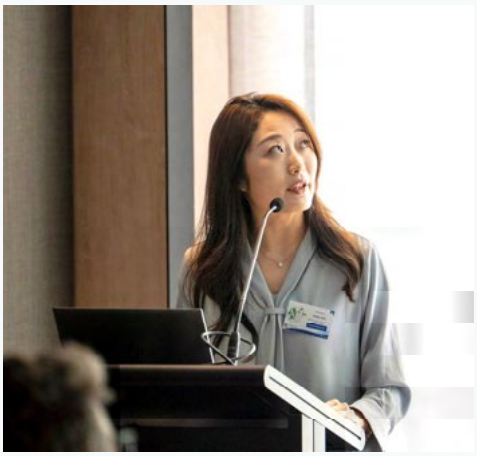
2) Plate anchors under combined VHM loadings:

- The increase in interface tension significantly enhances the normal bearing capacity of plate anchors, has a minor effect on the sliding bearing capacity, and exerts a negligible impact on the rotational bearing capacity;
- The yield envelope evolves significantly with increasing interface tension factors until a critical interface tension factor is achieved in the normal direction.



3) Estimation of suction:

A negative linear correlation is found between interface tension and the natural logarithm of dimensionless loading rates at the moment of anchor breaking away from underlying soils.



IEGRC 2024
SPLENDID CAPTURES OF THE DAY
21 October 2024

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 03 – Morning session- Environmental Hydrology and Water Resources

Session chair: Dr Wim Brown

Presentation title	Presenter
Worse Droughts Amidst Increasing Precipitation and and Impact on Water Resources	Seongyeol Park
Improved decision making in fluoride removal	Akshay Kashyap
Formation, Persistence, and Breakdown of Thermal Stratification in River Waterholes	Asma Rabiei
Decision Making under Deep Uncertainty for Environmental Water Management	Farkhondeh Sadat Hashemi Madani
Evapotranspiration Estimated Using Solar-Induced Fluorescence (SIF) from Airborne Hyperspectral Images over Agricultural Fields	Jia Xu
Towards Robust Monitoring of Total Suspended Solids (TSS) in the Ungauged Urban Reaches of Downstream Ganges River, India, Using Sentinel-2 Imagery and Machine Learning Approaches	Kunwar Abhishek Singh
Discrepancy between Simulated L-band Backscatter and UAVSAR Observations in a Wheat Field	Lilangi Wijesinghe
Distinct contribution of the blue region and solar-induced fluorescence to needle nitrogen and phosphorus assessment	Peiye Li
The Role of Soil Moisture, Evapotranspiration, and Baseflow in Annual Maximum Flood Events	Posa Poornima Chandra Lekha
Transferability of L-band SAR soil moisture retrieval parameters across surface conditions and view angles	Shilpa Koyyan
Community priorities for climate change adaptation	Madeline Grupper

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 03 – Afternoon session- Environmental Hydrology and Water Resources

Session chair: Dr Yuhang Zhang

Presentation title	Presenter
When is a knowledge gap filled in environmental monitoring?	Xiaoyan Dai
Leveraging On-Site River Data and Heteroskedasticity in Bayesian Rating Curves	Sai Vikas Kona
Changes to rainfall intermittency at the catchment scale in Australia	Steven Thomas
Atmospheric Rivers leading to extreme flooding	Sucheta Pradhan
Network topology drives population temporal variability in experimental habitat networks	Yiwen Xu
Challenges of using robustness metrics for water resources system management under uncertainty	Yuan Cao
Decadal Cycles in Global Rainfall – Initial Results	Tobias Selkirk
Improve representation of multi-annual dynamics in rainfall-runoff models	Ziqi Zhang
Estimating Nutrient Inputs to Agricultural Land Use to Predict Surface Water Quality	Olaleye John Babatunde
Flood Monitoring: A Hydrologically Guided Methodology for Infilling Missing Pixels in Satellite Images	Xinqi Guo
Evaluating evapotranspiration equations in conceptual hydrological models: insights from flux tower data	Gabrielle Burns

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Climate Change Paradox: Worse Droughts Amidst Increasing Average Precipitation across Korea

Name: Seongyeol Park
Email: seongyeol.park@student.unimelb.edu.au
Supervisors: Prof. Andrew Western, Dr. Murray Peel
Disciple: Environmental Hydrology and Water Resources

INTRODUCTION

- This study assesses century-long changes in drought trends and the potential impacts of climate change on water resources in South Korea. We investigate these trends by analysing precipitation and temperature data from six weather stations with long records and examine their relationship with streamflow from the catchments of South Korea's ten largest dams. Given the global rise in temperature, which increases the atmosphere's ability to retain moisture and alters water availability, we aim to elucidate how drought patterns have evolved and their potential implications for water resources.

METHODOLOGY

- This study proceed through three distinct phases to address each research questions.

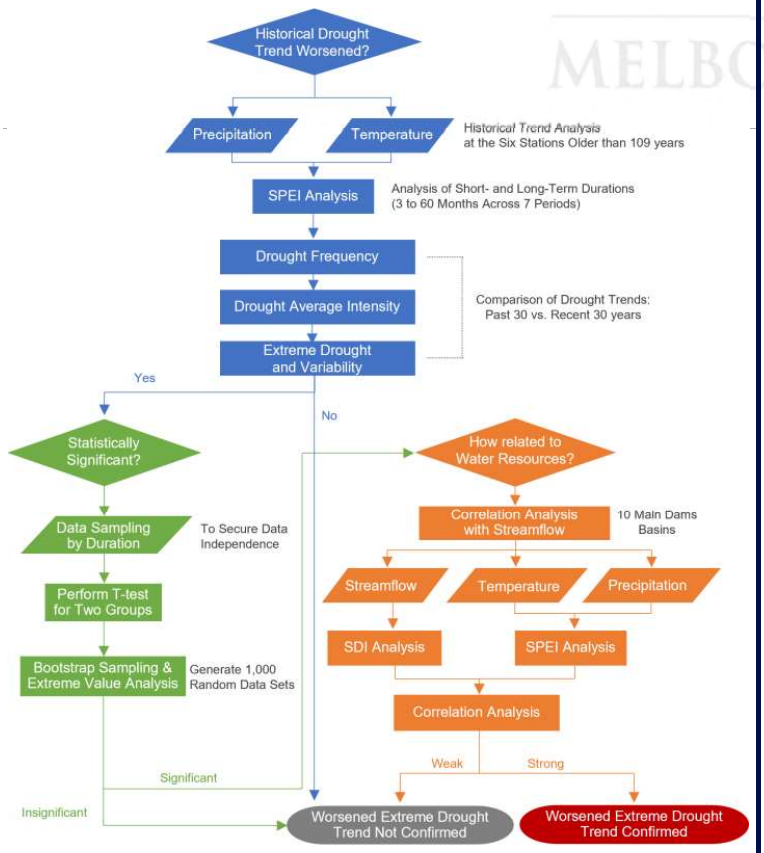

Figure 1. Flow chart in this study

RESULTS & DISCUSSION

- Our findings reveal an exacerbation of droughts, despite an overall increase in precipitation levels. This paradoxical trend, driven by changes in variability, indicates a critical reduction in the reliability of water supply, underscoring the urgent need for adaptive strategies in response to evolving climate dynamics.

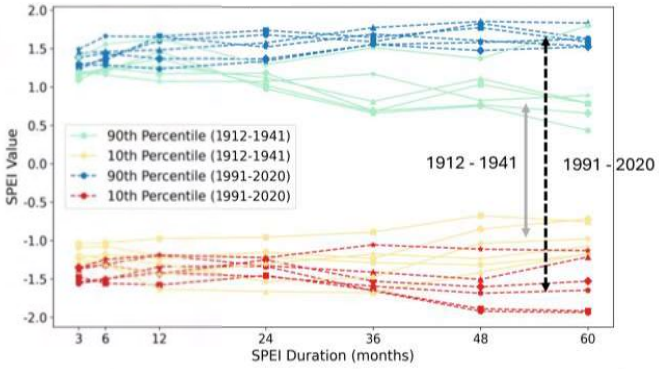

Figure 2. Comparison of 10th and 90th percentile SPEI values at six long-term South Korean stations across seven durations.

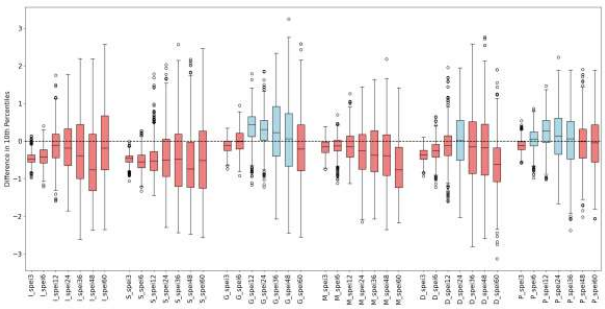

Figure 3. Results of bootstrap sampling for comparing trends in SPEI extreme droughts between the past 30 years and the recent 30 years.

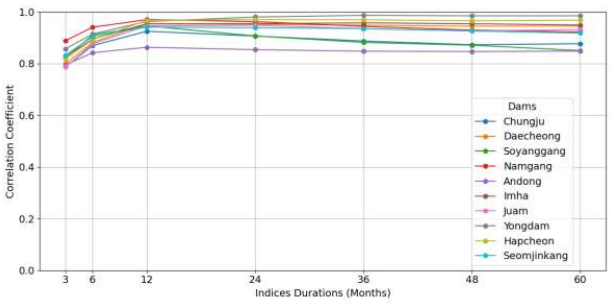

Figure 4. Correlation Coefficients between SDI and SPEI across seven durations within the main ten dam catchment areas

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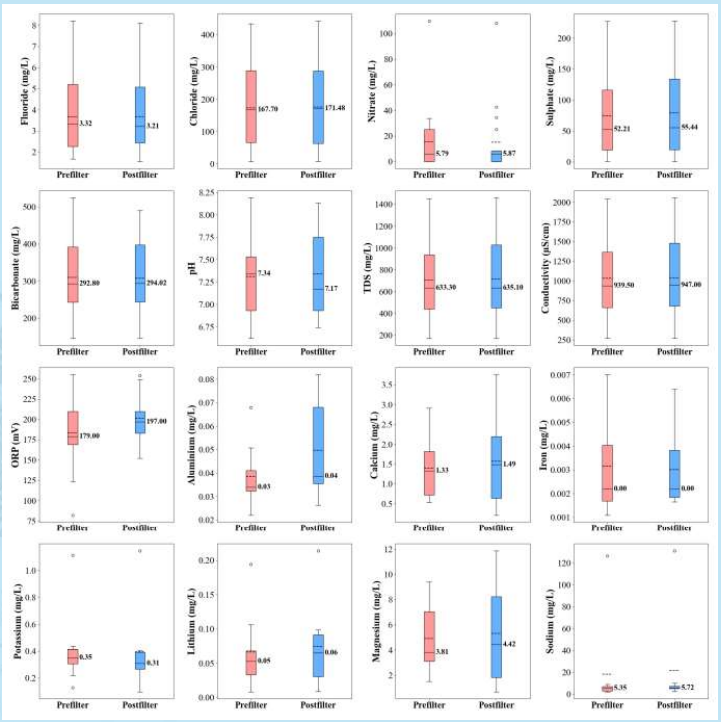
Improved decision making for fluoride removal from groundwater in peri-urban Indian communities lacking centralized water supply

- Akshay Kashyap[a,b], Meenakshi Arora[a,*]

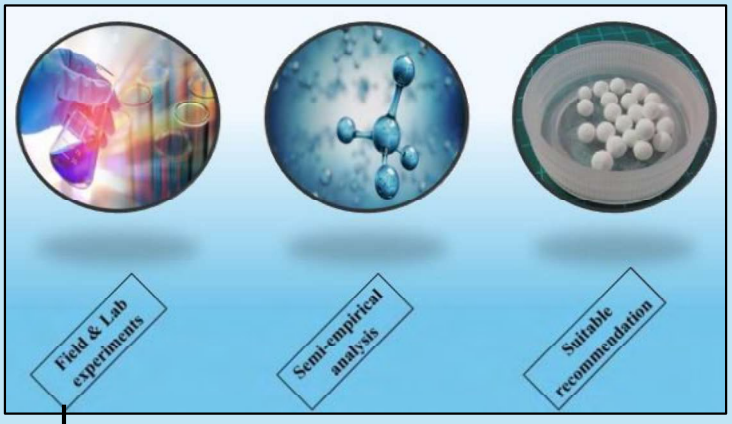
[a]*Department of Infrastructure Engineering, The University of Melbourne, Australia*
[b]*Department of Earth and Environmental Sciences, The University of Manchester, UK*

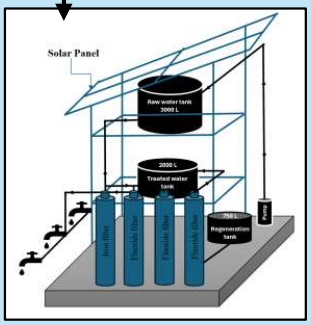
INTRODUCTION

RESULTS & DISCUSSION

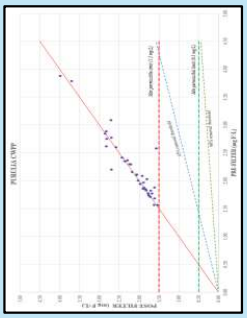


METHODOLOGY





F^-, Br^-, Cl^-, HCO_3^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}, Al, Ca, Fe, K, Li, Mg, Na



CONCLUSION

- The current treatment plants are largely ineffective in reducing fluoride to safe levels, posing a continued health risk to the local communities.
- 29.5% of the post-filter water samples from Bankura were found to contain fluoride in the range of 1.5 – 2.5 mg/L and 70.5% of them exceeds 2.5 mg/L.
- 24.4% of the post-filter water samples from Purulia were found to contain fluoride in the range of 1.5 – 2.5 mg/L and 75.6% of them exceeds 2.5 mg/L.

References

Meenakshi, & Maheshwari, R. C. (2006). Fluoride in drinking water and its removal. *Journal of Hazardous Materials*, *137*(1), 456–463. https://doi.org/10.1016/j.jhazmat.2006.02.024

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Formation, Persistence, and Breakdown of Thermal Stratification in River Waterholes

Name: Asma Rabiei
Email: arabiei@student.unimelb.edu.au
Supervisors: Prof. Andrew Western, Prof. Josef Klewicki & A/Prof. Jimmy Philip
Discipline: Environmental Hydrology & Water Resources

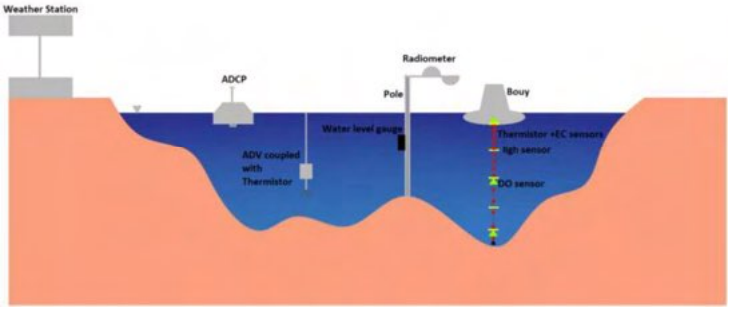
INTRODUCTION

Thermal stratification in river waterholes causes the formation of distinct layers, preventing oxygen from mixing into deeper layers and leading to hypoxic conditions that can harm aquatic life and result in fish kills. The persistence of thermal stratification, especially during warmer periods, exacerbates oxygen depletion and threatens the overall health of these ecosystems. Effective management of stratification is crucial for maintaining water quality and protecting aquatic habitats.

Catastrophic fish death events in the Lower Darling River, Australia (2018-2019).

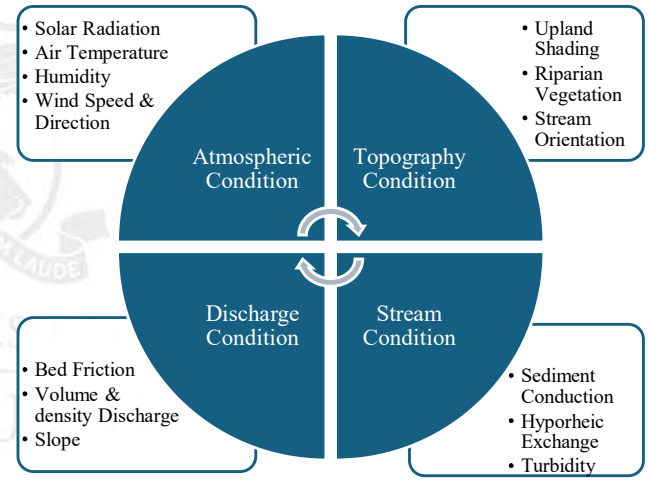
METHODOLOGY

This study integrates continuous monitoring and field campaigns from late spring to early fall. Sensor strings on a buoy measure temperature, salinity, dissolved oxygen, and light penetration, while a weather station continuously tracks atmospheric conditions. Radiometers and pressure transducers monitor radiation and water levels. Acoustic Doppler Velocimeters (ADV) equipped with a fast-response thermistor analyse heat flux in natural settings, and Acoustic Doppler Current Profilers (ADCP) measure velocity fields and bathymetry, providing a comprehensive assessment of stratification and mixing efficiency.

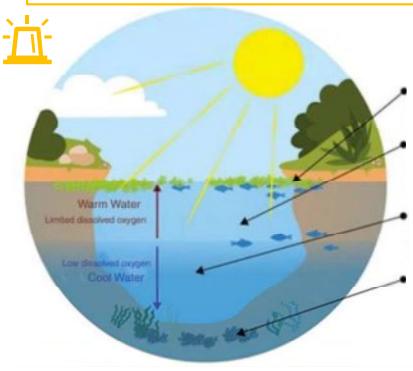


Expected outcomes

1) Identifying the primary drivers of the formation and disturbance of distinct thermal layers, along with their effectiveness and interactions in aquatic refugia.
2) Pioneering a novel technique to study vertical heat transport in stratified systems to calculate the dissipation rate.
3) Developing predictive models for stratification in river waterholes to forecast mixing events using readily available data.



Alert: Persistent thermal stratification detected.



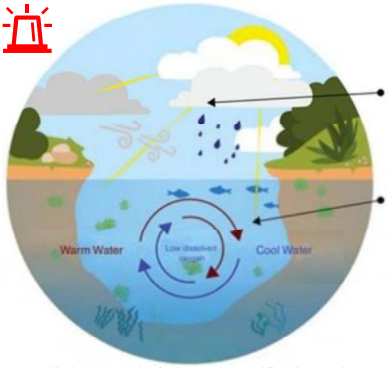
Algal bloom thrive in warm, still waters, especially in low-flow conditions.

Warm and nutrient-rich layer, gaining oxygen during the day but losing it overnight

Cooler, darker, and low in oxygen (hypoxic) layer

Decomposing materials deplete oxygen further in deeper waters.

Warning: Destratification imminent.



Sudden weather changes or slight increases in water flow can mix the warmer surface water with the cooler deep water, disrupting stratification.

This mixing can disrupt algal blooms and accelerate decomposition, further reducing oxygen levels.
The decrease in oxygen can affect the entire water body, potentially leading to fish kills, even in the surface layers.

Predictive Model of Thermal Stratification and Destratification (Adapted from Boys et al., 2022)

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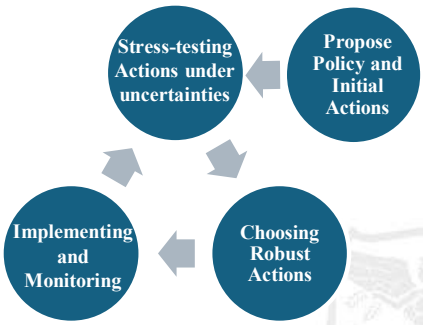
The potential for Decision Making Under Deep Uncertainty (DMDU) tools in Environmental Water Management

Name: Farkhondeh Sadat Hashemi Madani
Email: fhashemimada@student.unimelb.edu.au
Supervisors: Prof. A. Horne, Dr. A. John
Disciple: Environmental Hydrology and Water Resources

INTRODUCTION

The management of environmental water is a complex and critical challenge in the face of future deep uncertainties.

In such conditions, decision-making needs to shift from a 'predict-then-act' paradigm to a 'monitor and adapt' paradigm, which involves monitoring changes over time and adjusting strategies as new knowledge is obtained.



'Monitor and Adapt' Paradigm

Decision Making under Deep Uncertainties (DMDU) approaches have been developed to navigate this shift, with a key focus on implementing measures that remain robust in the face of uncertain future conditions. However, there is a broad variety of DMDU approaches suited to different decision contexts. This study aims to align the characteristics of various DMDU methods with the attributes of different environmental water management (EWM) options, providing a systematic framework for method selection.

EWM OPTIONS

Increasing the Share of Environmental Water
- Change environmental water volume through cap/ reserve
- Change environmental water volume through entitlements

Applying License Conditions and Restrictions
- Target specific flow components and change license condition
- Prioritize water uses (changes to a water allocation plan)

Optimization of Storage Operation Rules
- Modify storage operation rules
- Install new release structures for better flow management

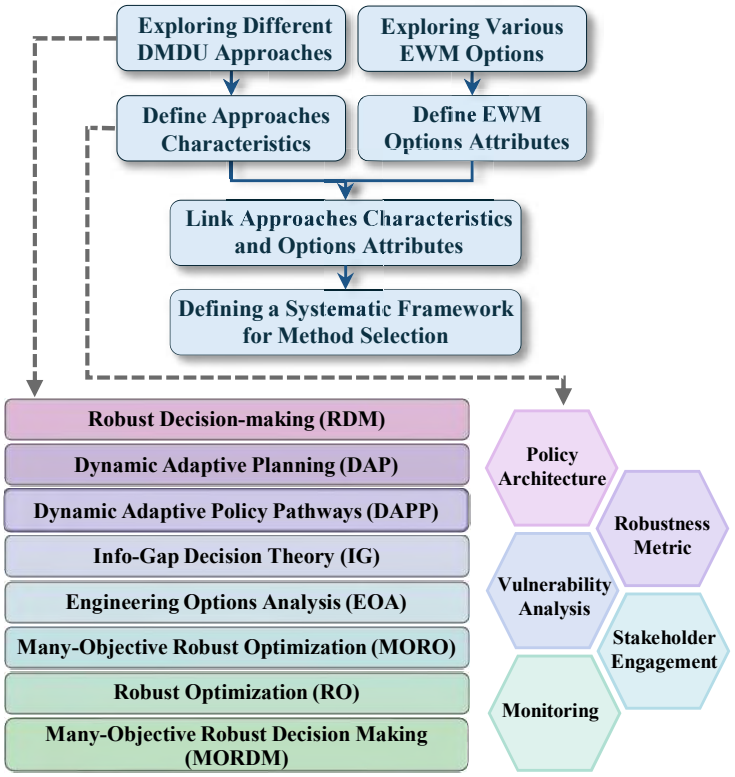
Enhancing Environmental Conservation and Resilience
- Set spatial priorities for environmental water across landscapes
- Conduct riparian corridor recovery/ wetland recovery
- Restore/ Adapt/ Transform ecosystems under climate change

Implementing Infrastructure and Engineering Solutions
- Use regulators for artificial floods
- Install and operate wetland pumps
- Construct stormwater control structures
- Dam Removal
- Construct and modify flow-control infrastructures

EWM Options Attributes

Strategic Level | Potential for Lock-in | Potential for Maladaptation | Potential for Generate Conflict | Potential for Disastrous Consequences | Level of Stakeholder Engagement | Level of required Monitoring

METHODOLOGY



EXPECTED OUTCOMES

DMDU approaches could offer potential tools to support the complexity and dynamism inherent in environmental water management under future uncertainties. However, the wide variety of DMDU methods available underscores the need for systematic guidance to help decision-makers select and apply the most appropriate techniques effectively.

In this paper, we aim to assess how various DMDU approaches can support decision-making for environmental water flows. We begin by identifying the range of decisions available to environmental water managers and then align these with the characteristics of different DMDU methods. By providing a structured framework, we seek to guide decision-makers in selecting the most suitable approach tailored to their specific environmental water management challenges.

By implementing this framework, environmental water managers will be better equipped to manage environmental water more effectively. Ultimately, this promotes sustainable environmental water management and enhances ecological resilience, even in the face of deep uncertainties.

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Evapotranspiration Estimated Using Solar-Induced Fluorescence from Airborne Hyperspectral Images over Agricultural Fields

Name: Jia Xu, Email: jiax5@student.unimelb.edu.au
Supervisors: Prof. Dongryeol Ryu, Prof. Andrew Western, Prof. Bingfang Wu
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

- Mapping spatially distributed evapotranspiration (ET) is useful for tracking regional crop water use.
- Conventional vegetation monitoring uses multi-spectral vegetation indices (VI) to evaluate chlorophyll content, biomass, and canopy structure, yet these indices serve only as indirect indicators of actual vegetation activity.
- The solar-induced fluorescence (SIF) can be used as an effective measure of photosynthesis rate. Disruptions in this process and resulting changes in SIF indicate stress in plants.

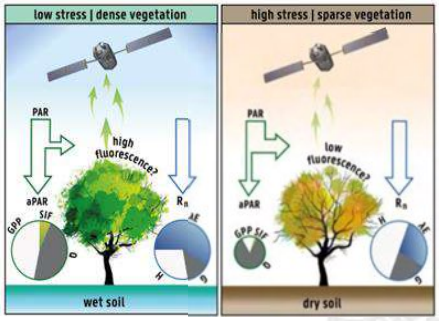

Figure 1: Conceptual diagram of how SIF varies under stress conditions from *R. Pagán et al. (2019).*

- The capacity of SIF to track vegetation stress levels and deliver early alerts of physiological stress may open new possibilities to enhance its application in ET modelling, serving as inspiration for this study.

METHODOLOGY

- Airborne land surface temperature (LST) maps are used in this study as a benchmark to evaluate the effectiveness of SIF in monitoring vegetation water stress and ET modelling at field scale.

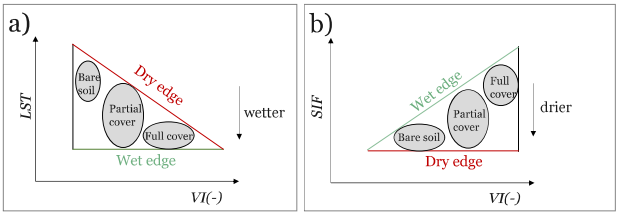

Figure 2: Theoretical triangle in a) LST-VI conceptual model adapted from Sandholt et al. (2002) and b) proposed SIF-VI model.

$$ET = \varphi \times \frac{\Delta}{\Delta + \gamma} \times (R_n - G)$$

- φ: the original Priestley-Taylor coefficient determined by the wet and dry edges in the triangular space.
- Δ: the slope of saturated vapor pressure against air temperature (kPa/°C).
- γ: the psychrometric constant.
- R_n: net radiation (W/m^2).
- G: ground heat flux (W/m^2).

RESULTS & DISCUSSION

- SIF-VI triangular space realization based on field data.

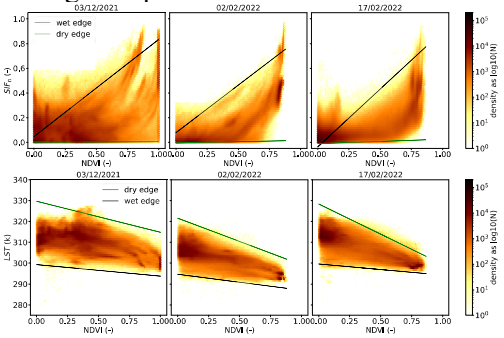

Figure 3: Pixel distributions within the SIF-VI (top row) and LST-VI (bottom row) triangular space coloured by density across three airborne campaign dates. *N* represents the number of pixels.

- Field-scale ET mapping.

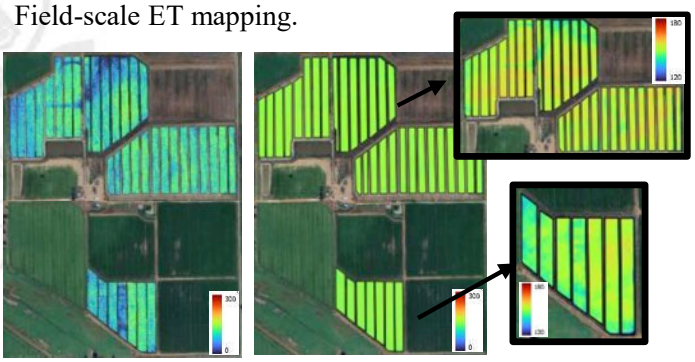

Figure 4: An example of ET maps based on SIF-VI (left) and LST-VI (right) model on 17/02/2022. The inset figures are rescaled versions of the main figures with the colorbar adjusted to enhance the spatial differences between bays. Unit of ET: W/m^2.

- SIF-VI derived ET evaluation

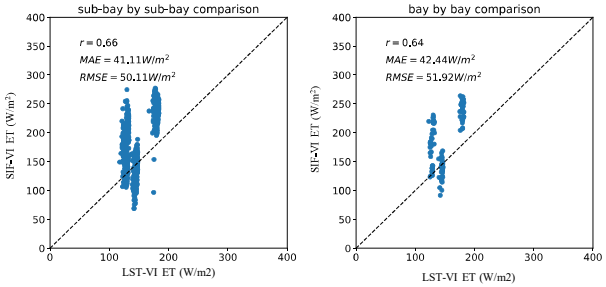

Figure 5: Comparison between ET derived from SIF-VI and LST-VI at sub-bay (left) and bay level (right).

- Conclusion
  - ❑ A new linkage between ET and SIF was established, which does not require complex parameterization for the interaction between photosynthesis and transpiration.
  - ❑ SIF can be used to constrain ET and crop canopy moisture levels in place of LST.
  - ❑ Spatial heterogeneity of SIF signal is larger than that of LST, whose implications require further investigation.

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Towards Robust Monitoring of Total Suspended Solids (TSS) in the Ungauged Urban Reaches of Downstream Ganges River, India, using Sentinel-2 Imagery and Machine Learning Approaches

Name: Kunwar Abhishek Singh
Email: *kunwarabhish@student.unimelb.edu.au*
Advisory Committee Chair: Prof. Guillermo Narsilio
Supervisors: Prof. Dongryeol Ryu, Prof. Meenakshi Arora, A/Prof. Manoj Tiwari, A/Prof. Bhabagrahi Sahoo
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

- Water quality monitoring for rivers is important for public health and proper management of water resources.
- The Hooghly River in West Bengal, downstream of the Ganges, flows through an **ungauged** reach in Kolkata, where water quality is affected by urban wastewater, stormwater and suspended matters from upstream sources.
- Traditional monitoring of suspended solids in the river involves the time-consuming and costly process of laboratory analysis. Alternatively, satellite-based remote sensing offers a unique way to assess water quality in challenging riverine systems stretching over large regions.
- During rainy seasons, when total suspended solids (TSS) concentration is usually high in rivers, the cloud effect on satellite imageries makes it difficult to extract the TSS with reasonable accuracy.
- This work presents an approach that can robustly monitor total suspended solids (TSS) over a targeted section of the river in both cloudy and non-cloudy conditions, using satellite imagery as input to machine learning algorithms.

METHODOLOGY

- To maximize the availability of high-quality radiometric information from Sentinel-2 imagery, a statistical resampling method based on the Gaussian Mixture Model (GMM), is utilized to screen cloud and cloud-shade-contaminated image pixels (Fig. 1).

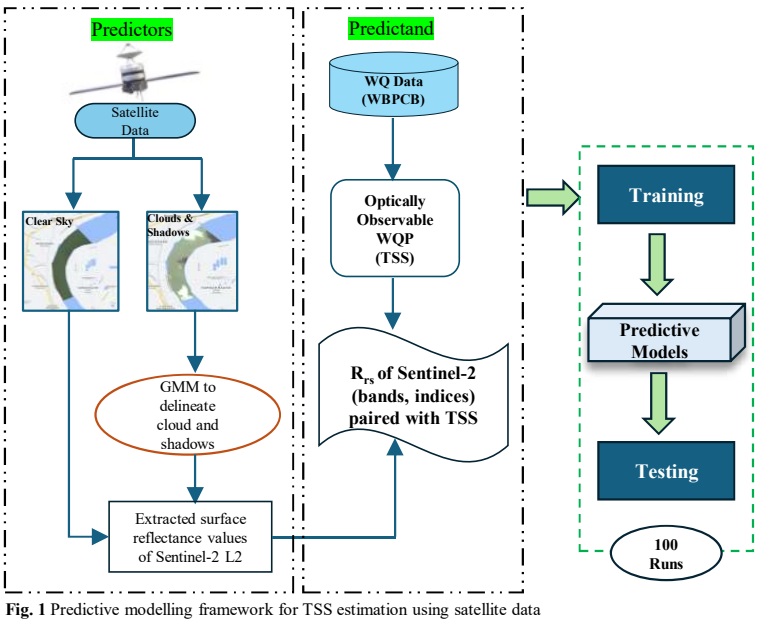


Fig. 1 Predictive modelling framework for TSS estimation using satellite data

RESULTS & DISCUSSION

- In optical remote sensing (Fig. 2), clouds act as a bright grey target, and shadows act as a bright dark target. Thus, delineation plays a crucial role in ensuring that only surface reflectance values from water pixels are used.

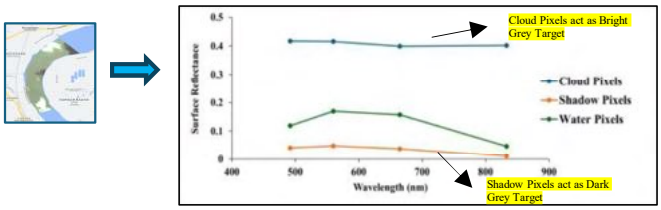
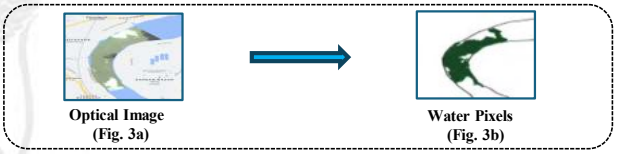


Fig. 2

- Filtered water pixels after delineating clouds and shadows using the Gaussian Mixture Model (GMM) (Fig. 3a and 3b).



- The ML models showed robust prediction ability across 100 different train-test splits. Results are expressed as average values of performance metrices in TSS prediction: R^2 = 0.77 (PLSR); R^2 = 0.69 (RFR); R^2 = 0.57 (XGBoost); R^2 = 0.65 (SVR).

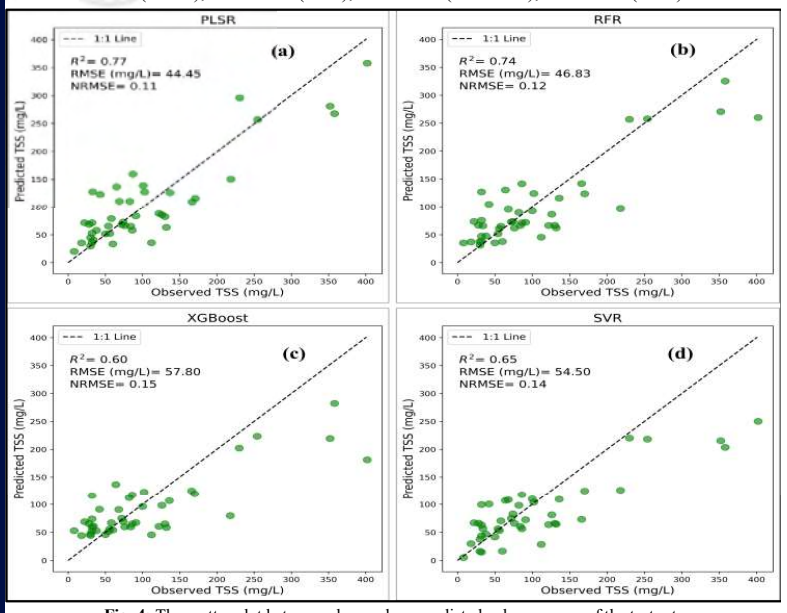


Fig. 4: The scatter plot between observed vs. predicted values on one of the test set.

- The mean absolute SHAP value quantifies the influence of predictors. It reveals a clear pattern, highlighting the key factors affecting the model's predictions (Fig. 5). Red edge 3 (B7) & red edge 1 (B5) of S2 have the most influence, as they have the highest mean absolute SHAP scores.

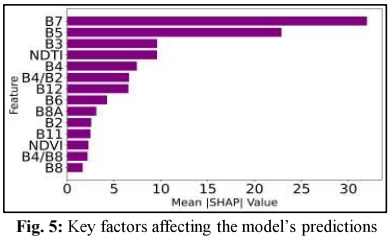


Fig. 5: Key factors affecting the model's predictions

- This study reinforces the idea of careful satellite image preparation and use of machine learning methods to predict water quality parameters, such as TSS in ungauged river stretches and diagnostic analysis of influential predictors for the prediction.

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Graduate Research Conference 2024

Discrepancy Between Simulated L-band Backscatter and UAVSAR Observations in a Wheat Field

Name: Lilangi Wijesinghe
Email: lvwijesinghe@student.unimelb.edu.au
Supervisor(s): Prof. Dongryeol Ryu, Prof. Andrew Western and A/Prof. Jagannath Aryal
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

Wheat is a major agricultural crop that accounts for 28% of the global grain production. Thus, improved management of agricultural resources and wheat yield enabled by accurate monitoring of soil moisture is important for food security and sustainable agriculture. Active microwave remote sensing, particularly Synthetic Aperture Radar (SAR) is ideal for agricultural field-scale soil moisture monitoring due to its ability to provide high spatial resolution (3-10m) soil moisture estimates. Consequently, realistic representation of microwave backscattering from wheat cropping fields is important to develop accurate soil moisture retrieval algorithms from SAR imagery. Although many studies have reported discrepancies between the simulated and observed backscatter, little has been done to identify their sources and contributions quantitatively. The objective of this study is to explore the factors causing discrepancies between backscattering model simulations and radar observations in terms of both model and observation uncertainty. This analysis is based on a first-order radiative transfer model developed to simulate backscatter from a wheat field; Wheat Canopy Scattering Model (WCSM) and ground measurements and UAVSAR image acquisitions of SMAPVEX12 campaign.

METHODOLOGY

- Sobol' method is used to identify and decompose WCSM uncertainty associated with input uncertainties into effects associated with inputs for two different crop growth stages; crop height 20cm (without wheat ears) and 80cm (with wheat ears).
- Standard deviations of 20 random points were estimated using Monte Carlo simulations of each location and the average was considered as the simulated uncertainty for each polarization.
- SMAPVEX12 study area is covered by four near-simultaneous UAVSAR flight lines, namely; 31603, 31604, 31605 and 31606 each of which has a systematic impact on observed backscatter due to incidence angle. Backscatter from the same locations from different line IDs were compared and the systematic influence from incidence angle was removed fitting a simple linear regression model to calculate the observed uncertainty.
- WCSM-simulated and UAVSAR-observed backscatter for sampling locations #2, #11and #14 of wheat fields were compared for all four line IDs.
- Errors for each polarization were discussed in terms of simulated and observed uncertainty.

RESULTS & DISCUSSION

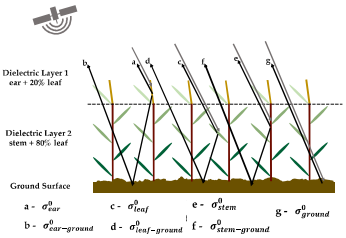


Figure 1: Scattering mechanisms considered in the Wheat Canopy Scattering Model (WCSM)

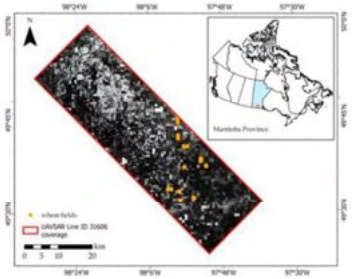


Figure 2: SMAPVEX12 study area and UAVSAR image (HH-pol) for line ID 31606

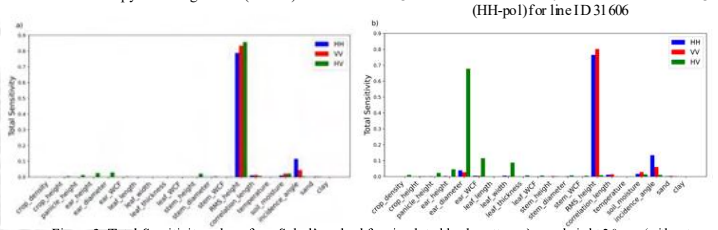


Figure 3: Total Sensitivity values from Sobol' method for simulated backscatter; a) crop height 20 cm (without wheat ears) and b) crop height 80 cm (with wheat ears)

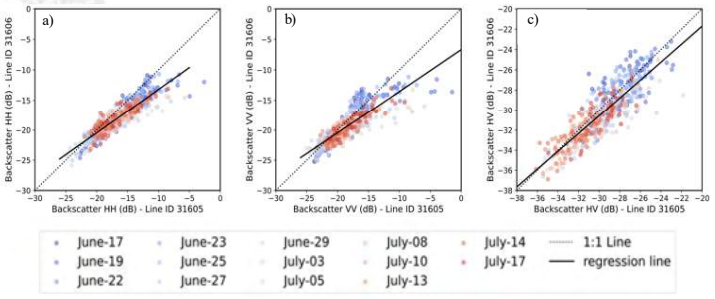


Figure 4: Correlation plots between UAVSAR-observed backscatter for different line ID combinations of 31606 vs 31605 for a) HH, b) VV and c) HV polarizations

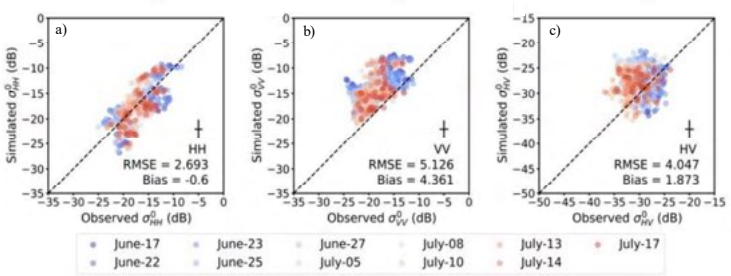


Figure 5: Comparison between WCSM-simulated and UAVSAR-observed backscatter for line ID 31606 for a) HH, b) VV and c) HV backscatter

- The results show that despite the presence of wheat ears, uncertainty in RMS height of 0.2cm significantly influences simulated co-pol uncertainty. After ear emergence, uncertainty in ears dominated simulated cross-pol uncertainty. In contrast, uncertainty in RMS height before ear emergence dominated the simulated cross-pol uncertainty.
- Uncertainty in surface roughness is likely the reason for high errors observed in VV-pol backscatter.
- Neglecting leaf curvature can be a potential reason for the positive bias observed in HV backscatter.

Infrastructure Engineering
Graduate Research Conference 2024

Contribution of the blue spectral region for explaining needle nitrogen and phosphorus variability in coniferous stands

Name: Peiye Li Email: peiyel@student.unimelb.edu.au
Supervisors: Prof Pablo J Zarco-Tejada,
Dr Tomas Poblete Cisterna, A/Prof Jagannath Aryal
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

Timely and accurate monitoring of nitrogen (N) and phosphorus (P) status in Radiata Pine plantations can facilitate sustainable forestry and maximize softwood production. Hyperspectral remote sensing provides a non-destructive approach for nutrient monitoring and mapping at an operational scale. Recent studies have shown the promise of using plant functional traits derived from Radiative Transfer Models (RTMs), solar-induced fluorescence (SIF), and narrow-band hyperspectral indices (NBHIs) to explain the leaf N variability, while such methods have not been tested in coniferous stands where the canopy complexity poses challenges for the analysis of optical signals. Moreover, there is a general lack of studies on leaf P assessment despite its important role in plant growth.

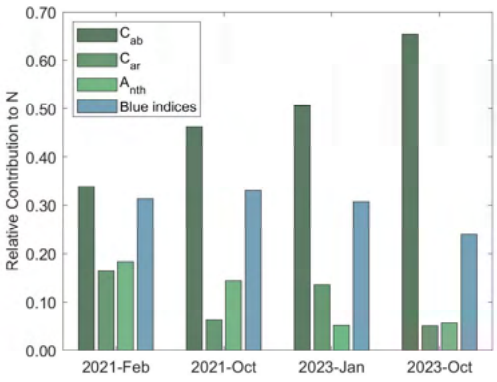
In this study, we investigated the contribution of parameters derived from airborne hyperspectral imagery, including plant functional traits retrieved from RTM, SIF and NBHIs, regarding their ability to explain needle N and P variability in coniferous canopies, with a specific focus on the role of the blue spectral region.

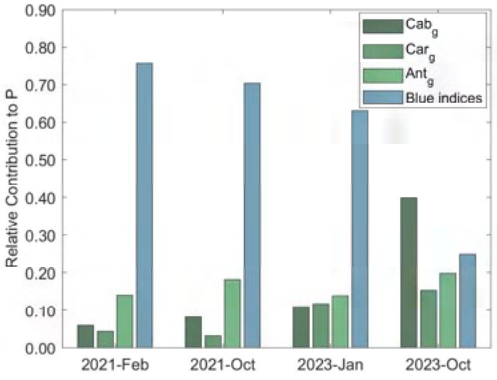
METHODOLOGY

Gaussian Process Regressor (GPR) was used to build needle N and P predictive models. Inputs for GPR included a selection of plant functional traits, SIF, NBHIs derived from the narrow-band hyperspectral imagery. Plant functional traits were retrieved by inverting the crown-level reflectance spectrum through the PRO4SAIL2 model using a Look-Up-Table (LUT)-based approach in the wavelet domain. SIF was quantified through the 3FLD method at the O_2A absorption feature around 760nm. A selection of 66 NBHIs were calculated as proxies for plant biochemical and biophysical parameters. Variation Inflation Factor (VIF) analysis was implemented to reduce the multicollinearity among indices. Only those with VIF <5 were kept as candidates for GPR model inputs. GPR model performance was evaluated via the leave-one-out (LOO) validation scheme. The contribution of parameters for needle N and P estimation accuracy was assessed through the out-of-bag (OOB) permutation method in Random Forest (RF).

RESULTS & DISCUSSION

- Regarding the contribution of functional traits, C_{ab} was the most important input for explaining the variability of needle N among all parameters. SIF was important for both needle N and P, while it has a more pronounced role in explaining needle P variability than N.
- Our analyses revealed the role of the blue spectral region for needle P assessment, while such region was not relevant for needle N assessment. Blue-region indices and those with at least one wavelength in the blue region contributed the most for needle P along with RTM-derived pigments (i.e., C_{ab}, C_{ar}, and A_{nth}).
- The response of the blue spectral region to variations in needle P levels could be explained by two hypotheses: the first is related to the changes in blue fluorescence emission due to the reduced fluorescence reabsorption by chlorophyll under stressed conditions ; the second one relies on the stress-induced chlorophyll degradation into phaeophytin.





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The Role of Soil Moisture, Evapotranspiration, and Baseflow in Annual Maximum Flood Events

Poornima Chandra Lekha Posa
pposa@student.unimelb.edu.au
Dr Wenyan Wu (University of Melbourne), Dr Conrad Wasko (University of Sydney), Rajarshi Das Bhowmik (Indian Institute of Science)
Environmental Hydrology and Water Resources

INTRODUCTION

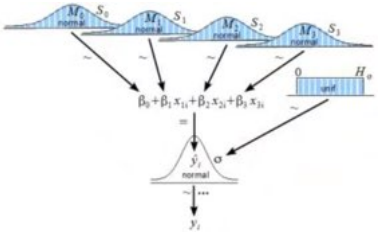
- Extreme flood events present serious threats to human lives and infrastructure.
- Traditional flood estimation methods often rely on annual maximum rainfall (AMR), potentially overlooking land and atmospheric processes.
- Hence, it is crucial to emphasize how different hydro-meteorological factors contribute to Annual Maximum Flood (AMF) events, comparing scenarios where AMF is driven by AMR versus heavy rainfall (HR) events.

OBJECTIVES

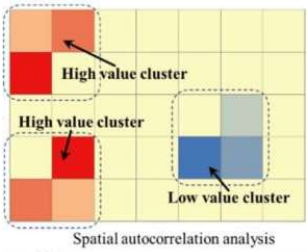
- To examine AMR-driven and HR-driven AMF events.
- To Quantify the relative importance of hydro-meteorological factors like rainfall (P), surface soil moisture (SMsurf), root-zone soil moisture (SMroot), evapotranspiration (E), and baseflow (Bf) in driving Annual Maximum Flood (AMF) events.
- Map the spatial distribution of critical hydro-meteorological variables to identify clusters that significantly contribute to extreme flood events.

METHODOLOGY

- A scenario-based approach is used to investigate the influence of hydrometeorological variables on extreme flood events:
- **Scenario 1**: AMR leads to AMF; **Scenario 2**: AMR results in streamflow (<AMF); **Scenario 3**: Heavy Rainfall (HR) triggers AMF in the same year.
- As streamflow is a time series, while hydrometeorological parameters are spatially distributed, studying their spatial and temporal variability is crucial for extreme flood events.

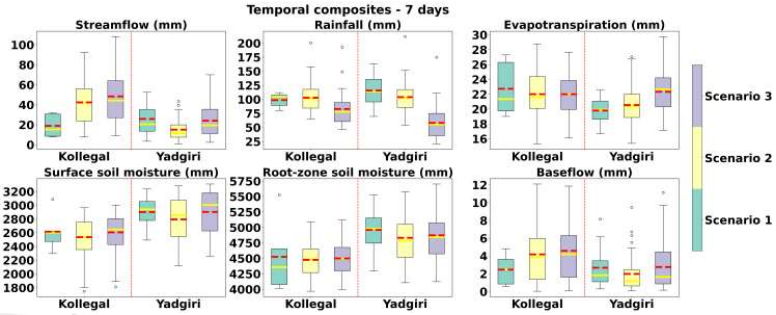


Quantifies the relative importance of hydro-meteorological variables in driving extreme streamflow



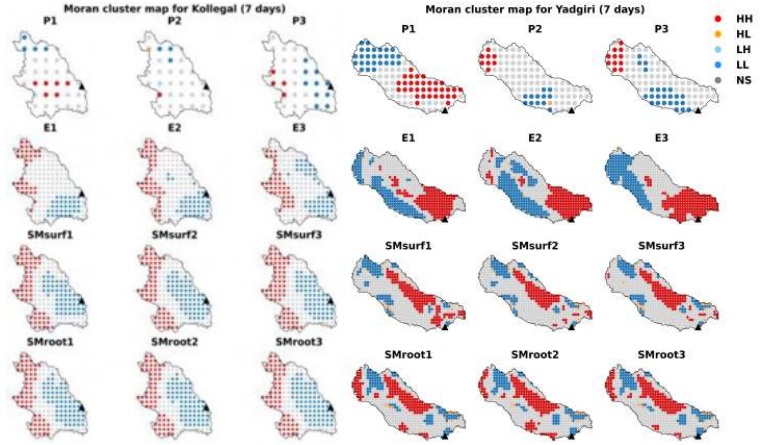
Identifies high and low-value clusters of hydro-meteorological variables.

RESULTS & DISCUSSION



Kollegal Basin – Cauvery River						
7-day analysis	BIC	P	E	SMsurf	SMroot	Bf
Case 1	-10	**0.055***	-0.059	0.0041	**-0.0021***	-0.037
Case 2	80	$4.9e^{-04}$	0.035	$-2.4e^{-05}$	$-1.2e^{-04}$	**0.11***
Case 3	78	0.0028	**0.053***	0.0002	$-2.5e^{-04}$	**0.098***

Yadgiri Basin – Krishna River						
7-day analysis	BIC	P	E	SMsurf	SMroot	Bf
Case 1	27	**0.02***	0.08	-0.0003	0.00016	0.061
Case 2	93	**0.014***	0.04	-0.00068	0.00043	**0.16***
Case 3	93	**0.012***	0.0014	-0.0011	0.00055	**0.17***



CONCLUSIONS

- In Kollegal, HR drives more intense AMF compared to AMR, whereas in Yadgiri, AMR dominates, underscoring the significant influence of hydro-meteorological factors in a catchment on extreme rainfall-flood events.
- Bayesian framework identifies the strong role of rainfall and baseflow in driving intensified AMF.
- Moran's I highlight the shifting spatial structure of high and low-value clusters of hydro-meteorological variables, revealing critical grids contributing to AMF.

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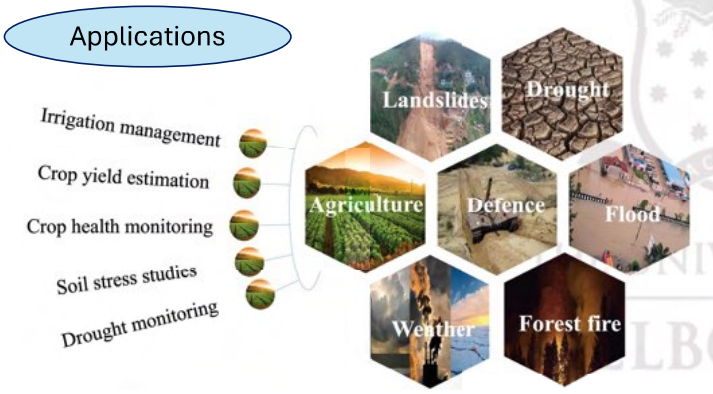
Transferability of L-band SAR soil moisture retrieval parameters across surface conditions and view angles

Name: Shilpa Koyyan
Email: skoyyan@student.unimelb.edu.au
Supervisors: Prof. Dongryeol Ryu, Prof. Andrew W. Western, Prof. D. Nagesh Kumar (IISc)
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

In this study, we explore the efficacy of using SAR-based vegetation parameters for soil moisture (SM) retrieval and examine the transferability of retrieval parameters across various sensing configurations and canopy densities. The potential transferability of retrieval parameters for the Water Cloud Model (WCM) across fields, canopy densities, polarisations and incidence angles is examined by analysing the posterior distribution of calibrated parameters obtained using the Markov Chain Monte Carlo (MCMC) method.

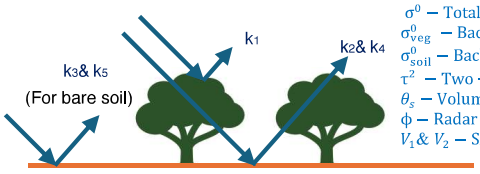


METHODOLOGY

Model Name:	Water Cloud Model (WCM)
Study Area:	Carman test site, Canada
Dataset used:	Ground and UAVSAR airborne data collected during the SMAPVEX12 field campaign.
Crop Type:	Wheat

$$\sigma^{\circ} = \sigma^{0}_{veg} + \tau^{2}\sigma^{0}_{soil}$$

$$\theta_s \approx \frac{\sigma^{\circ} + k_1 V^2 + k_2 V sec\phi + k_3}{k_4 V sec\phi + k_5}$$



σ^0 – Total backscattering coefficient (m^2/m^2)
σ^0_{veg} – Backscatter from vegetation
σ^0_{soil} – Backscatter from soil surface
τ^2 – Two – way attenuation factor
θ_s – Volumetric soil moisture (m^3/m^3)
ϕ – Radar incidance angle (Radian)
V_1 & V_2 – SAR vegetation index

Figure 1. Illustration of five retrieval parameters associated with modified WCM and linear soil backscattering.

RESULTS & DISCUSSION

- The SM retrieval error was minimized (RMSE = 0.073 m^3m^{-3}, R= 0.78) when all polarisations were combined.

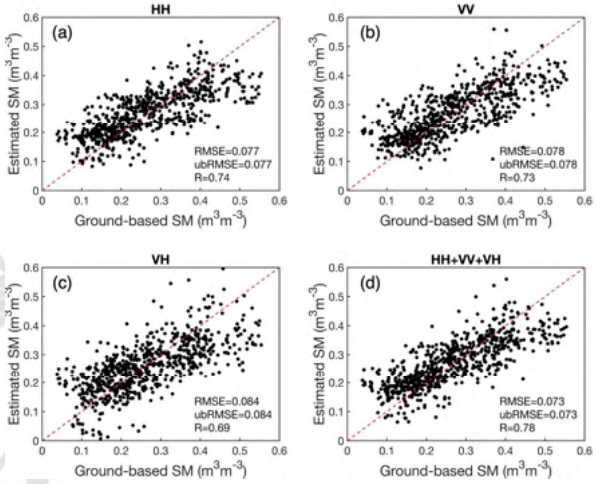


Figure 2. Cross-validation comparison of ground-based and estimated SM in (a) HH-pol, (b) VV-pol, (c) VH-pol, and (d) HH+VV+VH polarisations.

- The WCM parameters show distinctive distributions between different incidence angles and between co-pol and cross-pol imagery, the parameters are transferable between locations and canopy densities.

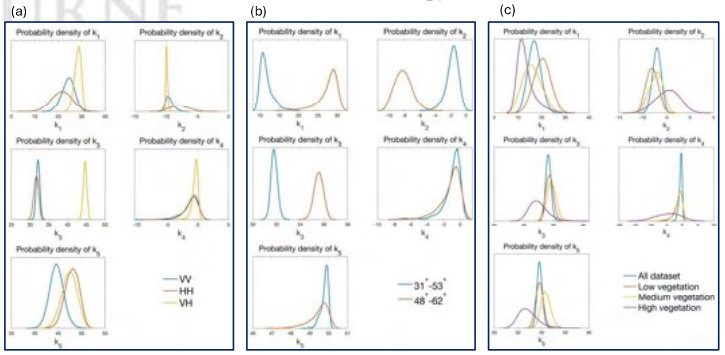


Figure 3. Posterior parameter distributions of WCM parameters for different (a) polarisations, (b) incidence angles, and (c) canopy densities of the wheat crop

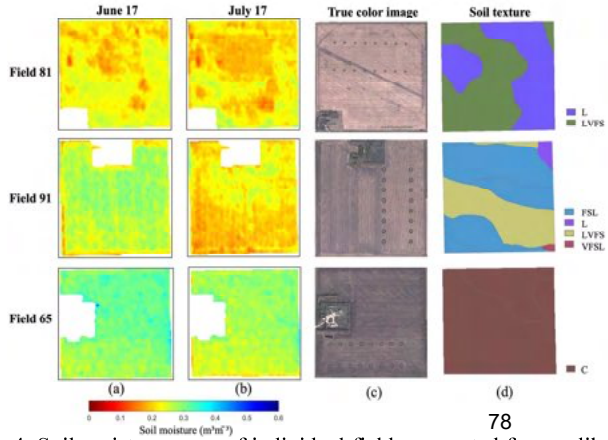


Figure 4. Soil moisture maps of individual fields generated from calibrated WCM parameters.

Infrastructure Engineering
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Community Values and Priorities for Water Scarcity

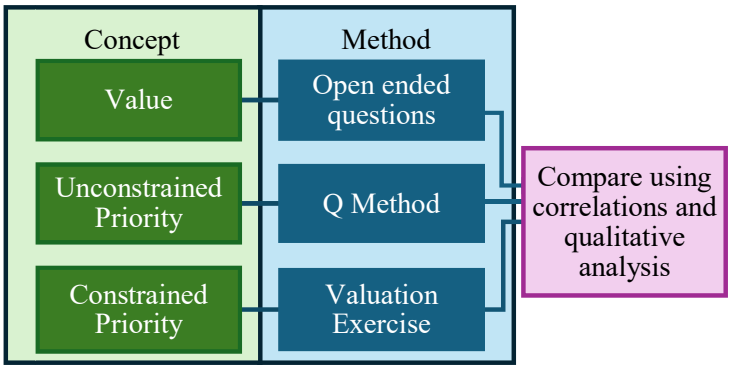
Name: Madeline Grupper
Email: mgrupper@student.unimelb.edu.au
Supervisors: Prof. Angus Webb, Prof. Avril Horne, Prof. Julian Olden
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

Freshwater management must adapt to uncertain water availability under climate change while balancing competing demands from human communities. These efforts are hampered by disconnects between the actions and objectives of managers, scientists, policymakers, and community members. To connect these parties and inform management decisions, researchers have studied the diversity and plurality of community values. However, this research has focused more on assessing value systems and less on explicit choices people would make under resource scarcity. We examine how community members prioritize values under water scarcity and how these priorities relate to patterns in value systems with a case study in the Goulburn-Broken River Catchment. We expected that the method used to ask about community values would change the information received. Our results will inform how to elicit information on values and priorities to inform decisions about declining water resources, thereby fostering a resilient water management approach.

METHODOLOGY

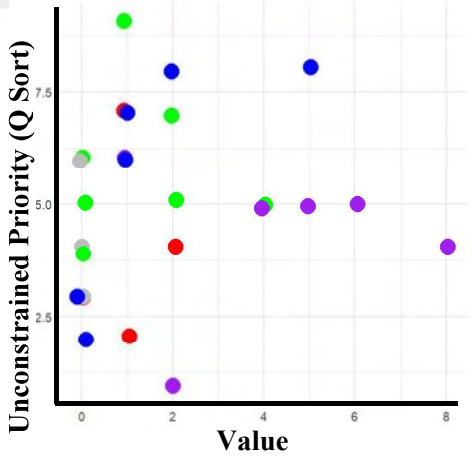
We conducted interviews with community members in the Goulburn Broken Catchment in Victoria Australia. The interviews employed a mixed-method approach to distinguish patterns of underlying value systems and priorities both without constraints and in the context of water scarcity.



RESULTS & DISCUSSION

As expected, the method used to ask about values and priorities influences the type of information received. There was a low correlation between the values people spoke about in the open-ended questions and what they prioritized in the Q sort. The Q-sort and valuation exercise priorities had a higher correlation, but differences remained. Qualitative analysis revealed that participants were changing the way they made decisions in the different exercises, despite maintaining similar values.

Our findings suggest that intentionality matters when eliciting information about values and priorities and greater precision with methods will help target how decisions about water are made



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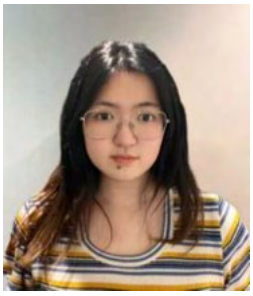
How much data do we need? Filling knowledge gaps through environmental monitoring



Xiaoyan Dai , J. Angus Webb, Avril C. Horne
Water, Environment and Agriculture Program, University of Melbourne

INTRODUCTION

Long-term monitoring is essential for environmental management, particularly for filling knowledge gap and improving predictive capabilities. However, through a pre-occupation with long-term monitoring, we may be putting unnecessary resources into knowledge-gap monitoring. It is critical that once monitoring data provides a sufficiently high level of confidence in the tested hypothesis, resources can be reallocated to other conservation actions or monitoring objectives. But how can this decision be made?

METHODOLOGY

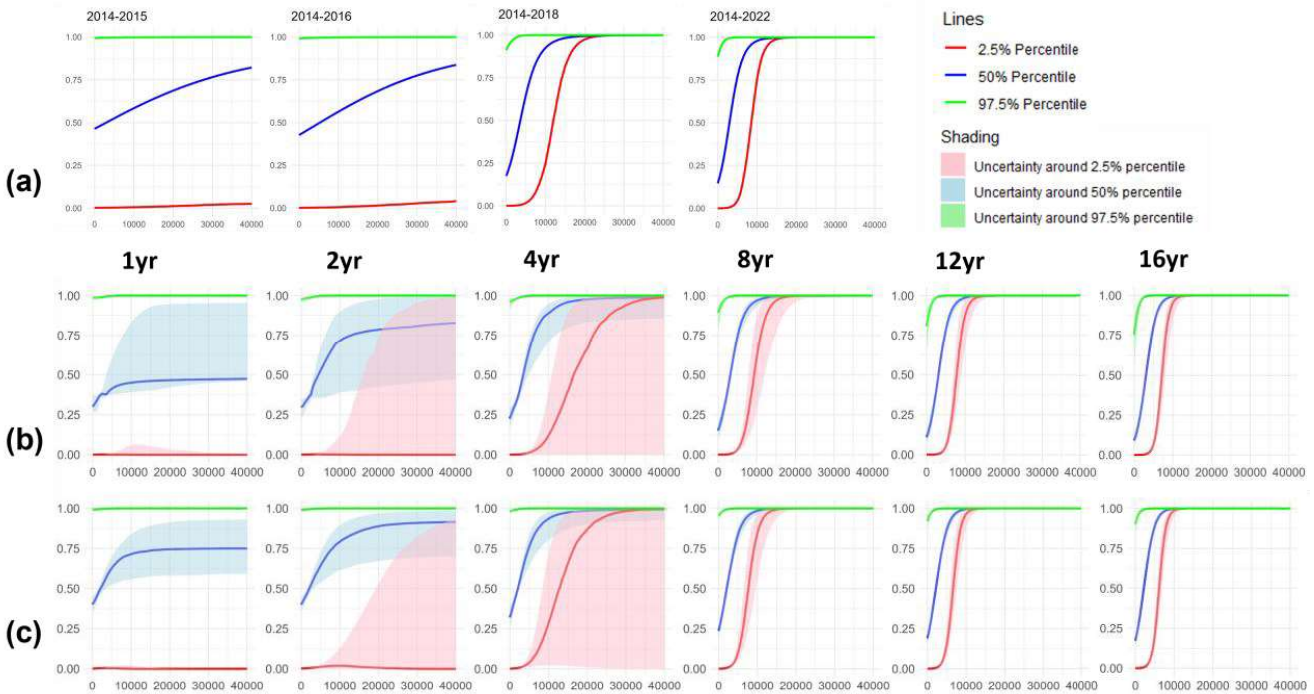
We used a case study of Golden Perch (*Macquaria ambigua*) spawning in response to river discharge to demonstrate a method to determine when continued data collection reduces uncertainty to a point where further monitoring yields little further understanding.

DISCUSSION

Results from the observed monitoring data indicate that the model only requires 4 years of data before additional data provides limited additional understanding. However, resampling from the same dataset suggests 8-12 years might be necessary. For this case study, we conclude that current understanding of the flow-spawning relationships is “good enough”.

This case study demonstrates that monitoring might not need huge time series to make the decision to move monitoring effort. The idea of using resampled or synthetic monitoring data to demonstrate the value of monitoring can be applied to other endpoints or other monitoring programs. This approach supports evidence-based decision-making by informing when it is appropriate to review and potentially reallocate resources to other monitoring priorities, ultimately contributing to more efficient ecological conservation.

We use three techniques to examine the contribution of additional data: (a) a historical 8-year monitoring dataset to evaluate the value of cumulative monitoring, (b) bootstrapping the existing dataset to verify whether the conclusion from (a) is robust across different datasets of different lengths, and (c) simulating synthetic monitoring data to validate the conclusion from (b).



Probability of Spawning in Pyke’s Road for (a) accumulated monitoring data for 1 year (2014-15), 2, 4 and 8 years; (b) bootstrapping historical monitoring years for 1, 2, 4, 8, 12 and 16 years; and (c) synthetic historical monitoring years. Y-axis shows the probability of spawning and X-axis indicates the flow discharge (ML/day). Shading area around percentile solid lines in (b) and (c) are 50% uncertainties for 1000 simulation of resampling.

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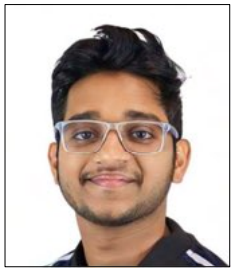
Leveraging On-Site River Data and Heteroskedasticity in Bayesian Rating Curves

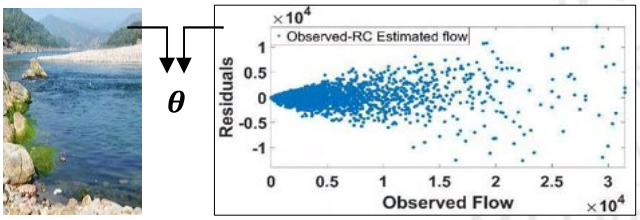


Sai Vikas Kona, Ph.D. student.
Email: kona1280@student.unimelb.edu.au
Supervisors: Prof. Andrew Western, Dr. Murray Peel, and Dr. Rajarshi Das Bhowmik.
Discipline: Environmental hydrology and water resources.

INTRODUCTION

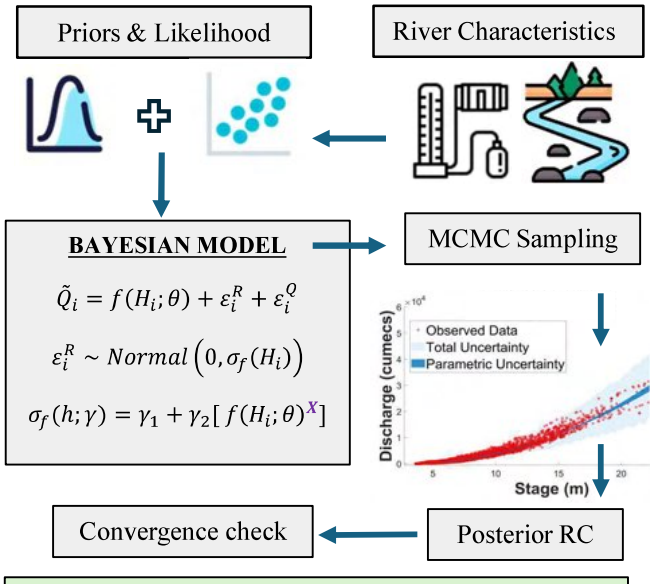
- **Rating Curves:** The relationship between stage (h) and discharge (Q) at a specific river section (control).
  Power Law Fit: $Q = a(h-b)^c$, if $h>b$ for a control.
- The parameters of the rating curve $\theta = \{a, b, c\}$, depends on the geomorphology at the river section.
- Rating models often fail to account for site-specific information, leading to high uncertainties.
- **Research Questions:** How can on-site river information be incorporated within a rating curve model? Is it possible to account for heteroskedasticity in stream data?

(1) (2)



- **Study Area:** Tikarapara, Mahanadi River Basin, India.

METHODOLOGY

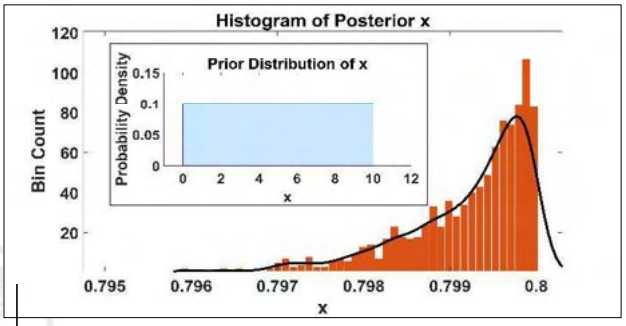


Case 1: X is known as 0; Case 2: X is an unknown

$(\tilde{H}_i, \tilde{Q}_i)$: Gaugings; ε_i^R & ε_i^Q: Remnant & gauging errors; γ_1, γ_2 are unknown constants; f is the Rating function.

RESULTS & DISCUSSION

- The posterior samples exhibit satisfactory convergence.

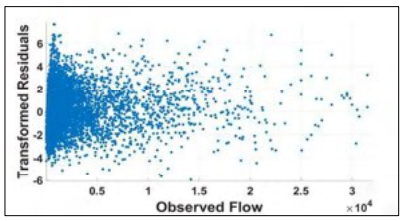


An uninformative prior to a converged posterior

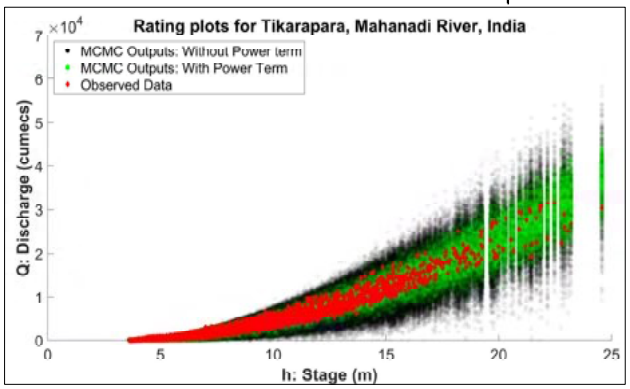
- The residual analysis underscore the importance of addressing heteroskedasticity in RC generation.

$$Transformed\ Residual = Residuals/\sigma_f$$

Reduction in heteroskedasticity using the posterior X.



- Inclusion of power term (X) substantially altered the estimation of the rating uncertainties.



Reduced Overestimation and intrinsic uncertainties

- **Conclusions**: The 'adaptive' Bayesian model facilitates robust rating curve estimation at any river site, countering heteroskedasticity, and enabling enhanced streamflow estimation using RCs.

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Changes in rainfall intermittency at the catchment scale in Australia

Name: Steven Thomas
Email: stevenjt@student.unimelb.edu.au
Supervisors: Dr. C. Wasko, Dr. M. Peel, Dr. U. Bende-Michl, Dr. D. Guo
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

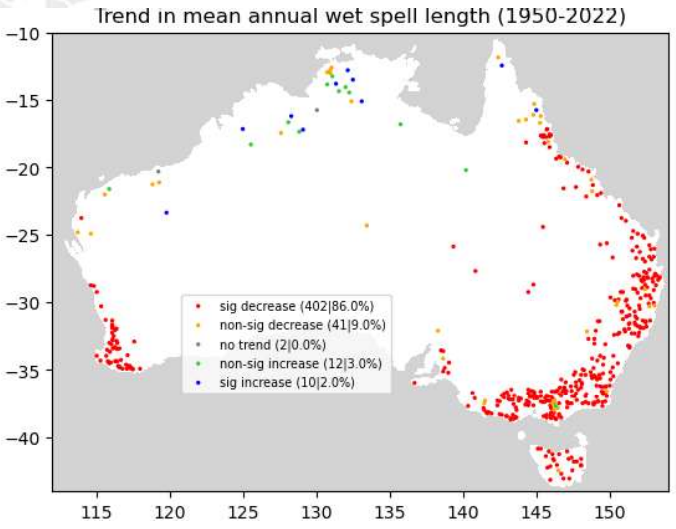
- Australia's climate is characterised by variable rainfall patterns, leading to sudden, intense downpours that can cause flash floods, especially in arid regions. Conversely, prolonged dry spells can result in severe droughts, stressing water resources, agriculture, and ecosystems.
- This variability affects soil moisture levels, vegetation health, and water management strategies and requires effective planning and infrastructure to account for these wet and dry extremes.
- Understanding rainfall intermittency or the day-to-day variability helps in forecasting, risk assessment and implementing sustainable practices to mitigate the impacts of climate-related challenges.
- While some research has explored the impacts of rainfall intermittency in Australia, gaps remain in understanding how intermittency impacts extremes events particularly at the catchment scale.

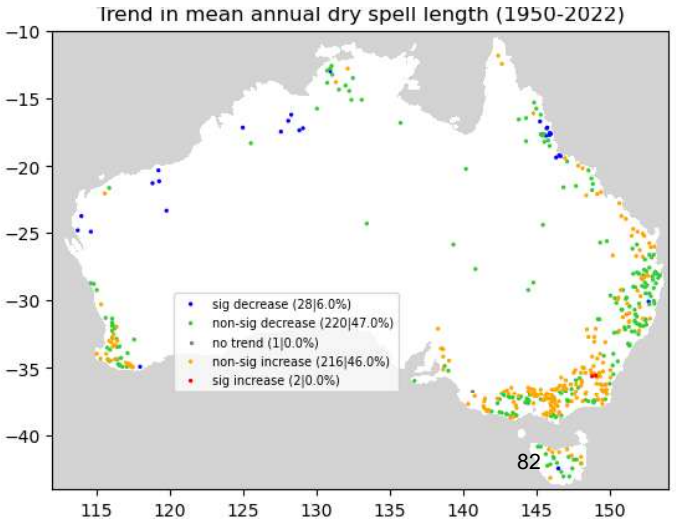
METHODOLOGY

- Daily catchment averages from 1950-2022 produced by the Bureau of Meteorology's AWAP rainfall dataset are used. Catchments are taken from the Bureau's Hydrological Reference Stations (HRS) as they are relatively unimpacted by human activity.
- Rainfall intermittency is represented through wet and dry spells, defined as the number of consecutive wet or dry days, respectively.
- A dry day threshold of 1 mm is used aligning with the ETCCDI, this threshold also minimises the impact of applying an average over larger catchments.
- We investigate changes in spell frequency (events per year), duration (annual mean and max length) and for wet spells we also analyse spell volume and intensity.
- Trends and slopes are investigated using the Mann-Kendell test and Sen slope, respectively, with trends presented as dots at catchment centroids.

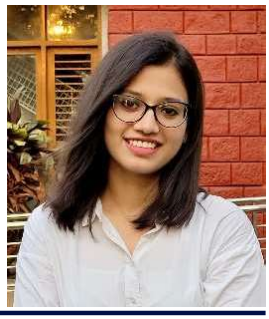
RESULTS & DISCUSSION

- The number of dry days per year is increasing across catchments in the south and east and decreasing in the north (not shown).
- Figure 1 (top) shows that the annual mean wet spell length is declining across most of Australia.
- Figure 2 (bottom) shows that despite increases in the number of dry days and declines in wet spell lengths there are few statistically significant trends in annual mean dry spell lengths.
- Understanding what is driving these changes and how they impact extremes events, and their sequencing remains the focus of our continuing work.





Atmospheric Rivers leading to extreme flooding



Name: Sucheta Pradhan
Email: ssuchetaprad@student.unimelb.edu.au
Supervisors: Dr. Murray Peel, Dr. Conrad Wasko
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

The effects of climate change have led to an alarming increase in the number of destructive floods worldwide in recent years. Atmospheric moisture movement has been identified as one of the primary sources of intense precipitation and subsequent flooding incidents.

Atmospheric River (AR) is an important weather phenomenon, characterised by a narrow-elongated corridor of enhanced moisture over the earth's atmosphere, which can transport large amounts of moisture from the subtropics to mid-latitudes.

Due to the strong link between ARs and extreme precipitation, this filamentous structure has emerged as a major focus for global water resources management. However, the relationship between ARs and flooding, the ultimate hazard resulting from extreme precipitation, remains poorly understood. In our study, we underscore the association between ARs and extreme flooding in Australia.

METHODOLOGY

Utilizing 467 Hydrologic Reference Stations (HRS) across Australia, the contribution of ARs to extreme flooding is investigated. Further, the magnitude to which ARs impact extreme events, and how this varies with event severity is quantified in different regions of Australia.

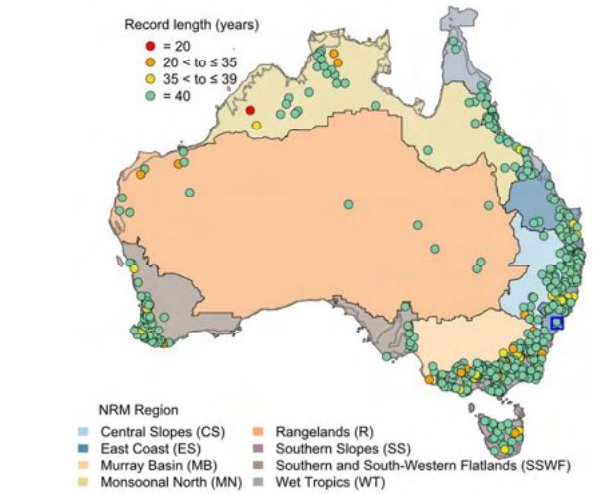
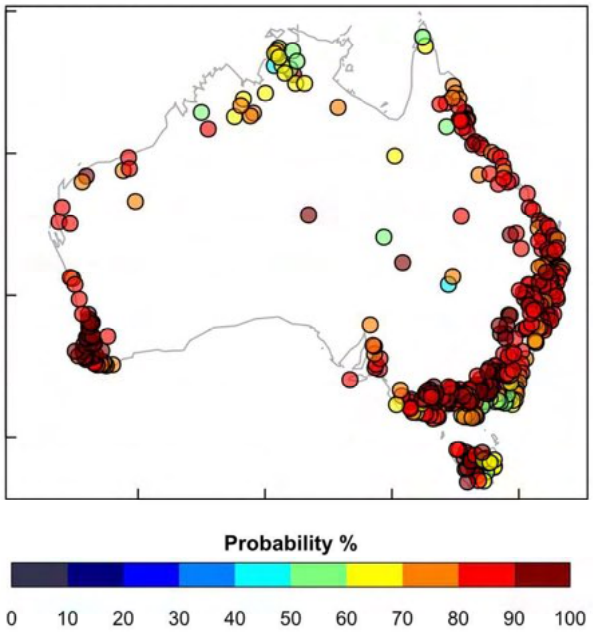


Figure: HRS locations and record lengths, underlain by Natural Resource Management (NRM) regions.

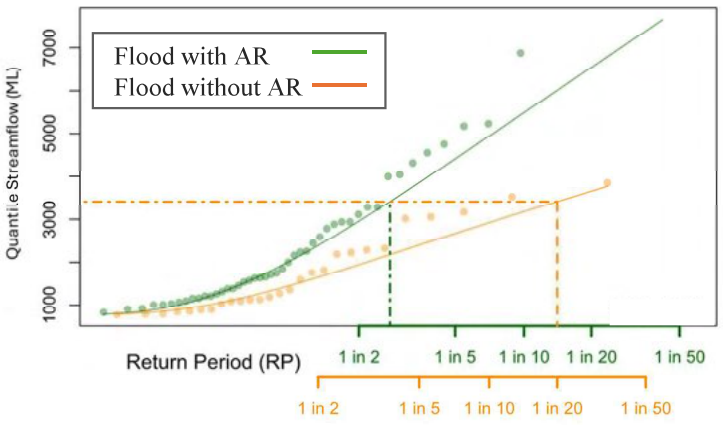
RESULTS & DISCUSSION

- The probability of AR occurrence on days of extreme events is 70-100% across most of Australia.
- The return periods of extreme flood events of a given magnitude are on average 2 to 12 times shorter when they coincide with an AR compared to when they do not coincide with an AR

Probability of ARs on Extreme Flooding



Frequency Curve for Extreme Flood with and without AR



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Network topology drives population temporal variability in experimental habitat networks

Name: Yiwen Xu
Email: yiwen3@student.unimelb.edu.au
Supervisors: Angus Webb, William Bovill
Discipline: Environmental Hydrology and Water Resources

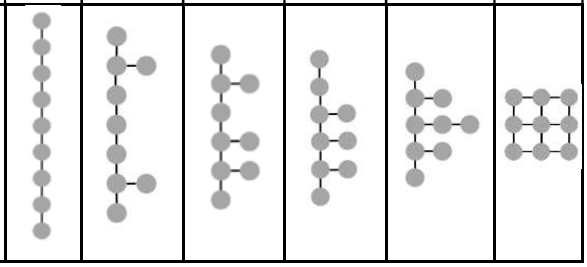
INTRODUCTION

- Habitat patches may be distributed across landscapes and connected by dispersal pathways, creating habitat networks at landscape scales. The structure of habitat networks can vary in complexity, depending on the spatial arrangement of habitat patches and the topology of dispersal pathways connecting patches. Theory predicts that changes in these elements of network structure will affect population outcomes (network carrying capacity, population distribution and temporal variation), but few empirical studies have been done because field tests are logistically difficult.

METHODOLOGY

- We conducted laboratory experiments to explore the effect of habitat network topology on population outcomes of a model species. Populations of *Daphnia carinata* were maintained in artificial habitat networks of six topologies with different connection pathways (Table 1). Three different network types were represented (linear, dendritic and lattice networks). Networks consist of individual nodes (jars) connected by clear tubing through which organisms can travel. Experiments started with 5 individuals in each node, and populations were censused regularly over three months.

Table 1. Topologies of the artificial habitat networks

Network type	Linear	Dendritic 1	Dendritic 2	Dendritic 3	Dendritic 4	Lattice
Network topology						

RESULTS & DISCUSSION

- Within lattice networks, the centrality of habitat nodes was significantly correlated with temporal variability in the size of node-scale populations. However, this effect was not observed in less complex networks.
- Network-scale carrying capacity had a weak positive correlation with network complexity.
- Spatial distribution of Daphnia among nodes was not significantly different among network types or topologies.

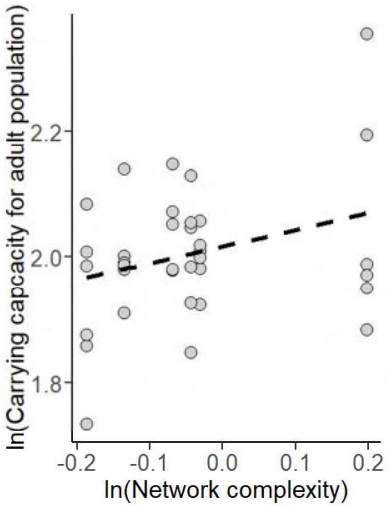


Figure 1. Correlation between adult carrying capacity and network complexity. Dotted line is fit by linear regression ($F_{1,34}$=3.317, p=0.077).

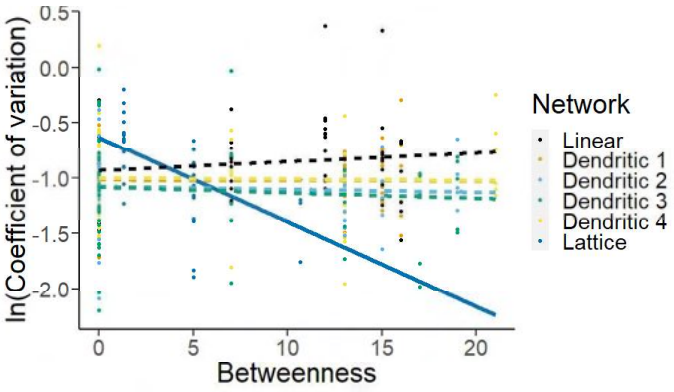


Figure 2. Correlation between log-transformed coefficient of variation after population growth phase and node betweenness. Straight lines show linear regressions. Solid lines show a significant effect (α = 0.05). Dotted lines show a non-significant effect.

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Infrastructure Engineering Graduate Research Conference 2024

Challenges of using robustness metrics for water resources system management under uncertainty

Name: Yuan Cao
Email: YUCAO3@student.unimelb.edu.au
Supervisors: Dr Wenyan Wu, Prof. Holger R Maier, Dr Matt Gibbs
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

Effective management of water resources systems is essential for sustainable development. However, the effectiveness of management decisions is often challenged by uncertain conditions such as natural variability and climate change. To address this challenge, the concept of robustness has been introduced to find robust management options that can provide acceptable performance across a range of uncertain conditions. Different robustness metrics, such as expected values and satisficing metrics, have been developed to characterise the robustness of management options. Since these robustness metrics are calculated differently and often represent different risk tolerance levels of decision-makers, the choice of robustness metric can influence the management decisions and thus the associated outcomes. This creates additional uncertainties in decision-making, reducing the confidence of decision-makers in the expected performance of their selected management strategies. This study aims to investigate the challenge of selecting appropriate robustness metrics, potentially highlighting the need for a more systematic approach for effective water resources management under uncertainty.

METHODOLOGY

To investigate the challenges in selecting appropriate robustness metrics, this study presents a comprehensive analysis of various robustness metrics using a real-world reservoir management problem in China. The analysis mainly focuses on identifying the variations of robustness metric values, and how these variations can potentially affect the final decisions.

Five commonly used robustness metrics, including best-case, expected value, WP25, WP10 and worst-case, have been selected based on the range of potential risk tolerance levels of decision-makers. Five optimal management solutions from a previous study have been selected as candidate management solutions. An ensemble of 100 inflow timeseries generated from historical data is used to consider uncertainty in inflow.

RESULTS & DISCUSSION

Results indicate that the selection of robustness metrics can lead to significantly different performance outcomes, as shown from variations of metric values across a range of different metrics in Figure 1. Moreover, even metrics representing similar risk tolerance levels can lead to varying results and solution rankings. This variability underscores the inherent challenge in selecting appropriate robustness metrics and further complicates the decision-making process, leading to reduced confidence in identifying optimal solutions.

This research explores the challenges in selecting suitable robustness metrics that align with management objectives and risk tolerance levels, highlighting negative consequences including sub-optimal and misguided decisions that may arise in real-world applications of this metric-based approach. Our findings further emphasise the need for a new systematic approach to achieve more informed and efficient decision-making for water resources system management in an uncertain world.

FIGURE/DATA

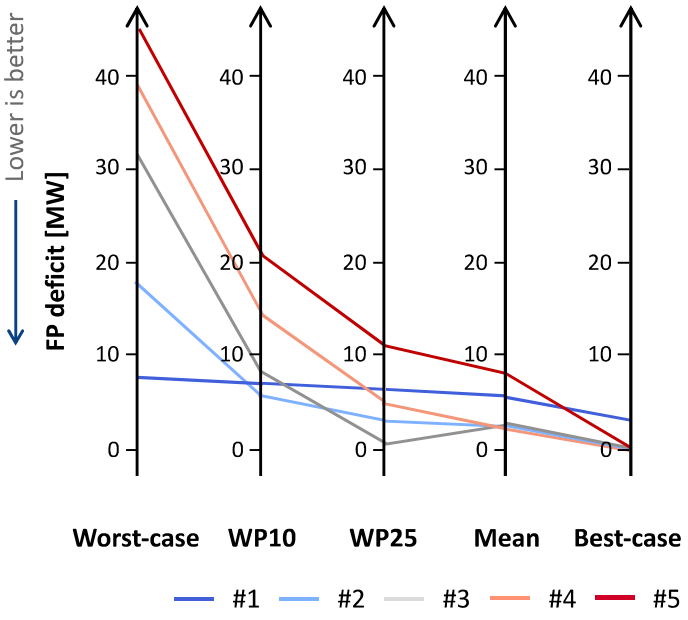

Figure 1. Robustness metric values of candidate management solutions for objective FP deficit.

Infrastructure Engineering
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Initial Findings of Global Analysis of Interdecadal Cycles in Rainfall

Name: Tobias Selkirk
Email: tobias.selkirk@student.unimelb.edu.au
Supervisors: A/Prof Angus Webb, Prof Andrew Western
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

- The presence of decadal cycles from 10 to 30 years in annual rainfall has been reported in many locations across the globe, including: South America (Currie, 1983), North America (Cook et al., 1997), China (Currie, 1995a), Mongolia (Davi et al., 2006), Egypt (Currie, 1995b), Russia (Currie, 1995c) and Australia (Noble & Vines, 1993). This work aims to build on three significant cycles recently discovered in annual rainfall in Eastern Australia (Selkirk, Western & Webb, 2024). Significant cycles of 12.9, 20.4 and 29.1 years were discovered by clustering the aggregate results of wavelet analysis across all sites, with an alignment to extreme rainfall of over 85% (between 1890 and 2020).
- A similar methodology was adopted and applied to a global dataset to see if these cyclic patterns could be observed at other locations.
- Discovering where these cycles impact rainfall globally may help to identify what the drivers could be causing this effect.

METHODOLOGY

- The Global Precipitation Climatology Centre (GPCC) V6 dataset provides Full Data Reanalysis monthly rainfall data from 1901-present. The raw data is taken from more than 85,000 stations worldwide and accessible as a 2.5° gridded cover of global land-surface rainfall. This data was filtered by locations that were informed by at least one gauge to minimise artefacts arising from the reanalysis. This gave 1,776 grid points which were each summed annually calendar year to give total annual rainfall.
- Wavelet analysis was used to extract all cycles between the years of 1901 and 2021 at each site. These results were then clustered using a Gaussian Mixture Model (GMM) and tested for significance over AR(1) red noise using a standard t-test.
- The sites which showed a peak in a significant cluster were then mapped to look for patterns and spatial coherence.

RESULTS & DISCUSSION

- Four significant cycles of 13.2, 19.6, 27.2 and 37.1 years were discovered in the global dataset of annual rainfall (Figure 1).
- These results seemed to correspond closely to the cycles of 12.9, 20.4 and 29.1 years discovered in eastern Australia. Mapping the results of each cluster show certain regions of spatial coherence for each cycle.
- The 13.2-yr and 19.6-yr cycles show the strongest influence, being present at approximately half the sites, with spatial coherence across eastern Australia, Southern Russia, Europe and parts of the Americas.

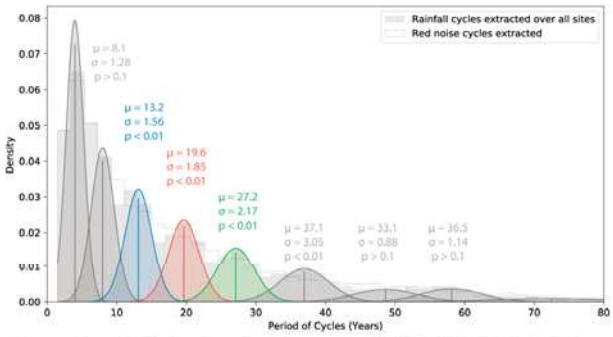

Figure 1: Results for the Gaussian Mixture Model of the GPCC (v6) global precipitation dataset. The light grey histogram represents the distribution of cycles extracted by wavelet analysis from all 1,776 sites. Four clusters were significantly different to red noise by t-test ($\alpha = 0.01$). The three coloured clusters matched closely to the cycles found in eastern Australian rainfall.

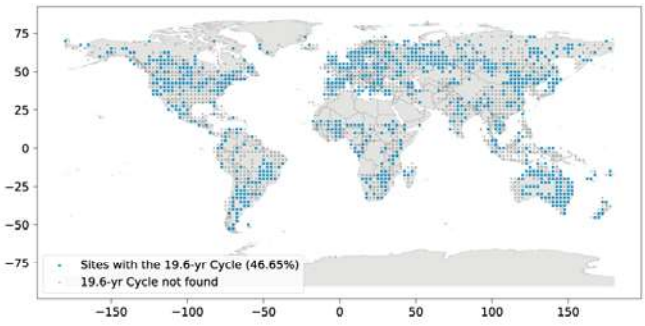

Figure 2: Distribution of sites globally which were in the 19.6-yr cluster (±1.8) of the GMM which accounted for 46.65% of all sites tested (with at least 1 gauge). Spatial coherence can be observed around eastern Australia as shown in previous studies, but also across southern Russia and into Europe.

Infrastructure Engineering
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Improve representation of multi-annual dynamics in rainfall-runoff models

Name: Ziqi Zhang
Email: zizhang3@student.unimelb.edu.au
Supervisors: Dr. Keirnan Fowler, Dr. Murray Peel
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

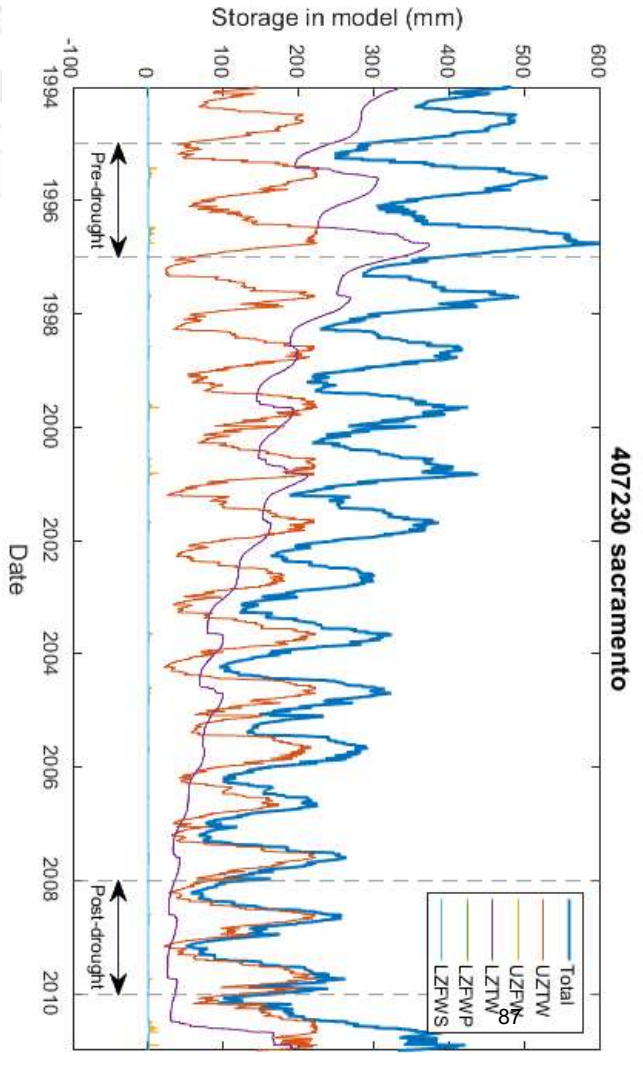
- Multi-year droughts cause shifts in hydrological response globally, potentially driven by interconnected groundwater processes such as declines in groundwater storage.
- Traditional rainfall-runoff models typically focus on seasonal or shorter streamflow responses, often neglecting multiannual dynamics and failing to capture drought-induced hydrological shifts.
- Under climate change, with more frequent and severe droughts expected, it is crucial to adapt our hydrological modelling practices to include mechanisms that can capture long-term dynamics for more accurate runoff projections.

METHODOLOGY

- Most conceptual models include a "soil moisture" store for seasonal moisture fluctuations and a "baseflow" store for hydrograph attenuation. We hypothesize that adding an independent store, which impacts flow-producing stores (without directly generating runoff), can track the slow-moving component of catchment wetness (e.g. groundwater), thereby enhancing streamflow predictions under changing climate conditions.
- To test the hypothesis, we evaluated 47 daily conceptual models from the Modular Assessment of Rainfall-Runoff Models Toolbox (MARRMoT) and a deficit dynamics version of GR4J.
- We applied two tests: (1) the multi-objective Pareto analysis of Fowler et al. (2020, https://doi.org/10.1029/2019WR025286) and (2) tests examining models' response to synthetic sequences of forcing data. For example, the synthetic data could consist of ten consecutive wet years and ten consecutive dry years, and we then quantified the time required for simulated streamflow to equilibrate to the step change.

RESULTS & DISCUSSION

- Of those models incorporating independent "groundwater" stores (11 out of 48), our results show that most can effectively capture storage declines while maintaining accurate streamflow predictions under prolonged drought conditions (e.g. SMAR, PENMAN and SACRAMENTO). However, results are variable and some of the process parameterization equations could be further improved (e.g. LASCAM). Consequently, our findings suggest that employing these models can offer valuable insights for water resource management and planning in regions susceptible to severe and extended droughts under climate change.



Infrastructure Engineering
Graduate Research Conference 2024

Estimating Nutrient Inputs to Agricultural Land Use to Predict Surface Water Quality

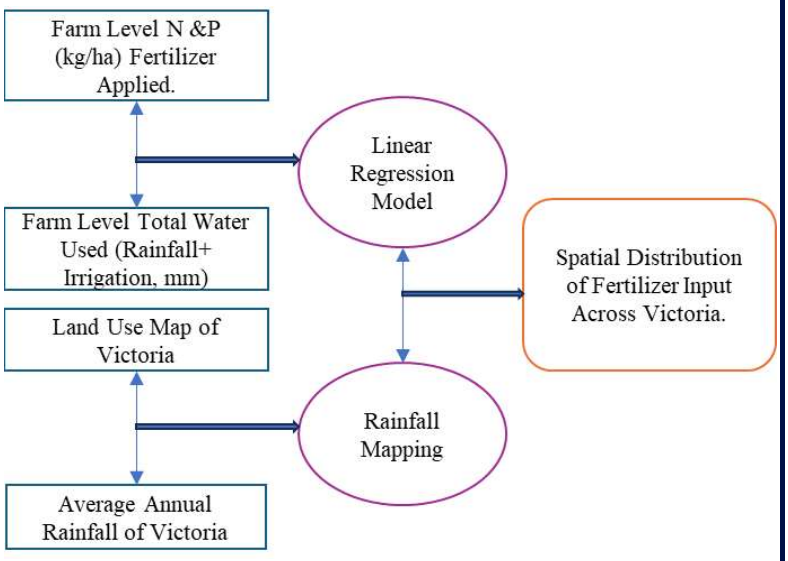
Name: Olaleye John Babatunde
Email: babatundeo@student.unimelb.edu.au
Supervisors: Prof. M. Arora., Prof. A. Western., Dr. V. Nara
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

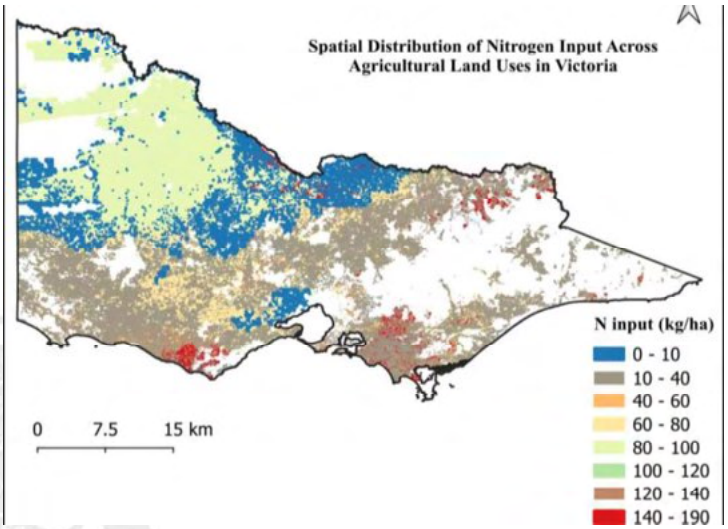
Nutrient inputs (NI), particularly nitrogen (N) and phosphorus (P) from agricultural fertilizers, significantly impact surface water quality. Understanding their spatial distribution is crucial for effective water quality management. While global studies have mapped fertilizer use patterns, they often lack the resolution to capture fine-scale spatial variability required for accurate water quality assessment. Previous approaches have either applied fixed fertilizer rates to different agricultural land uses or used land use percentages as surrogates for NI in predicting water quality responses. However, these methods are limited as land use does not directly correspond to actual NI.

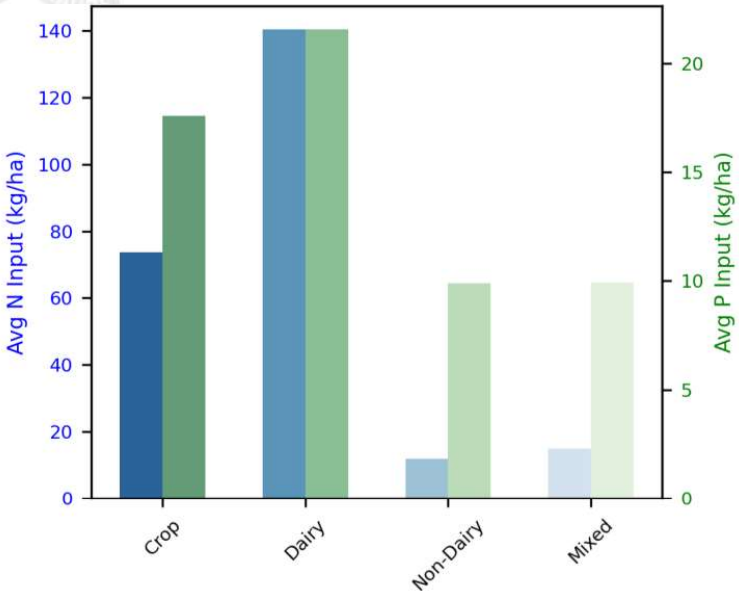
We hypothesize that nutrient inputs (NI) will be a better predictor of stream nutrient concentrations. This study models the spatial distribution of NI data across agricultural land uses in Victoria, Australia, to improve understanding of nutrient dynamics and support targeted water quality management.

METHODOLOGY



RESULTS & DISCUSSION





- High nutrient inputs were concentrated in southern and western Victoria, primarily due to intensive agricultural activities.
- Dairy farming contributed 50-60% of catchment-scale nutrients input, followed by cropping in the northern regions, mixed farming, and non-dairy livestock grazing.
- Future studies will test the relationships between the estimated nutrient inputs and stream nutrient concentrations.

Infrastructure Engineering
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A Fusion of Model and Data to Infill Missing Pixels in Flood Monitoring Satellite Images

Name: Xinqi Guo Email: xinqig@student.unimelb.edu.au
Supervisors:
Prof. Q J Wang, Prof. Andrew Western, Prof. Dongryeol Ryu & Dr. Wendy Sharples
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

- Floods pose significant risks to lives, property, and infrastructure. For effective impact assessment and emergency management response, satellite imagery is used to monitor flood extents and predict flood hazard footprints. However, the fidelity of such optical images is affected by atmospheric conditions (e.g., clouds and aerosols) and instrument failure, resulting in missing or poor-quality pixels. This study addresses this issue by developing a feature extraction, mixing, and matching (FEMM) methodology to infill missing pixel values in flood inundation maps derived from high-resolution optical satellites.

METHODOLOGY

- In the FEMM approach, dominant spatial features of floods are extracted from long timeseries of simulated flood inundation maps. Missing pixel values in a satellite image are then inferred by mixing the dominant spatial features to match the non-missing pixel values. The Empirical Orthogonal Functions (EOF) technique is used in the feature extraction, mixing and matching. To evaluate the performance of the FEMM methodology, we use archetypal cloud masks sampled from real cloud-affected images to systematically degrade cloud-free images. These degraded images are then infilled and compared with the original images to assess the efficacy of FEMM.

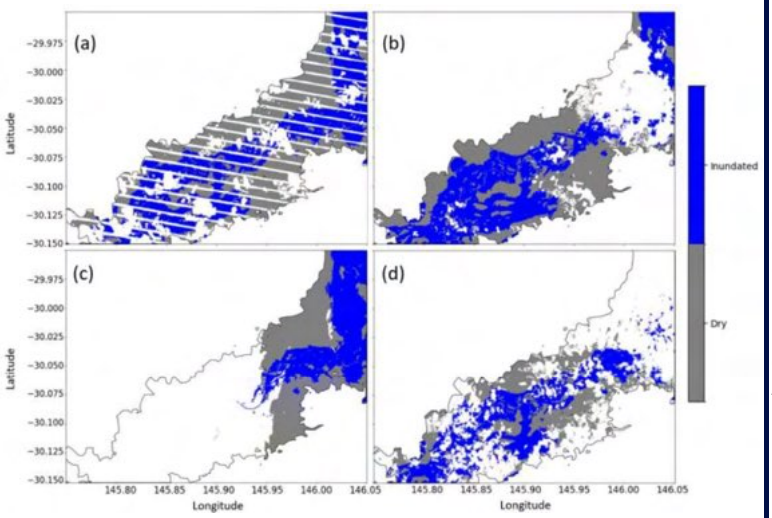

Figure 1. Experimental settings with four masked images.

RESULTS & DISCUSSION

- The FEMM-based infilling effectively restores the flood inundation information for the missing pixels with critical success rate of 67-77%. Moreover, the critical success rate improves to 81-83% when FEMM is combined with a terrain-based local infilling scheme as a pre-processing. However, the efficacy drops when observations are completely missing in large patches. The infilled images can be valuable for monitoring flood extents from natural events or environmental watering, and for downscaling high-temporal-frequency but low-spatial-resolution satellite observations of flood inundation.

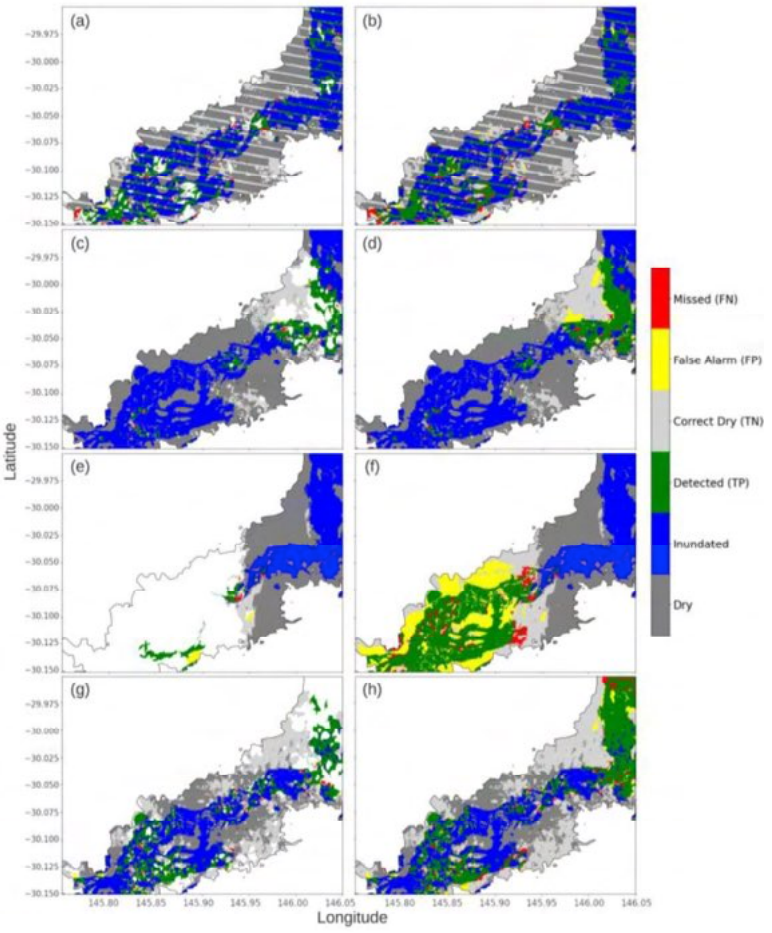

Figure 2. Terrain-based local infilling results (left) and complete images after the FEMM approach (right).

Infrastructure Engineering
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Integrating vegetation dynamics into conceptual hydrological modelling

Gabrielle Burns, gburns1@student.unimelb.edu.au
Supervisors: Dr. Keirnan Fowler, Dr. Murray Peel, Dr. Clare Stephens
Discipline: Environmental Hydrology and Water Resources

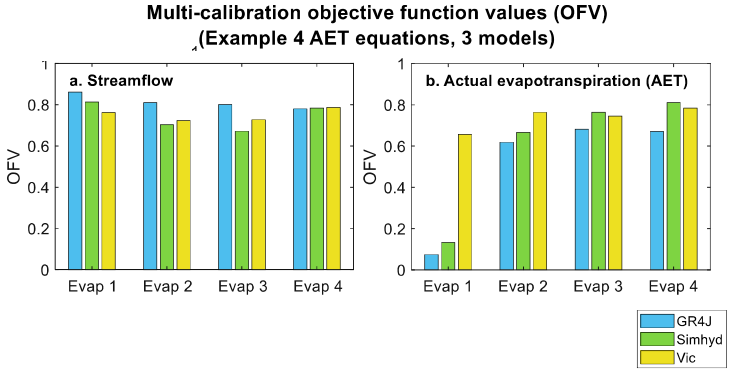
INTRODUCTION

- We use hydrological models to understand and manage how long-term climatic changes will impact streamflow and water availability for downstream users and the environment.
- **Conceptual models** simplify underlying physical processes, offering advantages over physical models by facilitating implementation across large scales and time frames.
- Model accuracy is crucial for extrapolating to future climates. If internal fluxes like evapotranspiration aren't currently reliable, can we trust them with changing conditions?

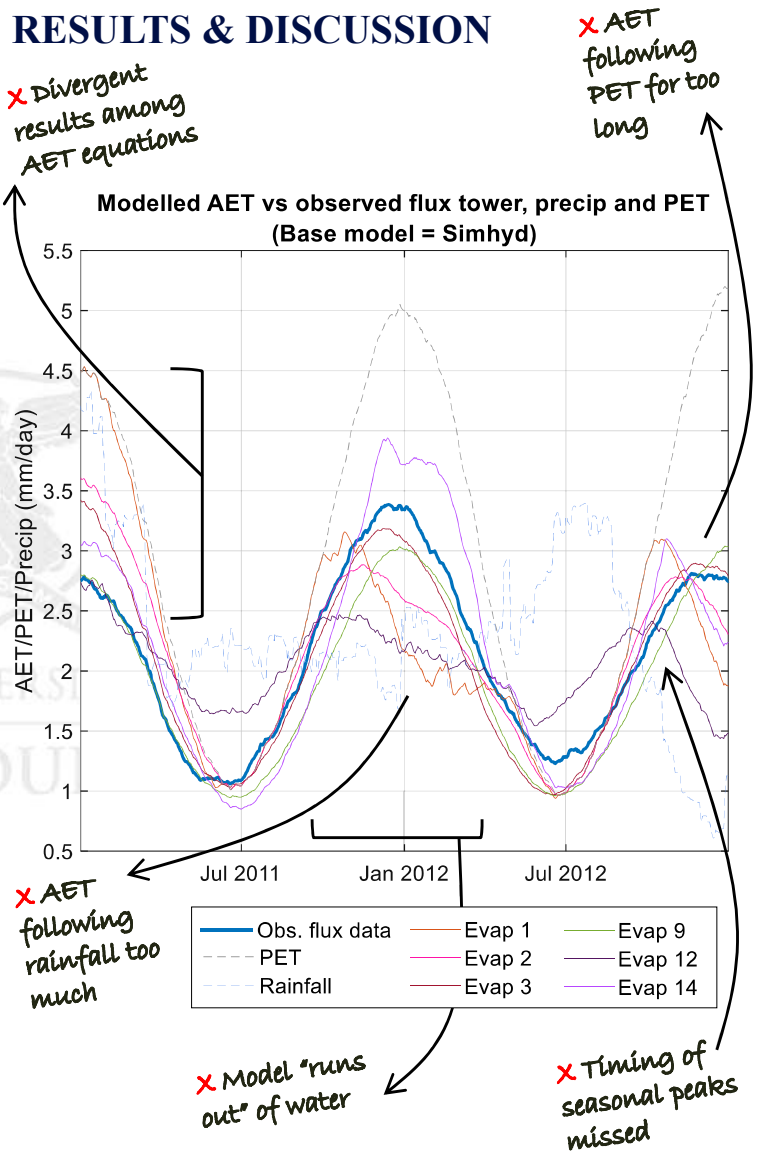
Conceptual rainfall-runoff models are not replicating evapotranspiration effectively

METHODOLOGY

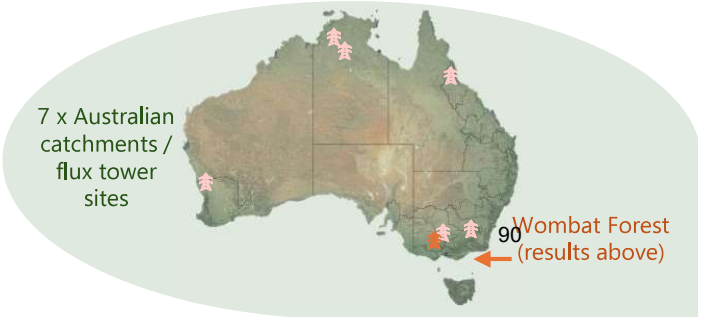
- There are many forms of actual evapotranspiration (AET) equations used across conceptual models – converting potential ET to actual.
- Here we systematically test **15 AET equations** by switching them out within 3 models (GR4J, SIMHYD & VIC).
- We apply a multi-objective calibration using observed streamflow and flux tower evapotranspiration data



RESULTS & DISCUSSION



- This pilot study has been expanded to 6 additional catchments throughout Australia.
- Our goal is to determine the underlying physical processes dictating different AET equations success.



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Transforming Engineering Education with Threshold Learning in First Nations Australian Engineering

Aurora Greane, Indigenous Engineering (a.greane@unimelb.edu.au)
Supervisors: A/Prof Juliana Kaya Prpic, Susan Beetson, Professor Sally Male, and Dr Craig Cowled

Background

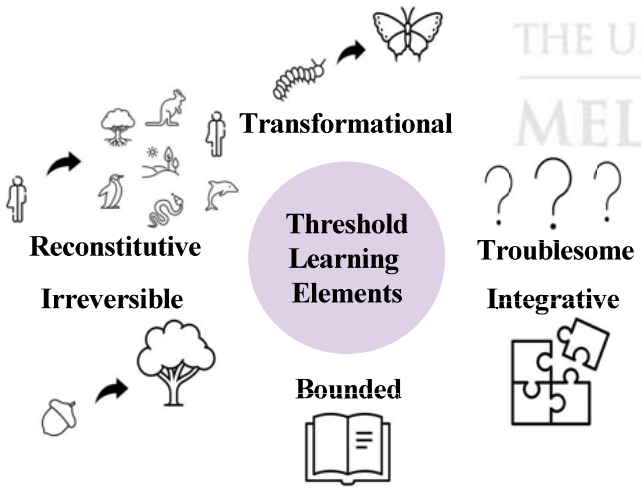
Australian professional organisations and universities have committed to embedding First Nations Australian engineering Knowledges, perspectives, and value systems in the engineering curriculum [1], [2].

Threshold learning describes discipline-specific learning elements that students find most transformative and troublesome. Designing curricula to focus on these elements enables educators to best facilitate transformational learning [3], [4].

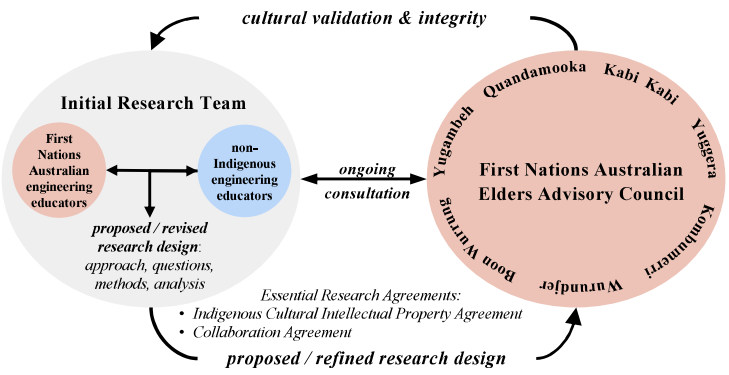
This project seeks to identify threshold learning elements in First Nations Australian engineering. It also aims to design threshold learning experiences and assessment methods to educate emerging engineers who understand and appreciate First Nations Australian engineering Knowledges, perspectives, and value systems.

Threshold Learning Elements

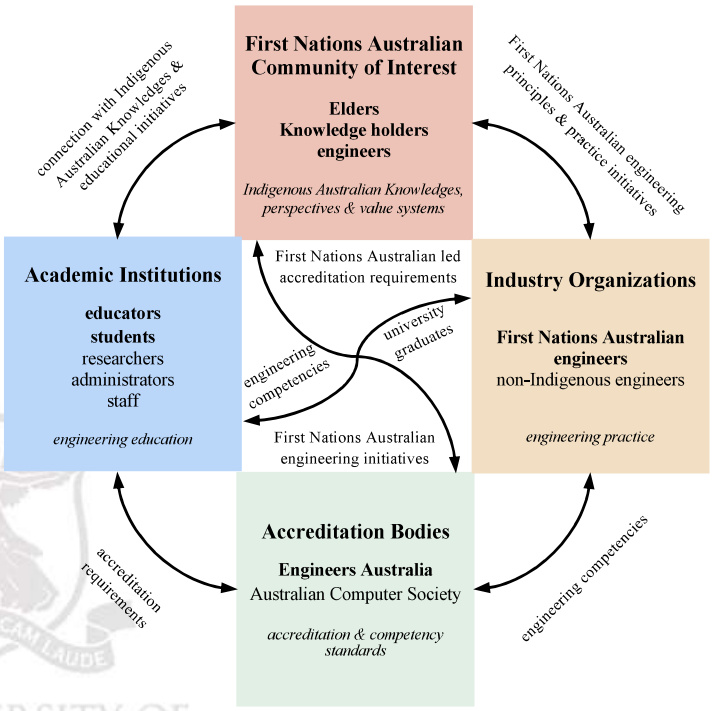
(Concepts [4], [5], Capabilities [3], and Values)



Research Approach

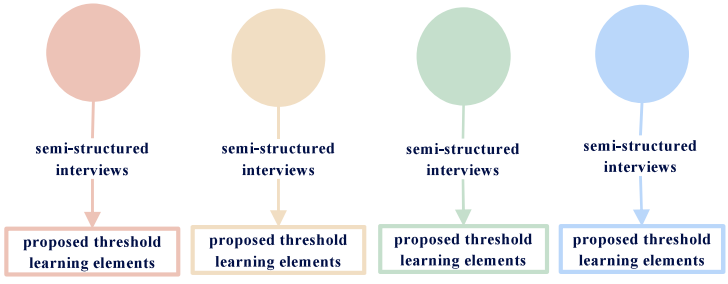


Stakeholders

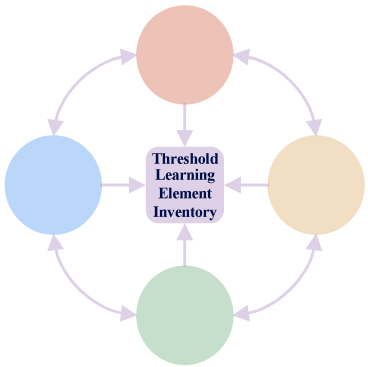


Proposed Research Design

Diverging Phase [10]: Separate semi-structured interviews with stakeholders from each group to gather diverse perspectives and identify a broad range of potential threshold learning elements.



Integrating Phase [10]: Focus groups with stakeholders from all groups to discuss and develop a cohesive threshold learning element inventory.



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Infrastructure Engineering Graduate Research Conference 2024

Spatial-temporal assessment of streamflow for rainwater harvesting using GR4J

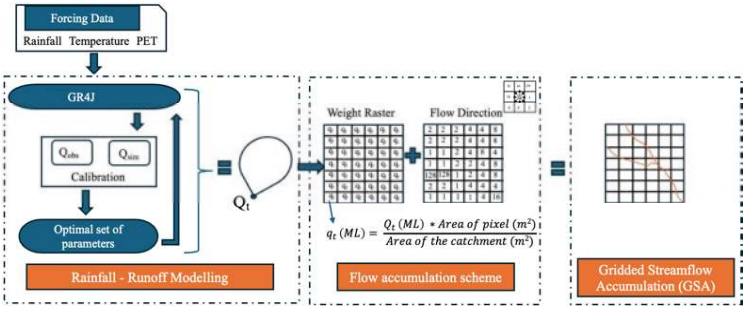
Name : Sri Priyanka Kommula
Email: skommula@student.unimelb.edu.au
Supervisors: Prof. Dongryeol Ryu, Prof. Stephan Winter, Prof. Bharat Lohani
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

- Estimating water availability in terms of runoff volume over time and space is crucial for identifying suitable locations for micro rainwater harvesting (RWH) structures.
- Majority of hydrological assessments for siting RWH structures rely on empirical formula, such as the Soil Conservation Service (SCS) method, which can only provide relative indication of available water with a weak basis on hydrological processes
- Conventional rainfall-runoff models, calibrated over semi-distributed catchments can only provide runoff volume at the outlet of catchments.
- The study aims to develop a methodology that integrates GR4J model results at the catchment outlet into the GIS flow accumulation scheme to create a grid-based streamflow accumulation (GSA) map, while estimating water volume on monthly and seasonal scales at feasible locations to support more tailored designs for RWH structures.

METHODOLOGY

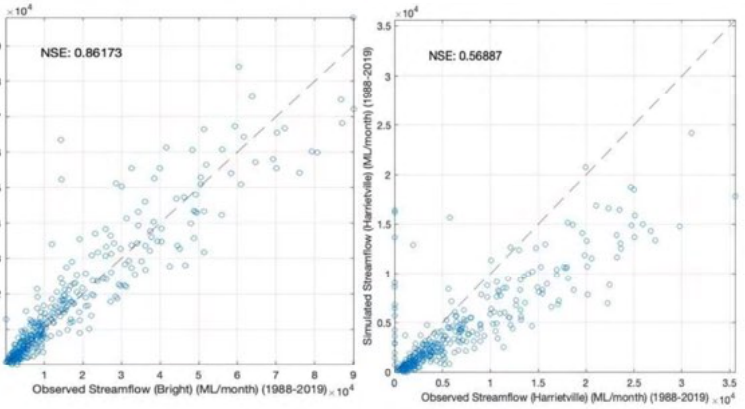
- A daily lumped GR4J model is employed to predict streamflow for an experimental catchment (Ovens) of 490 km^2 located in New South Wales, Australia.
- Daily input forcing data of 40 years (1980-2019) was used along with other static inputs that include soil hydraulic parameters and topography data.
- Daily observed streamflow data at the Bright station (403205) located at the catchment outlet, and Harrietville (403244) station situated within the catchment were used to calibrate and validate the model.

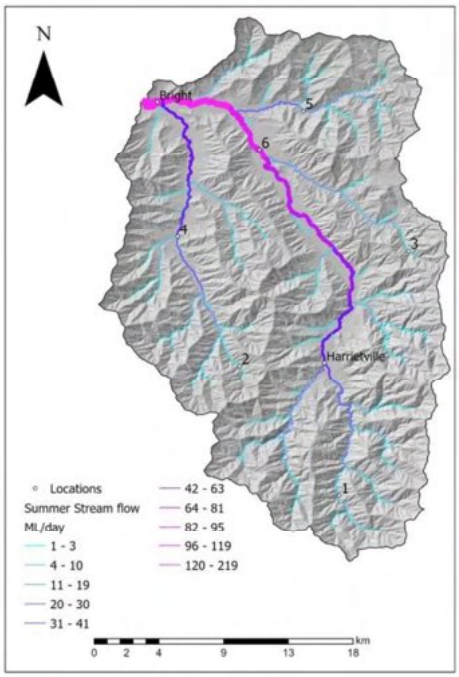


Schematic diagram illustrating the integration of rainfall-runoff modelling and flow accumulation scheme for the gridded streamflow accumulating (GSA)

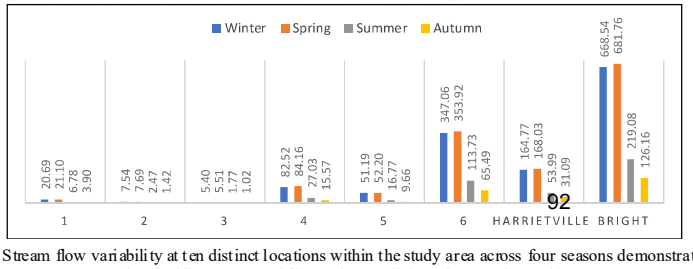
RESULTS & DISCUSSION

- The integrated GR4J and Flow Accumulation accurately represented the main stream channels and realistic flow patterns in the study catchments
- The spatially distributed monthly results at the Bright station yielded and NSE of 0.86 and were validated using data from upstream Harrietville gauging station, an NSE value of 0.56 is observed.





Spatially distributed streamflow over the Bright catchment for summer season, estimated by the proposed 'GR4J + Flow Accumulation'. Six locations were selected across all seasons, and their variations were analyzed. Background grey-scale image is the shaded relief map of the LiDAR DEM.



Stream flow variability at ten distinct locations within the study area across four seasons demonstrate the significant seasonal fluctuations. All the values are in ML/day.

Paving the Way to Greener Roads and Healthier Waterways

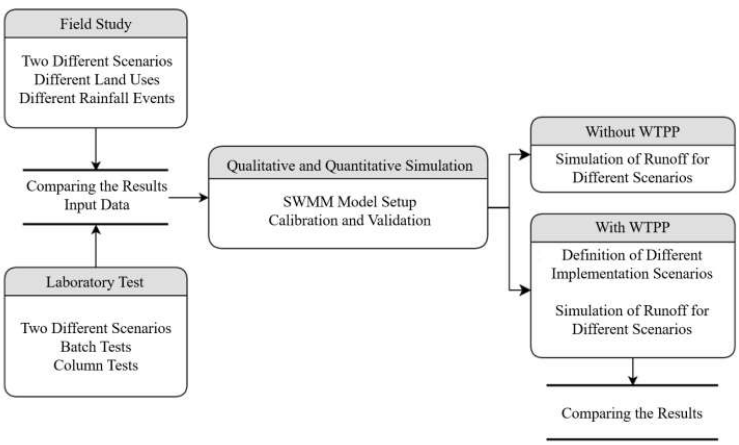
Name: Alireza Motovalibashi Naeini
Email: motovalibash@student.unimelb.edu.au
Supervisors: Prof. Meenakshi Arora, A/Prof. Mahdi Miri Disfani
Discipline: Environmental Hydrology and Water Resources

INTRODUCTION

Urban areas face significant challenges in stormwater management, particularly regarding flood risks and water quality. Traditional impermeable pavements exacerbate these issues by increasing surface runoff and rapid stormwater flow. Recent studies highlight the benefits of permeable pavements, especially waste tyre permeable pavements (WTPPs), in mitigating stormwater runoff and improving infiltration rates while utilizing recycled materials.

However, there is a gap in evaluating WTPPs specifically for flood reduction and their effectiveness under various storm events and the impact on infiltered water quality. Limited research addresses their hydrological performance, the impact of clogging over time, and the potential for additional filtration layers to enhance pollutant reduction. Filling these gaps is essential for improving stormwater management strategies and promoting sustainable urban infrastructure.

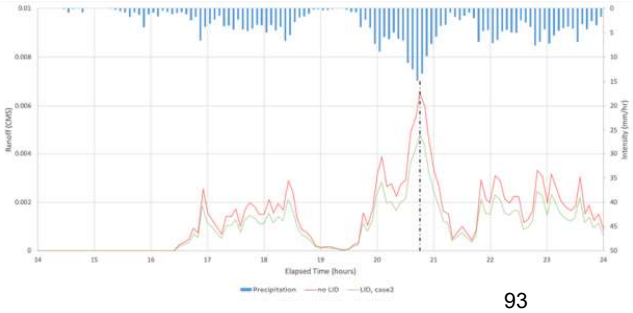
METHODOLOGY



RESEARCH AIM & RESULTS

The primary aim of this research is to assess the capability of waste tyre permeable pavements in reducing flooding and providing treatment to infiltered water through enhanced stormwater management. Through laboratory and field investigations, this study will analyse the performance of these pavements under different storm conditions and evaluate whether the infiltration process effectively diminishes pollutant concentrations.

Preliminary findings suggest a notable reduction in stormwater runoff during intense rainfall events. Additionally, literature indicate that stormwater quality may improve as it passes through the permeable pavement systems. The research will further explore the potential benefits of incorporating additional filtration layers to enhance pollutant removal efficiency.



Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 04 – Morning session- Geomatics

Session chair: Dr Amir Khodabandh

Presentation title	Presenter
Ionospheric Modelling for Precise Satellite Positioning	Parvaneh Sadegh Nojehdeh
Pole-NN: Few-Shot Classification of Pole-Like Objects in Lidar Point Clouds	Cipher Zhang
Developing 3D Spatial Graph Database for Underground Utility Networks	Ensiyeh Javaherian Pour
AI-Driven Land Administration for Large Infrastructure Projects	Hamid Hosseini
BIM-based Land Administration Data Model for Large Infrastructure Projects	Lanxuan Shen
Spatially enabled 3D Asset Recognition in Industrial Plants	Masoud Kamali
Scan-to-SARBIM: Producing a Structural-Analysis-Ready BIM from Point Clouds	Mojtaba Akhoundi Khezrabad
Deep Learning for Vegetation Segmentation from MLS Point Cloud	Aditya
AI-augmented construction cost estimation	Peyman Jafary
A Multi-Temporal Remote Sensing Approach to Analysing Disaster Impacts on Informal Settlements	Ricardo Camacho Castilla
Above-ground biomass estimation using 3D synthetic data	Habib Pourdelan

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 04 – Afternoon session- Geomatics

Session chair: Dr Serene Ho

Presentation title	Presenter
Equi-GSPR: Equivariant SE (3) Graph Network Model for Sparse Point Cloud Registration	Xueyang kang
Open World Object Detection with Vision-Language Model	Zizhao Li
Predictive Models and Tools for Real-Time Flood Monitoring	Alireza Haji Heidari
Global localization for Mixed Reality visualization using wireframe extraction from images	Sajjad Einizinab
AI-Driven BIM Model Requirements for Automated Building Code Compliance	SeyedehFatemeh Mirhosseini
Low Earth Orbit (LEO)-augmented positioning in heavily GNSS signal-obstructed environments	Songfeng Yang
Occupancy Grid Mapping with Uncertain LiDAR Data	Yuguang Liu
Latent-conditioned point cloud diffusion for object augmentation in driving scenes	Zhengkang Xiang
Strategic Allocation of Landmarks to Reduce Uncertainty in Indoor Navigation	Reza Arabsheibani

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Infrastructure Engineering Graduate Research Conference 2024

Estimation of Ionospheric Process Noise Using Single-Receiver GNSS Data

Name: Parvaneh Sadegh Nojehdeh
Email: psadeghnojeh@student.unimelb.edu.au
Supervisors: Dr. Amir Khodabandeh, A/Prof. Kourosh Khoshelham
Discipline: Geomatics

INTRODUCTION

Precise positioning with Global Navigation Satellite Systems (GNSS) is often achieved by processing data over multiple epochs to enhance positioning accuracy through the accumulation of redundant observations. To fully utilize the advantages of multi-epoch data processing, a thorough understanding of the temporal behavior of the underlying model parameters is required. This temporal behavior can be characterized by a dynamic model, with the associated uncertainty captured by the parameters' process noise variances. The more randomly the temporal behavior deviates from the dynamic model, the larger the process noise variance should be.

In the context of GNSS positioning, first-order slant ionospheric delays are known to be highly time-varying, for which nominal process noise variances are often incorporated into the estimation process. As a result, the estimation process loses its minimum-variance optimality. In this study, we present a simple data-driven method that directly estimates ionospheric process noise variances, minimizing the risk of a suboptimal estimation process.

METHODOLOGY

The algorithmic steps for estimating the ionospheric process noise variances, σ^2, are given below.

Algorithm 1 Process noise variance estimation over the pair of epochs $k-1$ and k.

Inputs

$\phi^s_{k-1,GF}$ and $\phi^s_{k,GF}$: GF phase measurements of satellites $s = 1, \ldots, m$
$\text{var}_{n^s_{k-1}}$ and $\text{var}_{n^s_k}$: variances of the GF measurements of satellites $s = 1, \ldots, m$
z^s_k: zenith angles of the ionospheric piercing point of satellites $s = 1, \ldots, m$
$g(z^s_k)$: zenith-dependent function, e.g., $g(z^s_k) = \exp(\frac{z^s_k}{15^\circ})$
τ : measurement sampling-rate
ϵ : small positive value as stopping criterion, e.g., $\epsilon = 0.0001$
σ_0^2 : initial value of the ionospheric process noise variance

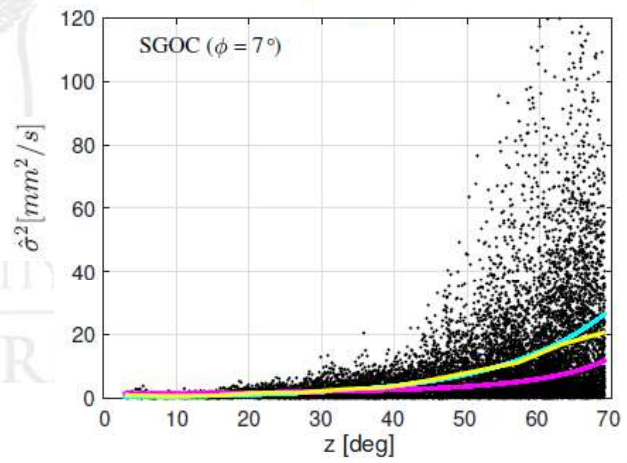
Output

$\hat{\sigma}^2$: estimated ionospheric process noise variance

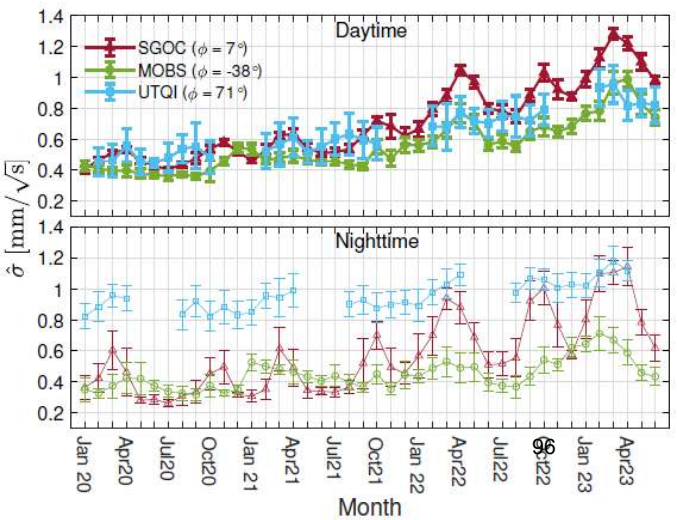
$y \leftarrow \text{zeros}(m, 1)$ ▷ Initialize the observation vector by a zero vector
$A \leftarrow \text{zeros}(m, 1)$ ▷ Initialize the design matrix (vector) by a zero vector
$t \leftarrow 1 + \epsilon$
while $t > \epsilon$ do
  for $s = 1$ to m do
    $\text{var} \leftarrow (\tau\, g(z^s_k)\, \sigma_0^2 + \text{var}_{n^s_{k-1}} + \text{var}_{n^s_k})$
    $v \leftarrow \sqrt{2}\,\text{var}$ ▷ square-root of entries of Q_{y_k}
    $w \leftarrow (\phi^s_{k-1,GF} - \phi^s_{k,GF})$
    $y[s] \leftarrow (w^2 - \text{var}_{n^s_{k-1}} - \text{var}_{n^s_k})/v$ ▷ transformed observation vector
    $A[s] \leftarrow \tau\, g(z^s_k)/v$ ▷ transformed design matrix
  end for
  $\hat{\sigma}^2 \leftarrow (A^T y)/(A^T A)$
  $\Delta \leftarrow |\hat{\sigma}^2 - \sigma_0^2|$
  $t \leftarrow \Delta\sqrt{A^T A}$
  $\sigma_0^2 \leftarrow \hat{\sigma}^2$
end while
return $\hat{\sigma}^2$

RESULTS & DISCUSSION

We estimated the ionospheric process noise for each GPS satellite at a GNSS station, with the results shown in the figure below. The ionospheric process noise increases as the zenith angle, z, increases; hence, we used curve fitting techniques to parametrize the process noise variances. The exponential function (cyan curves) fits the average process noise values (yellow curve) at 5-degree intervals better than the cosine function (magenta curve). Consequently, we used the exponential function to model the ionospheric process noise.



Using the least-squares estimation technique, the black dots were aggregated to produce a 'daily' daytime and nighttime solution, as shown in the figure below. The results revealed significant differences in ionospheric process noise between daytime and nighttime, as well as across geographic locations for three GNSS stations, highlighting the need for spatiotemporal-dependent ionospheric process noise estimation.



Infrastructure Engineering
Graduate Research Conference 2024

3D Underground Utility Networks

Name: Ensiyeh Javaherian Pour
Email: ensiyehj@student.unimelb.edu.au
Supervisors: Dr. B. Atazadeh, Prof. A. Rajabifard, Dr. S. Sabri
Discipline: Geomatics

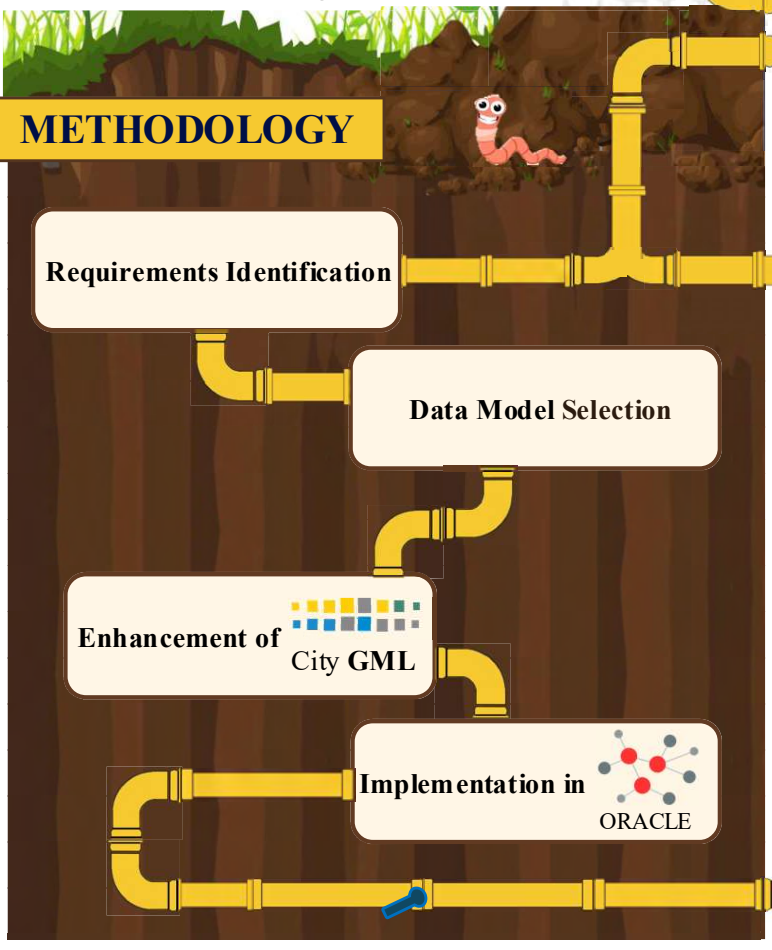
INTRODUCTION

Underground utility networks, **Essential but Hidden**, are typically mapped poorly in 2D, leading to costly construction errors and frequent reinstallations. This highlights the need for an accurate **3D Data Model** to improve the **management**, **maintenance**, and **spatial analysis** of these utilities.

This thesis identifies specific requirements for modelling underground utility networks, which differ from other city objects, and implements these requirements on a **3D Graph Database**. A comparative analysis of existing 3D spatial data models and 3D spatial graph databases are conducted to determine the most suitable one.

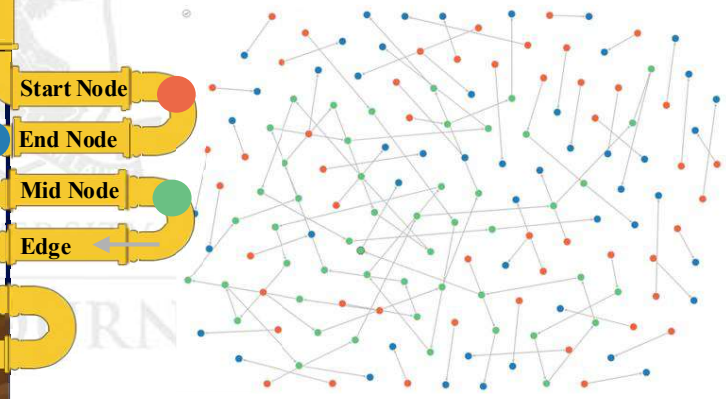
The network-like nature of underground utility networks enhances the choice of a graph database over traditional relational databases. This method offers **Flexible Schema**, more accurate **Visualisations**, efficient path **Queries**, and connection **Searches**, thus strengthening urban planning and infrastructure management.

METHODOLOGY

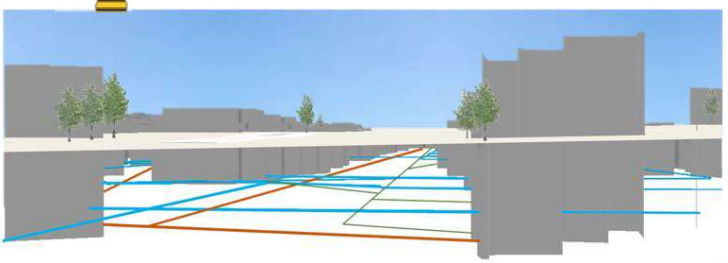


RESULTS & DISCUSSION

The case study involving water, sewer, and recycled water systems in Frankston . Initially, **2D** utility network data was converted into a 3D format. The transformed data was then modelled in **CityGML**. Subsequently, the **3D** CityGML model was implemented within the **Oracle Graph Database**, facilitating a graph-based representation of the utility networks. This approach allowed the utilities to be modelled as **nodes** and **edges**, where various data properties were stored as **attributes**, enabling dynamic and interconnected data management.



The graph database proved to be highly effective in representing the **complex relationships** between different elements of the utility network, offering significant advantages over conventional table-based methods.



Overall, the project's results highlight the superiority of a 3D graph-based approach over traditional relational databases for managing underground utility networks, making it a compelling choice for future urban infrastructure management and planning. This advancement addresses the challenges associated with the hidden nature of utilities, providing a more accurate, efficient, and scalable solution.

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Infrastructure Engineering
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AI-Driven Land Administration for Large Infrastructure Projects

Researcher: ***Hamid Hosseini***
E-mail: ***hamid.hosseini@student.unimelb.edu.au***
Supervisors: ***Dr. Behnam Atazadeh and Prof. Abbas Rajabifard***
Discipline: ***Geomatics - CSDILA***

INTRODUCTION

The development of a new large infrastructure project, such as metro tunnel, rails, bridges, and roads, spatially intersects with many land parcels and properties, with multiple ownerships. Physical and legal data on these affected land parcels and properties is essentially required for land surveying and land registration practices, which are undertaken frequently during the life-cycle of the projects.

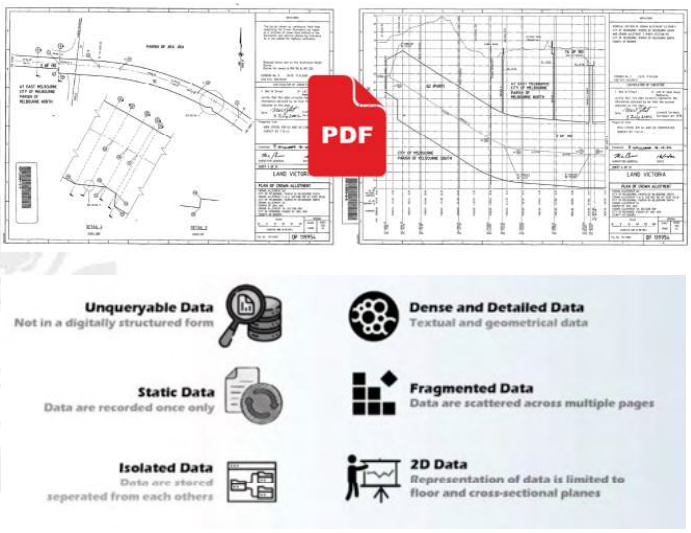
However, due to the fragmented form of the data, often dispersed across survey plans, the information is not easily accessible and usable, leading to significant costs and delays. It is particularly pronounced in large infrastructure projects, where numerous land parcels and properties that can vertically be aboveground or underground are impacted, and the access and use of the data require much more cognitive effort. The aim of this project is to develop an AI model using machine and deep learning, computer vision, and NLP techniques to understand land administration concepts for analysing and interpreting the data, aiming at accelerating practices dealing with the data in complex infrastructure developments.

METHODOLOGY

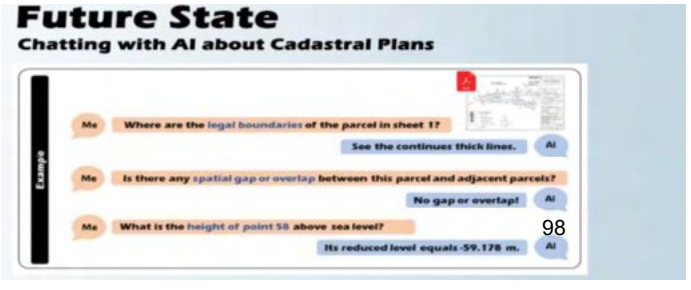
The research methodology encompasses five main stages including foundation, requirement analysis, design and development, implementation, and verification. Each stage plays a crucial role in ensuring the structured progression of the research process. The description of each stage is illustrated in the figure below.

DISCUSSION

The most used land and property data within land administration practices are cadastral plans such as subdivision and crown plans that provide legal data, and Abstract of Field Records (AFR) containing survey data. However, there are several issues when dealing with these that are shown in the figure below.



Although researchers have proposed the mapping of the data to suitable 3D digital data models like CityGML and IFC, significant challenges remain in fully realizing this approach. Most existing cadastral plans in many jurisdictions like Victoria have not been mapped into the data models, yet. Moreover, the data modelling procedure is not yet fully automated. In this regard, providing an intelligent environment to automatically extract and interpret information from the plans and generate appropriate responses to the stakeholders can potentially accelerate the procedure. Upon successful completion of the project, various applications, such as chatbots, could be developed to assist land surveyors and land registries, leading to making decisions more quickly and reducing cognitive effort.



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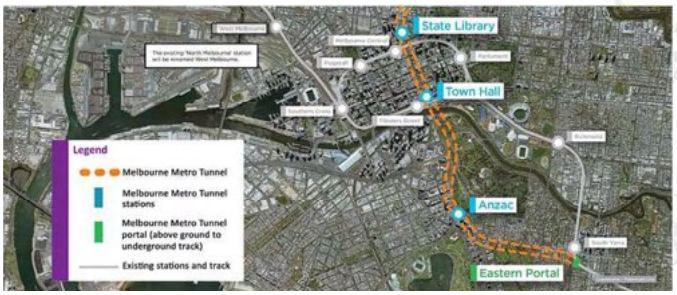
BIM-based Land Administration Data Model for Large Infrastructure Projects

Name: Lanxuan Shen
Email: lanxuan@student.unimelb.edu.au
Supervisors: Dr. Behnam Atazadeh, Dr. Serene Ho, Prof. Abbas Rajabifard
Discipline: Geomatics

INTRODUCTION

- **Complexity of current large infrastructure projects:**

Large infrastructure projects, such as roads, railways, and tunnels, are becoming increasingly complex within the AEC industry due to the complex spatial relationship and large scale. 3 main aspects of limitations for traditional 2D methods, namely Scale issues, Spatial issues and Visualization issues. There is a critical need for advanced data management approaches that can comprehensively model the legal data requirements for managing these projects.



(Victoria' s Big Build, 2024)

- **Research gap:**

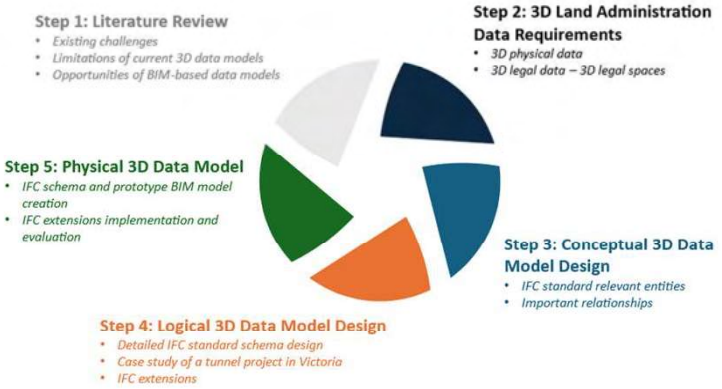
The knowledge gap exists in defining the important relationships between the 3D physical and legal dimensions of large infrastructure projects to effectively address issues related to land and property ownership.

- **Research aim:**

Develop a BIM-based data model to:

1. Represent legal ownership (RRRs) in large infrastructure projects.
2. Link legal ownership to the physical reality of these projects.

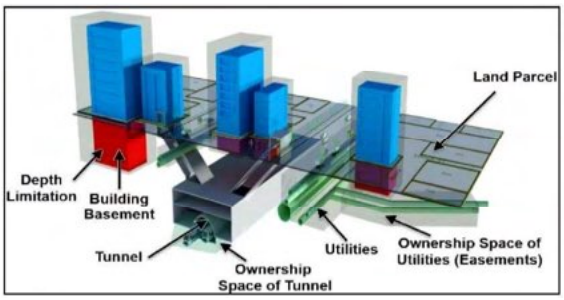
METHODOLOGY



RESULTS & DISCUSSION

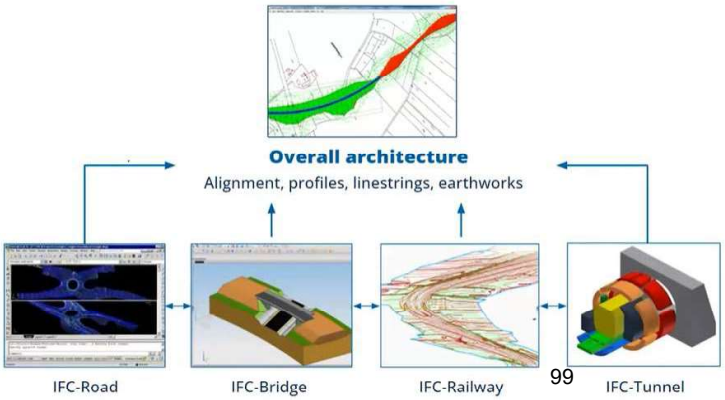
- **Data requirements for large infrastructure:**

1. Physical data: Built environment data & Natural environment data
2. Legal data: 3D Legal spaces & 3D Legal boundaries
3. Survey data



(Saeidian et al., 2021)

- **BIM-based data models – IFC 4.3**



(Borrmann., 2024)

Infrastructure Engineering
Graduate Research Conference 2024

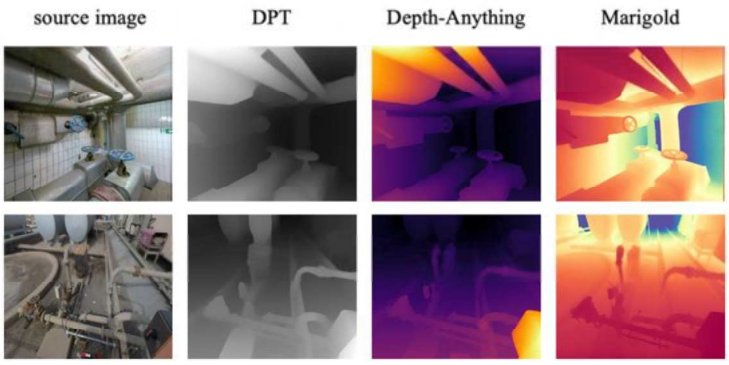
3D Asset Recognition in Industrial Plants

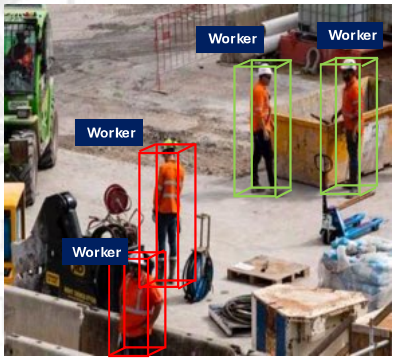
Name: Masoud Kamali
Email: mkkamali@student.unimelb.edu.au
Supervisors: Dr B. Atazadeh, Prof A. Rajabifard, Dr B. Chen
Discipline: Geomatics

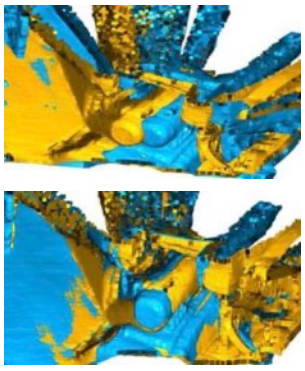
INTRODUCTION

- **3D** Asset Detection
- **Single** Image
- **No** Prior Training
- **Indoor** & **Outdoor** Scene

RESULTS & DISCUSSION



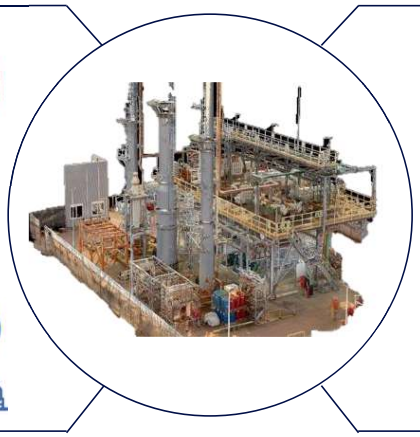




METHODOLOGY

1 Open Vocabulary Object Detection

2 Monocular Depth Estimation



3D Asset Localisation

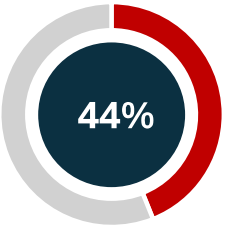
3D Monocular Asset Detection

3 4

ESSENTIAL DEMAND

Industrial facilities poor maintenance cost

Unscheduled asset downtimes due to the inadequate maintenance



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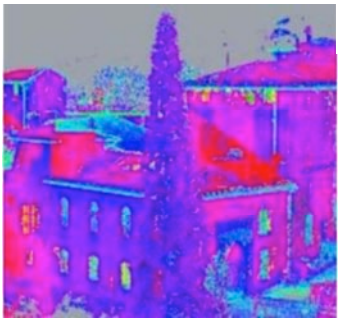
Infrastructure Engineering
Graduate Research Conference 2024

Scan2SARBIM: Producing a Structural-Analysis-Ready Building Information Modelling from Point Clouds

By: Mojtaba Akhoundi Khezrabad
Email: makhoundikhe@student.unimelb.edu.au
Supervisors: Dr. Davood Shojaei, A/Prof Martin Tomko
Discipline: Geomatics

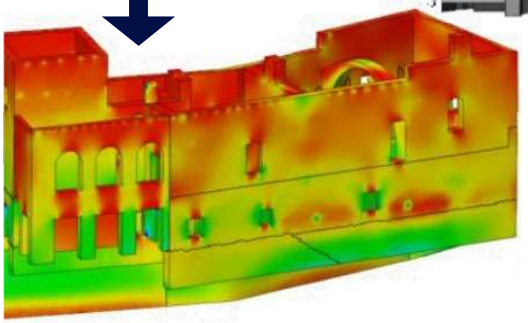
INTRODUCTION

Structural analysis can help protect human lives and valuable resources by identifying potential vulnerabilities in buildings. A geometric model enriched with structural information is essential for conducting structural analysis. However, this model is not available for many buildings.



Scan-to-SARBIM

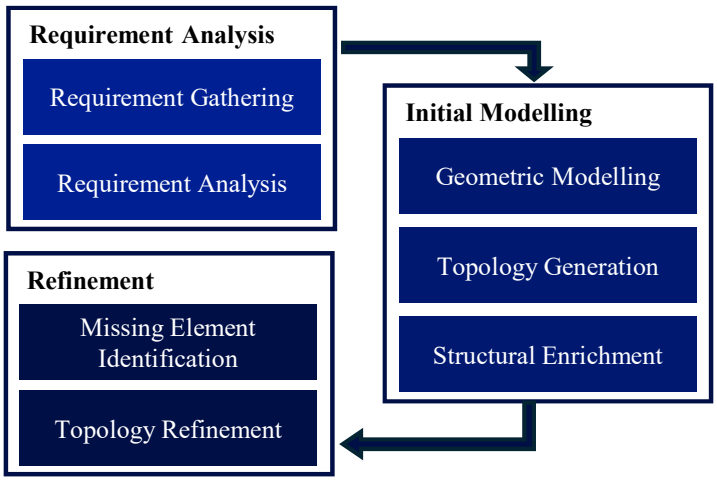
Structural Assessment



Barazzetti L. et al

METHODOLOGY

Design Science research methodology is followed.

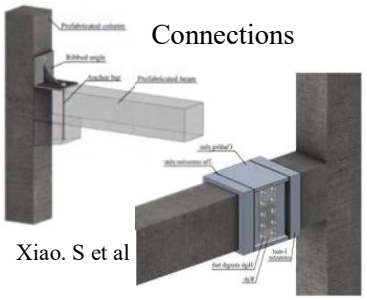


RESULTS & DISCUSSION

SARBIM requirements can be classified into four groups of 1- material and mechanical properties, 2- cross section shape, 3- reinforcement content and 4- connections types.

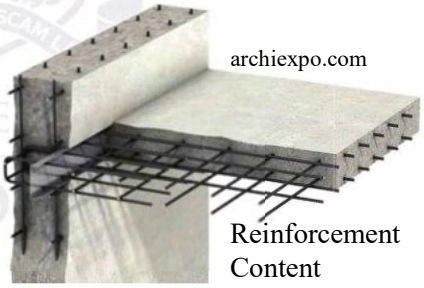
Material & Mechanical Properties

Connections



Xiao. S et al

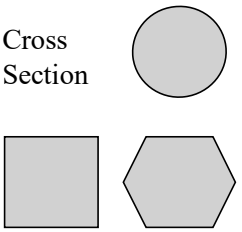
SARBIM Requirements



archiexpo.com

Reinforcement Content

Cross Section



EEE Dataset

Electrical and Electronic Engineering building of the University of Melbourne is scanned by Leica BLK360.

gharpedia.com

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Infrastructure Engineering Graduate Research Conference 2024

GreenSegNet for Vegetation Segmentation from MLS point cloud

Name: Aditya
Email: aditya1@student.unimelb.edu.au
Supervisors: A/Prof. Jagannath Aryal, Prof. Stephan Winter and Prof. Bharat Lohani (ext.)
Discipline: Geomatics

INTRODUCTION

Accurate vegetation mapping is fundamental for proper management strategies of urban forests. Deep learning (DL) models combined with mobile laser scanning (MLS) datasets have demonstrated immense potential for vegetation segmentation. However, restricted performance and inconsistent behavior across datasets by generic DL models offer notable concerns (Fig 1). Further, to capture the characteristic distribution of vegetation points towards effective segregation, a dedicated model for vegetation segmentation is essential. To address this problem, we propose a novel DL architecture, Green Segmentation Network (GreenSegNet), tailored for vegetation segmentation from MLS point cloud. GreenSegNet has been compared with seven representative DL models, namely PointCNN, KPConv, RandLANet, SCFNet, PointNeXt, SPoTr and PointMetaBase.

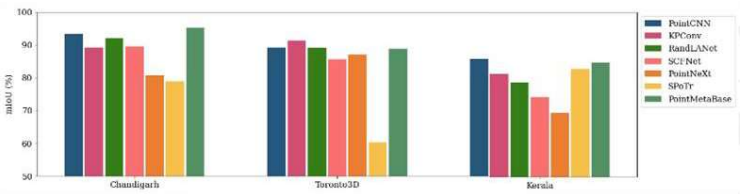

Fig 1: Performance of DL models (mIoU)

METHODOLOGY

GreenSegNet has been investigated on MLS datasets from three sites, Chandigarh, Toronto3D, and Kerala for a comprehensive assessment. The model has been tested in a ten-fold cross-validation mode to enhance the reliability of results (Fig 2). With a combination of SetAbstraction and GreenBlock, GreenSegNet adopts a hierarchical encoder-decoder structure to capture both local and global information (Fig 3).

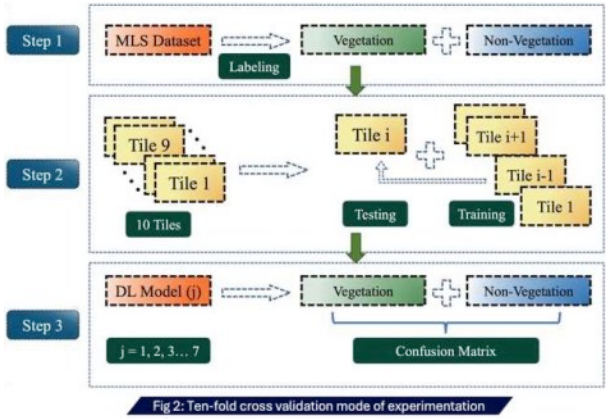

Fig 2: Ten-fold cross validation mode of experimentation

RESULTS & DISCUSSION

GreenSegNet utilizes vectorized feature representation, positional embeddings, and aggregation techniques, for enhanced segmentation. The resulting vector of vegetation has a smaller magnitude than that of non-vegetation (Fig 4). GreenSegNet has illustrated state-of-the-art (SOTA) as well as consistent segmentation performance across all the datasets, surpassing top performing DL models by a significant margin (Tab 1). Additionally, the model is quite efficient with less than one million parameters. Unlike other SOTA models, GreenSegNet is found robust across different datasets and terrains (Fig 5 and 6). Overall, GreenSegNet enables more informed decision-making in complex urban landscapes.

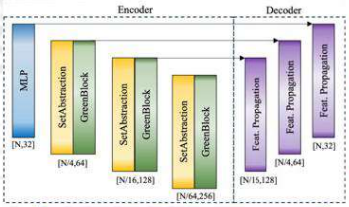

Fig 3: GreenSegNet Architecture

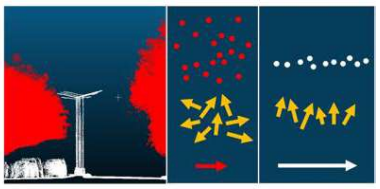

Fig 4: Vectorized Feature Representation

DL Models	Toronto3D	Chandigarh	Kerala
PointCNN	89.22	93.32	**85.68**
KPConv	**91.26**	89.16	81.14
PointMetaBase	88.69	**95.24**	84.60
GreenSegNet	**92.70**	**96.43**	**90.16**
Improvement	+ 1.44	+ 1.19	+ 4.48

Tab 1: Comparison of GreenSegNet with other top performing DL models

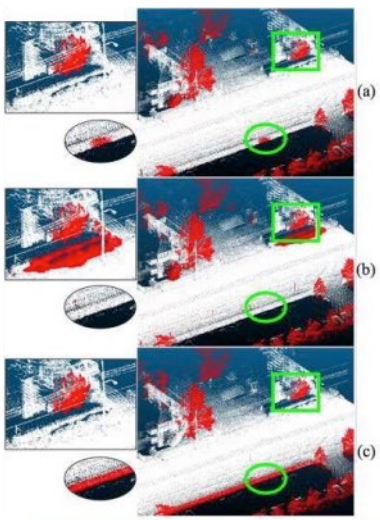

Fig 5: Segmentation results on Toronto3D dataset. Red: vegetation and white: non-vegetation: (a) GreenSegNet, (b) KPConv, and (c) Ground truth.

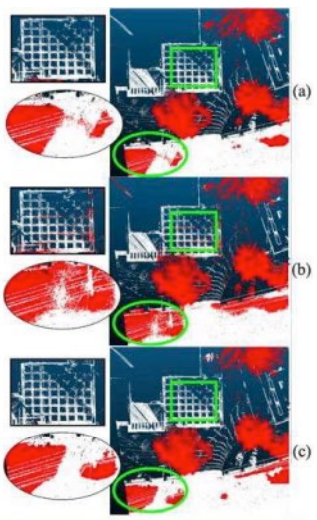

Fig 6: Segmentation results on Kerala dataset. Red: vegetation and white: non-vegetation: (a) GreenSegNet, (b) PointCNN, and (c) Ground truth.

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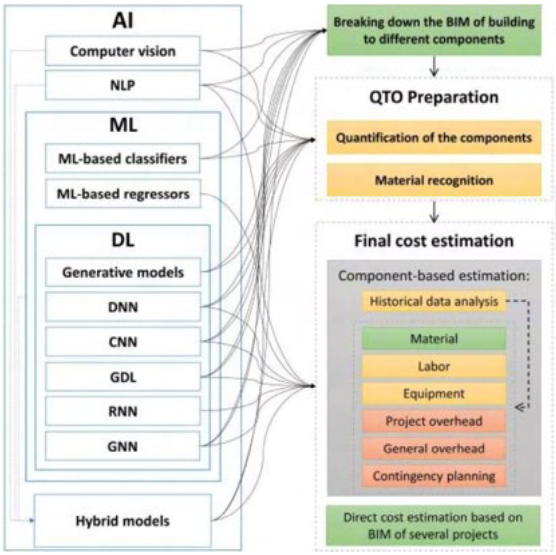
AI-augmented construction cost estimation

Name: Peyman Jafary
Email: pjafary@student.unimelb.edu.au
Supervisors: Dr Davood Shojaei, Prof Abbas Rajabifard, Prof Tuan Ngo
Discipline: Geomatics

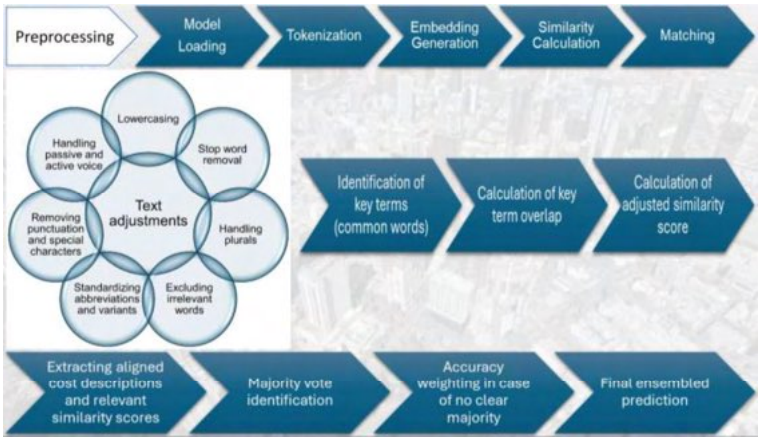
INTRODUCTION

Accurate construction cost estimation is vital for a project's financial success. Building Information Modeling (BIM) provides precise Quantity Take-Offs (QTOs), but traditional manual matching of items in QTOs with cost indexes by Quantity Surveyors (QSs) is labor-intensive and error-prone. We introduce an ensemble Natural Language Processing (NLP)-based method that automates the alignment of QTOs with cost indexes across various building classifications.

METHODOLOGY



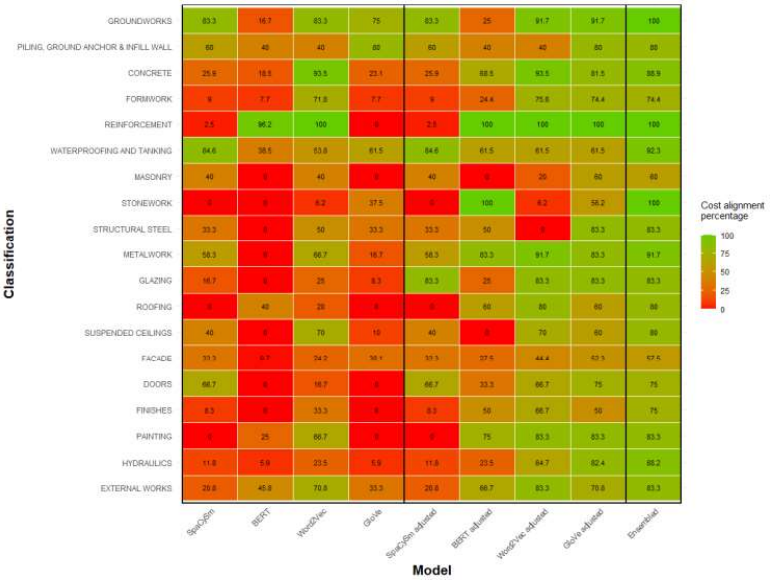
This figure portrays the possible integrations of various AI, machine learning and deep learning techniques throughout different stages of BIM-based cost estimation.



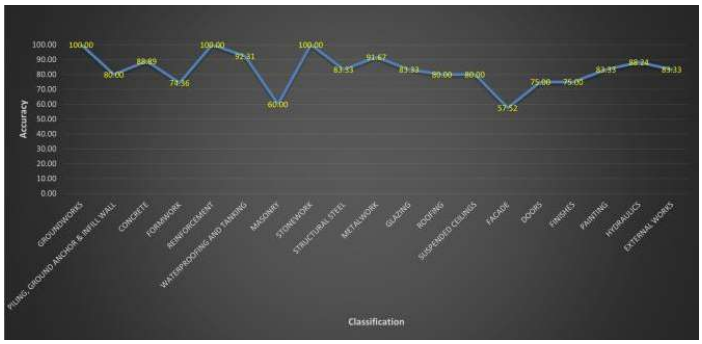
This figure presents the research method, where a series of NLP-based models that analyze textual descriptions in the QTO and align them with the relevant cost data from AIQS Building Cost Index (BCI) are established, including four initial models (spaCy, BERT, Word2Vec, GloVe), four adjusted models, and an ensemble model.

RESULTS & DISCUSSION

The performance of nine different NLP-based models was evaluated based on their ability to match building work item descriptions in QTOs with BCI item descriptions and assign the relevant costs accordingly for a 13-level residential building. To evaluate the models, the agreement percentages between the cost descriptions assigned by a QS and those predicted by the models were calculated for each classification. The ensemble model, as the best model, achieved a remarkable alignment accuracy of 82.96% across 592 items, indicating its effectiveness in capturing the semantic nuances of the descriptions and aligning them with the appropriate cost entries in the BCI.



For most classifications, the model's alignment percentage was above 80%, underscoring its robust performance across various types of work items.



The proposed AI-driven system complements QSs by serving as a notification tool, highlighting discrepancies between human and system-generated estimates. This approach aids QSs in refining their cost assessments, enhancing accuracy and mitigating potential financial risks.

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A Multi-Temporal Remote Sensing Approach to Analysing Disaster Impacts on Informal Settlements

Ricardo Camacho Castilla (rcamachocast@student.unimelb.edu.au)
Supervisor: A/Prof. Jagannath Aryal, **Co-Supervisor:** Prof. Abbas Rajabifard
Geomatics

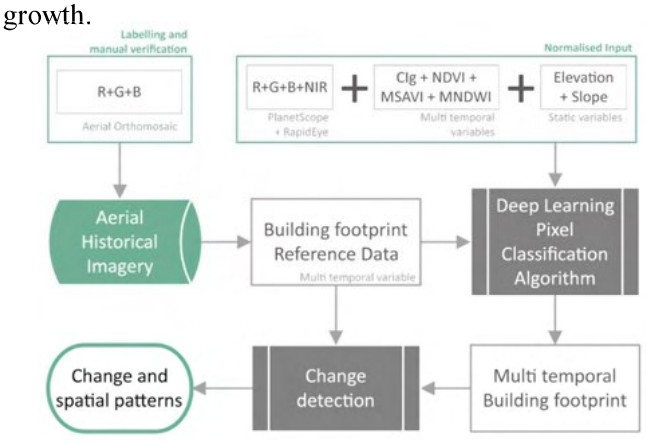
INTRODUCTION

Informal urban settlements (IUS) are a growing concern, especially in disaster-prone regions of the Global South. These communities, characterized by rapid and often unplanned expansion, are particularly vulnerable to natural hazards. The 2017 Mocoa disaster in Colombia, where landslides and mudslides devastated informal settlements, serves as a stark reminder of the urgent need for effective disaster risk reduction strategies tailored to these vulnerable communities.

This research utilizes a novel framework combining historical remote sensing data with deep learning techniques to analyse the spatial growth patterns of IUS before and after the Mocoa disaster. By examining the changes in land cover and building footprints, we can quantify the disruptive effects of such events and inform the development of disaster risk reduction strategies that prioritize the unique vulnerabilities and resilience of informal urban communities.

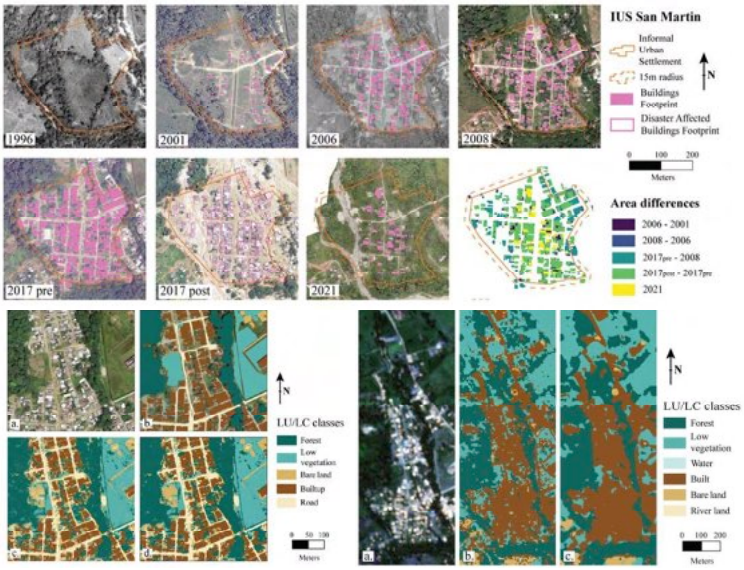
METHODOLOGY

This research analysed how the 2017 Mocoa disaster impacted informal settlement growth using historical aerial photographs (HAP), RapidEye, and PlanetScope satellite imagery. The study concentrated on changes in land cover and building footprints before and after the disaster within twelve informal urban settlements (IUS). Deep learning models (U-Net and DeepLab) were trained to classify land cover, with the best-performing model (U-Net - resnet50) selected for further analysis. Building footprints were analysed to quantify urban growth patterns, and land cover distribution changes were assessed to understand the disaster's impact on IUS growth.

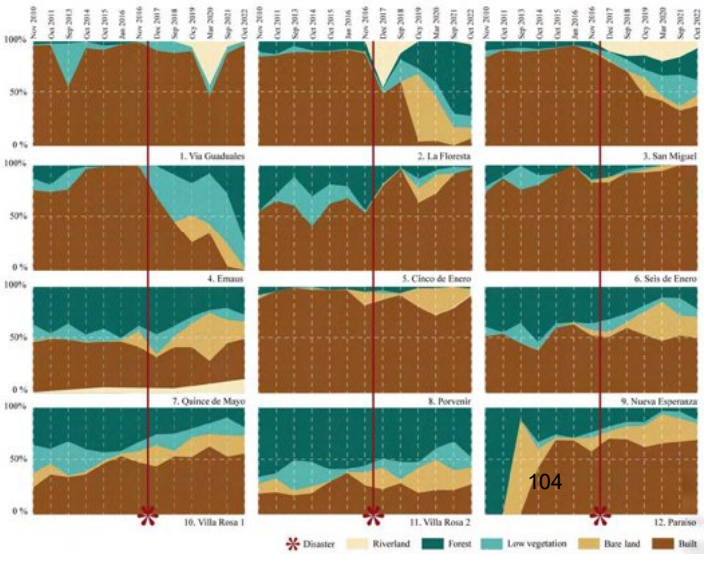


RESULTS & DISCUSSION

The analysis revealed that the 2017 Mocoa Disaster significantly disrupted the spatial growth patterns of IUS. Some settlements were completely destroyed, while others experienced substantial reductions in built-up areas. The disaster also led to the emergence of new informal settlements in hazardous zones, highlighting the urgent need for proactive urban planning and disaster risk reduction strategies.



The deep learning models employed in the study proved effective in classifying land cover, enabling accurate quantification of the disaster's impact on informal settlement growth. However, there are limitations of relying solely on high-resolution satellite imagery for detailed analysis of small, dynamic settlements.



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EQUI-GSPR: EQUI-SE(3) GRAPH NETWORK FOR SPARSE POINT CLOUD REGISTRATION

Xueyang Kang, Zhaoliang Luan, Kourosh Khoshelham, Bing Wang
The University of Melbourne, The Hong Kong Polytechnic University, Queen Mary University of London, KU Leuven

WeChat Github

INTRODUCTION

Point cloud registration is critical for 3D alignment and reconstruction. While traditional and learning-based approaches have shown success, the role of intrinsic symmetries like rotation equivariance in point cloud data has been underexplored, leading to higher data requirements and model complexity. We address this by proposing a graph neural network with local Spherical Euclidean equivariance using SE(3) message passing. Our model comprises a descriptor module, equivariant graph layers, similarity matching, and regression layers, allowing for efficient use of sparse input points and easy integration of self-trained or pre-trained geometric descriptors.

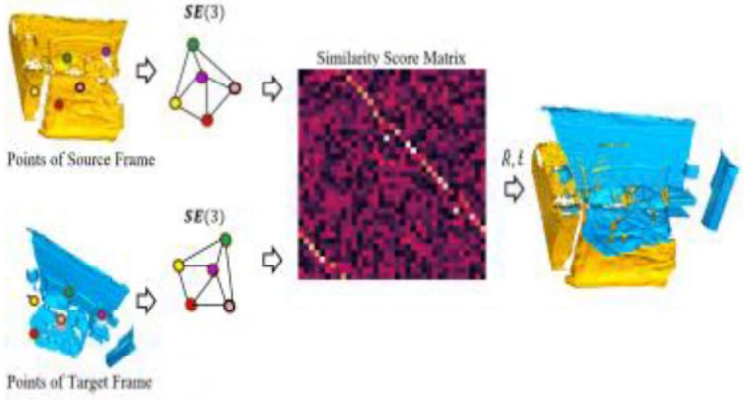

Fig. 1: The registration model converts the sparse point descriptors of the source and target frames into an equivariant graph feature representation, respectively. Then the SE(3) equivariant graph features are used for the similarity score calculation. The matched features are then decoded into the relative transform to align scans.

METHODOLOGY

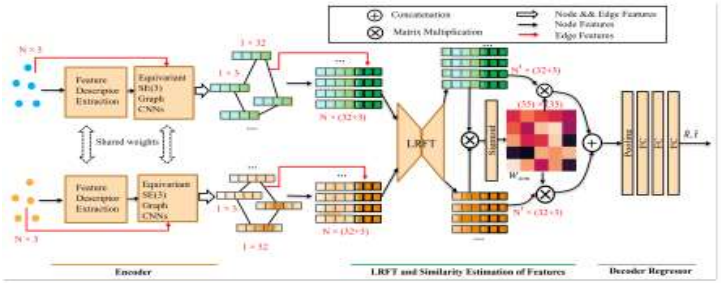

Fig. 3: The registration model consists of an encoder, a feature match block, and a decoder. Pointwise feature descriptors are extracted from the source and target scan points, passed through equivariant graph layers, and combined with coordinate embeddings to form a row-major order matrix. Next, the feature matrices from the source and target frames are compressed using our proposed MLPs-based Low-Rank Feature Transformation (LRFT). The aggregated features are used to create a similarity map through dot product of feature descriptors. In the decoder, features are weighted by similarity scores, then concatenated, and processed through pooling and fully connected layers to predict relative translation $\vec{r}_i$ and quaternion q_i^1.

$$\vec{h}_i^{l_1+1} = \frac{1}{n} \sum_{k \in \mathcal{N}(i)} f_h(\vec{h}_k^{l_1}, \vec{x}_k - \vec{x}_i). \tag{1}$$

$$\vec{m}_{ik} = \phi_m(\vec{h}_i^{l_2}, \vec{h}_k^{l_2}, \left\| \vec{x}_k^{l_2} - \vec{x}_i^{l_2} \right\|^{\frac{1}{2}}), \tag{2}$$

$$\vec{x}_i^{l_2+1} = \vec{x}_i^{l_2} + C \sum_{k \in \mathcal{N}(i)} \exp(\vec{x}_k^{l_2} - \vec{x}_i^{l_2}) \phi_x(\text{proj}_{\vec{\mathcal{F}}_{ik}} \vec{m}_{ik}), \tag{3}$$

$$\vec{h}_i^{l_2+1} = \phi_h(\vec{h}_i^{l_2}, \sum_{k \in \mathcal{N}(i)} (\text{proj}_{\vec{\mathcal{F}}_{ik}} \vec{m}_{ik})), \tag{4}$$

$$\vec{\mathcal{F}}_{ik} = (\vec{a}_{ik}, \vec{b}_{ik}, \vec{c}_{ik}), \tag{5}$$

$$= (\frac{\vec{x}_i^l - \vec{x}_k^l}{\|\vec{x}_i^l - \vec{x}_k^l\|}, \frac{\vec{x}_i^l \times \vec{x}_k^l}{\|\vec{x}_i^l \times \vec{x}_k^l\|}, \frac{\vec{x}_i^l - \vec{x}_k^l}{\|\vec{x}_i^l - \vec{x}_k^l\|} \times \frac{\vec{x}_i^l \times \vec{x}_k^l}{\|\vec{x}_i^l \times \vec{x}_k^l\|}), \tag{6}$$

$$\text{proj}_{\vec{\mathcal{F}}_{ik}} \vec{m}_{ik} = \vec{m}_{ik} = x_{ik}^{\vec{a}} \vec{a}_{ik} + x_{ik}^{\vec{b}} \vec{b}_{ik} + x_{ik}^{\vec{c}} \vec{c}_{ik}. \tag{7}$$

RESULTS & DISCUSSION

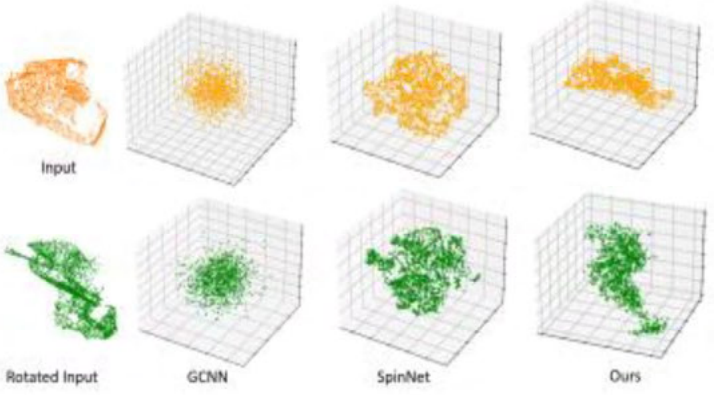

Fig. 2: The t-SNE comparisons of equi-features outputs.

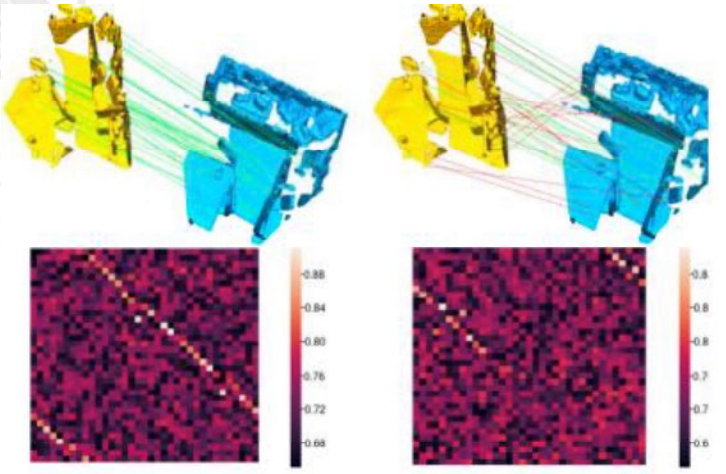

Fig. 5: This figure illustrates the comparison between correspondence results with and w/o equivariant features in gr layers horizontally, and the relationship vertically between the feature similarity score matrix and point correspondenc

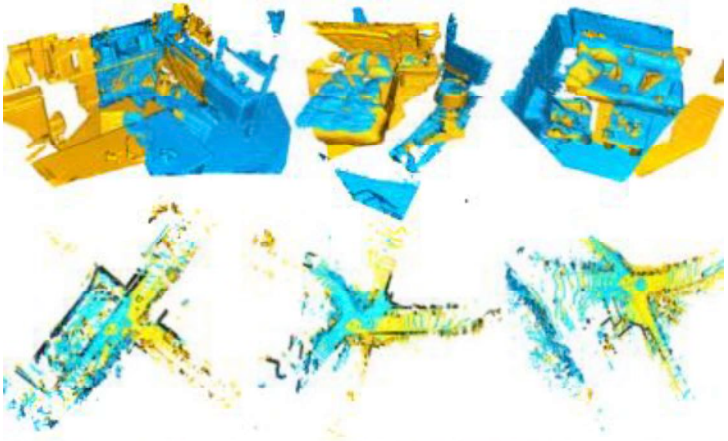

Fig. 6: The visual registration results of the proposed model on 3DMatch and KITTI are illustrated in the registrati samples. Points from the target frame are represented in blue, whereas points converted from the source frame to t target frame by the predicted transform are visualized in yellow.

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Predictive Models and Tools for Real-Time Flood Monitoring

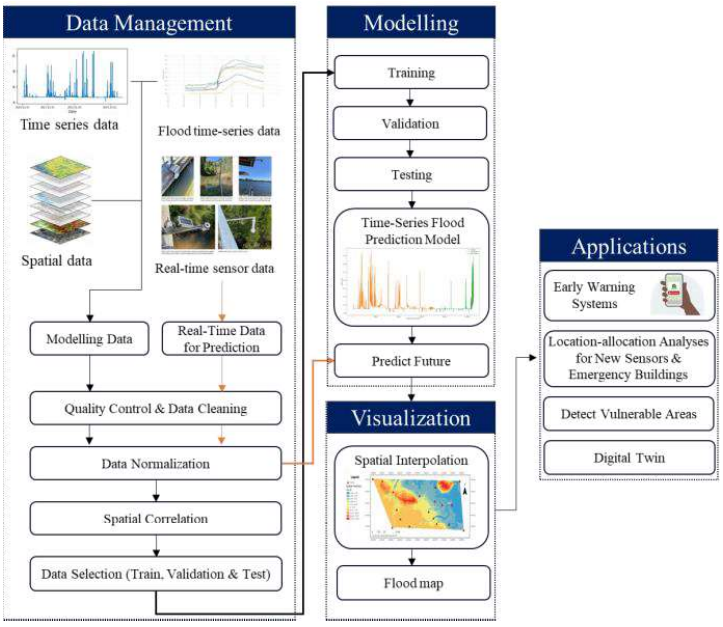
Name: Alireza Haji Heidari
Email: ahajiheidari@student.unimelb.edu.au
Supervisors: Prof. Abbas Rajabifard, A/ Prof. Jagannath Aryal.
Discipline: Geomatics

INTRODUCTION

Floods, with 44% portion of all disasters, are one of the most devastating, frequent and widespread natural disasters around the world. Floods impacted about 58 million people and caused 20,000 deaths worldwide over the past decades. In Australia, a flood-prone country, the financial damage from floods surpasses that of other natural disasters, averaging $8.8 billion per year from 2006 to 2017. Therefore, real-time flood prediction and early warning systems can play an important role in reducing damages and costs of flood. According to the World Bank, every dollar spent on flood prediction and warning systems prevents $9 in damages.

Even with the progress made in flood prediction technologies, many current models struggle to effectively combine spatial and temporal data. The complexity of flood events, influenced by both spatial elements (like topography) and temporal factors (such as water level), presents a significant challenge. Many existing models either oversimplify these factors or lack the computational power for real-time processing.

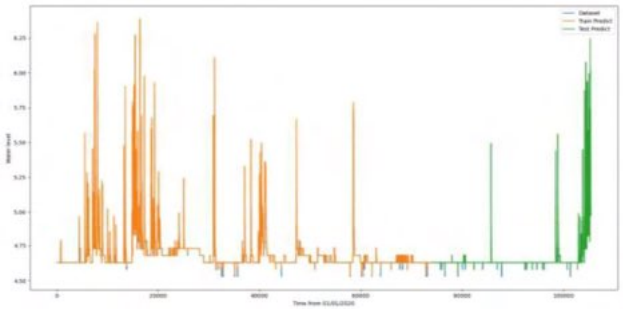
METHODOLOGY

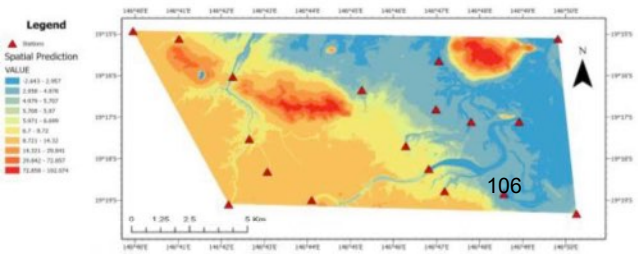


RESEARCH AIM & RESULTS

The aim of this research is to develop an AI predictive model for mapping floods by leveraging real-time data, with a particular emphasis on spatiotemporal aspects. This model will integrate various data sources, such as satellite imagery, spatial and hydrological data from sensors such as water level or rainfall time-series data, to predict floods in advance and create accurate and timely flood maps. By focusing on spatial dimensions, the model will analyse spatial patterns, features and correlations between different sensor data in the study area to predict flood-prone areas.

An AI model has been trained with water level time-series sensor data from Townsville, Queensland. The model achieved a Root Mean Square Error (RMSE) of 0.01030 meters. The study area, predictive model and spatial interpolation are shown below.





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Global localization for Mixed Reality visualization using wireframe extraction from images

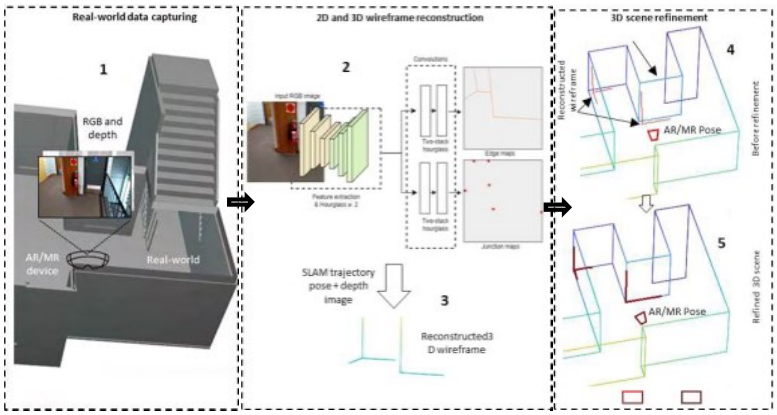
Sajjad Einizinab, Kourosh Khoshelham, Stephan Winter, and Philip Christopher

Geomatics, Department of Infrastructure Engineering, University of Melbourne

INTRODUCTION

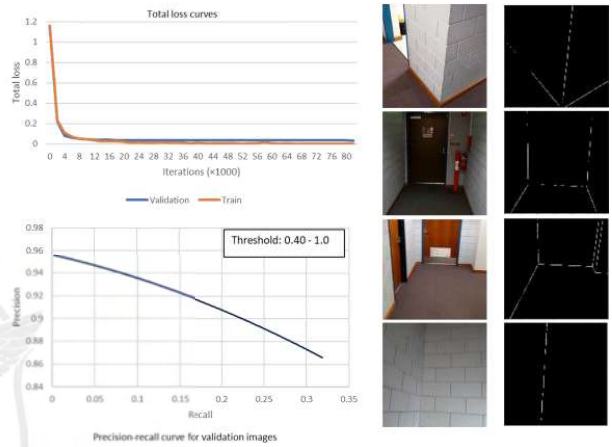
Mixed Reality (MR) global localization involves precisely tracking the device's position and orientation within a digital representation, such as Building Information Model (BIM). Existing model-based MR global localization approaches have difficulty addressing environmental changes between the BIM and real-world, particularly in dynamic construction sites. Additionally, a significant challenge in MR systems arises from localization drift, where the gradual accumulation of positional errors over time can lead to inaccuracies in determining the device's position and orientation within the virtual model. We develop a method that extracts structural elements of the building, referred to as a wireframe, which are less likely to change due to their inherent permanence. The extraction of these features is computationally inexpensive enough that can be performed on MR device, ensuring a reliable and continuous global localization over time, thereby overcoming issues associated with localization drift. Real-world experiments demonstrate the method's effectiveness in 3D wireframe extraction and alignment with the BIM, successfully mitigating drift.

METHODOLOGY

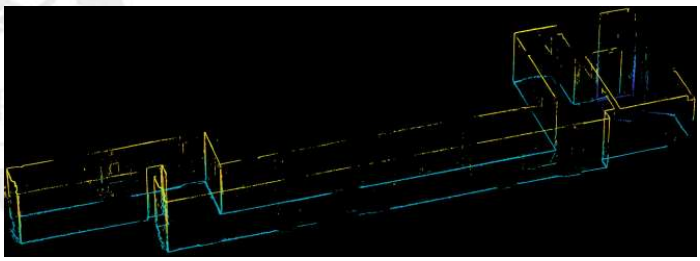


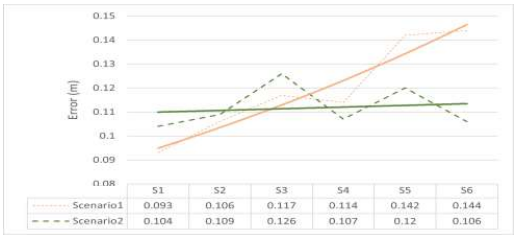
RESULTS & DISCUSSION

2D wireframe



3D wireframe





	S1	S2	S3	S4	S5	S6
Scenario1	0.093	0.106	0.117	0.114	0.142	0.144
Scenario2	0.104	0.109	0.126	0.107	0.12	0.106

- Advantages:
  - Perfect reliability in 3D model alignment.
  - Precise BIM registration with a single image.
  - Shifts registration methods to pixel domain.
  - No need for external data or servers.
  - Real-time 3D model modification capability.
  - No privacy issues; self-contained process.
- Disadvantages:
  - Deep learning requires extensive training data.
  - Wireframe absence necessitates alternative methods.
  - Relies on depth sensor's capture range.

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Low Earth Orbit (LEO)-augmented positioning in heavily GNSS signal-obstructed environments

Name: Songfeng Yang
Email: songfeng.yang@student.unimelb.edu.au
Supervisors: Dr. A. Khodabandeh, Prof. P. J. G. Teunissen, Dr. S. Zaminpardaz
Disciple: Geomatics

INTRODUCTION

The Global Navigation Satellite Systems (GNSS) can realize near real-time sub-centimeter level short baseline positioning after integer ambiguity resolution (IAR) in open-sky environments. However, such precision can be easily compromised if receivers are located in urban canyons with limited visible satellites. The deployment of thousands of Low Earth Orbit (LEO) communication satellites offers several advantages for positioning over the GNSS satellites due to their lower altitudes, including stronger signal strength and more rapid geometric changes. Thus, GNSS can be augmented with LEO measurement data to provide more reliable positioning. We investigate the performance of ambiguity-resolved positioning using LEO frequency-varying phase measurements in GNSS-challenged environments (e.g. at a satellite elevation cut-off angle of 50°), showing that centimeter-level ambiguity-resolved positioning is achievable. This performance relies on precise satellite orbit products (at the meter level) and receivers equipped with high-grade clocks (the single-differenced clock offset remains below 0.1 microseconds).

METHODOLOGY

In the absence of code data, we employ the dual-epoch phase-only model to achieve the 5-km short baseline positioning conducted via the simulation platform (see Fig. 1).

$$\mathrm{E}\left(\begin{bmatrix}\Delta\phi_t\\ \Delta\phi_{t+1}\end{bmatrix}\right)=\begin{bmatrix}G_t\\ G_{t+1}\end{bmatrix}\Delta x+\begin{bmatrix}0\\ e\end{bmatrix}\underbrace{(dI_{t+1}-dI_t)}_{\Delta}+\begin{bmatrix}\Lambda\\ \Lambda\end{bmatrix}\underbrace{(a+\Lambda^{-1}e\,dI_t)}_{\tilde{a}}$$

$$\mathrm{D}\left(\begin{bmatrix}\Delta\phi_t\\ \Delta\phi_{t+1}\end{bmatrix}\right)=\begin{bmatrix}Q_{\phi_t\phi_t} & 0\\ 0 & Q_{\phi_{t+1}\phi_{t+1}}\end{bmatrix}$$

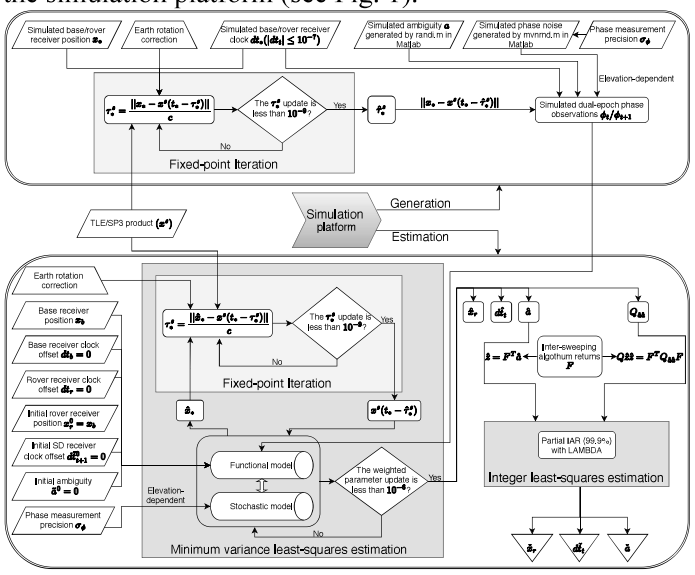


Fig. 1 Simulation platform that provides full control over the generation of parameters and measurements, followed by the estimation of estimable parameters

RESULTS & DISCUSSION

Positioning performance at a cut-off elevation of 50°

- Among 14 globally distributed stations (see Fig. 2), not all are tracking more than 4 satellites, which falls below the minimum requirement for positioning (see the inset in Fig. 3).

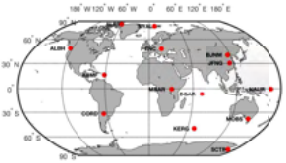


Fig. 2 Distribution of 14 stations

- Before IAR, 13 stations achieve position errors of less than *10 cm* in all three directions (see grey bar charts). After applying IAR, these stations attain *millimeter-level* accuracy in the horizontal plane and *centimeter-level* accuracy in the vertical direction (green boxes).

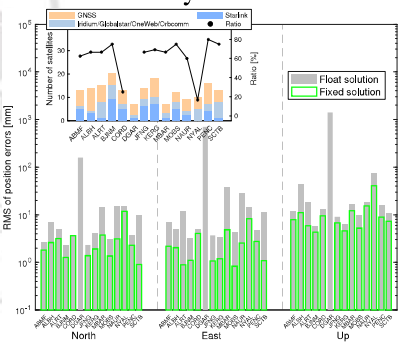


Fig. 3 RMSs (mm) of ambiguity-float positioning errors (grey bar charts) and their fixed versions (green boxes) after partial IAR. The top-left inset in each figure illustrates the available numbers of satellites for each constellation, where GNSS includes GPS, Galileo and GLONASS signals, while LEO includes Iridium, Globalstar, Starlink, OneWeb, and Orbcomm signals

Prominent role of orbit products in LEO positioning

- The five-meter biases in LEO satellite orbits (e.g. Iridium) lead to single-differenced range biases as large as 12 mm whose effect on the positioning solution is less than 6 mm (see Fig. 4).

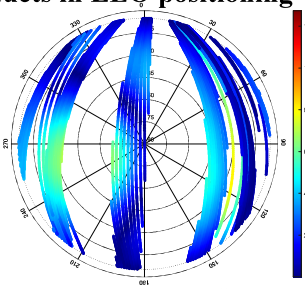


Fig. 4 Positioning solution effects caused by the 5-m orbit biases

High-grade receiver clocks required for LEO positioning

- The single-differenced clock offset must be less than 0.1 microseconds, potentially enabling IAR.
- This clock quality can be relaxed for ambiguity-float solutions, as long as it remains below 10 microseconds.

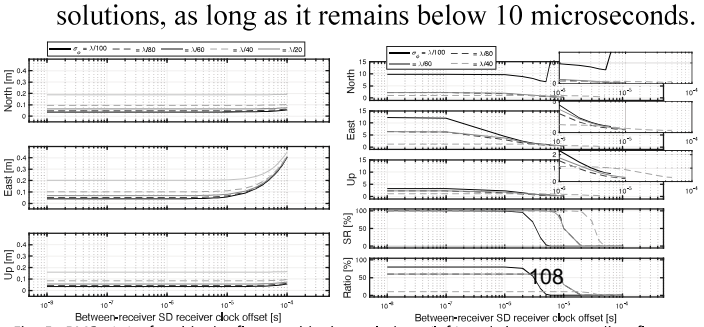
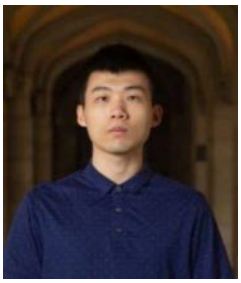


Fig. 5 RMSs (m) of ambiguity-float positioning solutions (left) and the corresponding float-to-fixed RMS ratios after partial IAR

Occupancy Grid Mapping with Uncertain LiDAR Data



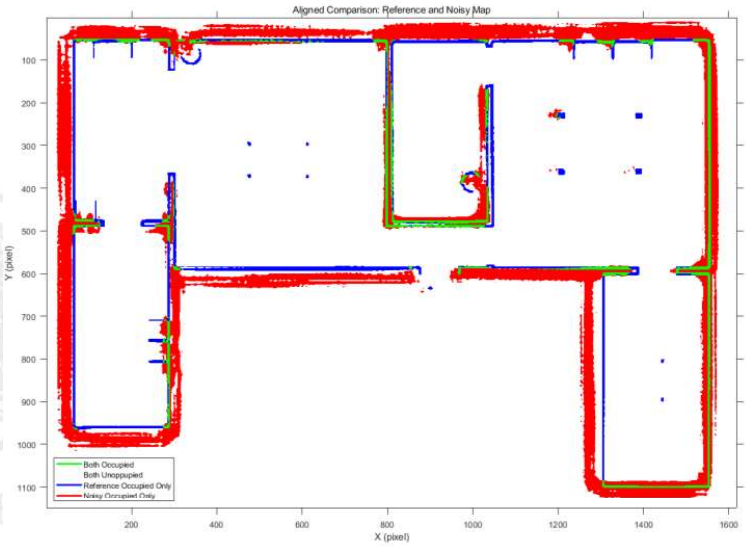
Name: Yuguang (Leo) Liu
Email: yuguangl@student.unimelb.edu.au
Supervisors: A/Prof Kourosh Khoshelham, Dr Krista Ehinger
Disciple: Geomatics

INTRODUCTION

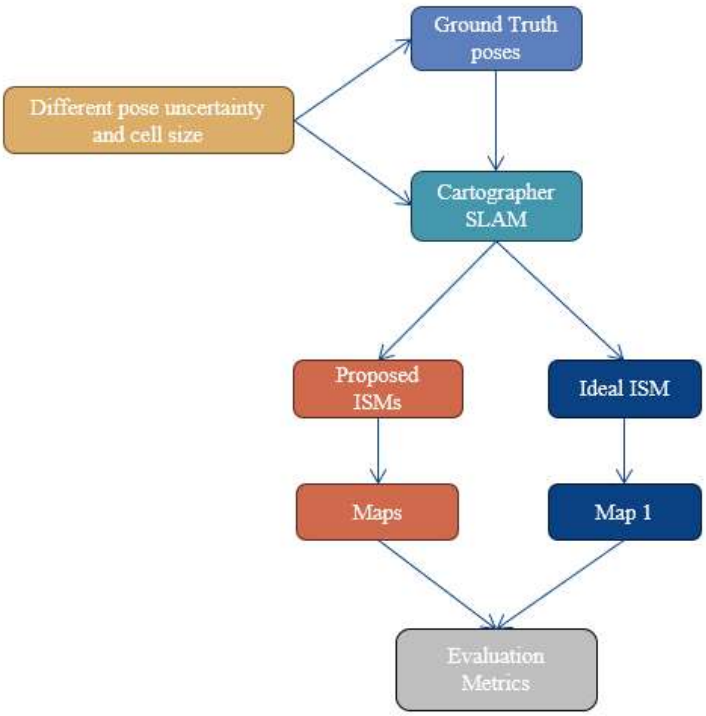
- Occupancy grid mapping using LiDAR data is a promising approach for automated generation of detailed navigation maps for autonomous driving. Conventional probabilistic mapping methods use Bayes filters to update occupancy probabilities based on sensor measurements. However, a drawback is the lack of incorporating pose uncertainty into the sensor model, which would be problematic when creating maps with noisy sensor poses, leading to map inaccuracies and expansion.
- This research aims to incorporate, quantify, and predict the impact of LiDAR pose uncertainty on 2D occupancy grid mapping methods in geometric inverse sensor models. This aim will be achieved by modifying the inverse sensor models, evaluating the impact of the uncertainty of LiDAR pose, and solving an optimization problem that how to maximize the map quality using crowd-sourced Lidar datasets.

RESULTS & DISCUSSION

- Gaussian Noise in pose: 15 cm; Cell size: 1 cm



METHODOLOGY



The figure above shows the comparison between two occupancy grid map. Cells in the two maps that have occupancy probabilities higher than 65% are considered as occupied cells. Occupied cells in the two maps are extracted. Green cells are cells that are occupied in both maps. White cells are cells that are free in both maps. Blue cells are cells that are occupied in the reference map only, and red cells are cells that are occupied in the noisy map only. It is found that the noisy map not only have thicker walls but also the position of the walls are behind the walls in the reference map, which proofs that the peak shift problem also occurs in Cartographer SLAM.

Latent-conditioned point cloud diffusion for object augmentation in driving scenes

Name: Zhengkang (Alex) Xiang
Email: zhengkangx@student.unimelb.edu.au
Supervisors: A/Prof. Kourosh Khoshelham, Dr. Amir Khodabandeh
Discipline: Geomatics

INTRODUCTION

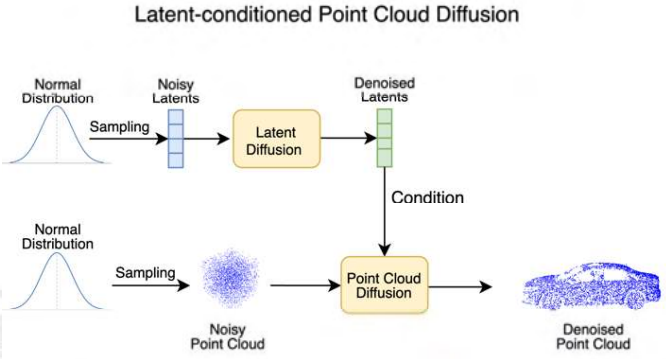
A robust 3D perception system is essential for intelligent vehicles, playing a crucial role in detecting obstacles and traffic participants. Driving scene perception is usually achieved by training machine learning models using examples of various objects on the road. However, the imbalanced distribution of road scene objects presents a significant challenge for training such systems, often causing machine learning algorithms to become biased toward majority classes, such as cars. To address this challenge, we propose the Latent-conditioned Point Cloud Diffusion model, a generative approach designed to augment minority classes in road scene objects. We present a comprehensive evaluation of the synthetic data generated by our model using two road scene perception datasets, nuScenes and ONCE. For evaluation, we incorporated both Early Stopping and Exponential Moving Average techniques to ensure accurate and stable performance assessment. Under both settings, our model demonstrated superior data augmentation performance compared to various other generative modeling architectures.

METHODOLOGY

We present Latent-conditioned Point Cloud Diffusion (L-PCD), a generative model specifically designed for data augmentation in road scene lidar objects. Our approach addresses the challenge faced by traditional diffusion models, which require large and diverse training datasets to achieve optimal performance compared to other generative models. We propose a hierarchical architecture consisting of two diffusion models: one dedicated to generating point clouds and the other focused on latent features. This design allows us to efficiently train the primary point cloud diffusion model while leveraging a latent diffusion model with lower computational complexity for minority classes.

More specifically, let X represent the lidar point clouds and Z the latent variables extracted from X using a representation learning method. $X_{minority}$ and $Z_{minority}$ denote the lidar point clouds and latent variables corresponding to the minority classes in the dataset we aim to augment. We train two diffusion models to learn P (X|Z) and P ($Z_{minority}$) respectively.

RESULTS & DISCUSSION



Dataset	Augmentation Model	F1 ± SD	Δ F1
nuScenes	None	80.74 ± 0.80	-
	GMM	81.35 ± 0.80	+0.61
	VAE	81.52 ± 0.91	+0.78
	AAE	81.56 ± 1.54	+0.82
	L-GAN	82.34 ± 1.69	+1.60
	PCD	82.25 ± 1.42	+1.51
	Ours (L-PCD)	**82.35** ± 0.53	+1.61
ONCE	None	85.80 ± 0.60	-
	GMM	86.63 ± 0.29	+0.83
	VAE	86.47 ± 0.72	+0.67
	AAE	86.80 ± 0.20	+1.00
	L-GAN	86.86 ± 0.55	+1.06
	PCD	86.59 ± 0.92	+0.79
	Ours (L-PCD)	**87.07** ± 0.63	+1.27

This dual approach helps address the challenges associated with diffusion models, particularly their need for large amounts of training data. Since training solely on the limited samples of minority classes would lead to underfitting performance, the LDM focuses specifically on learning the features of these minority classes by operating in a compressed latent space. Meanwhile, the PCD is trained on the entire dataset, ensuring that the model benefits from a comprehensive representation of all available data. By conditioning the PCD on the minority latent features learned by the LDM, L-PCD effectively balances the need for robust minority class representation with the extensive data requirements of diffusion models, overcoming the limitations posed by class imbalance.

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Strategic allocation of landmarks to reduce uncertainty in indoor navigation

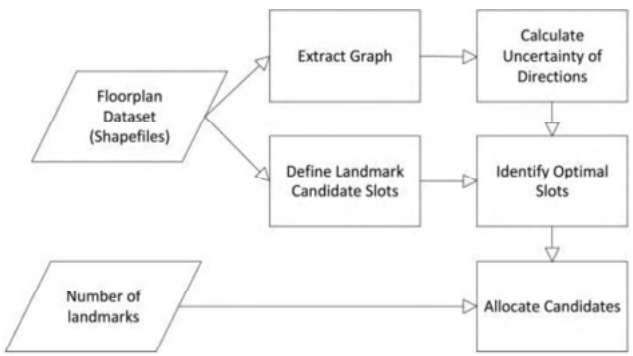
Reza Arabsheibani
arabsheibani@unimleb.edu.au
Supervisors: A/Prof Martin Tomko, Prof. Stephan Winter
Geomatics

INTRODUCTION

- Indoor navigation systems often rely on verbal, turn-based route instructions. These can, at times, be ambiguous at complex decision points with multiple paths intersecting under angles that are not well distinguished by the *turn grammar* used. Landmarks can be included into turn instructions to reduce this ambiguity. Here, we propose an approach to optimize landmark allocation to improve the clarity of route instructions. This study assumes that landmark locations are constrained to a pre-determined set of slots. We select a minimum-size subset of the set of all slots and allocate it with landmarks, such that the navigation ambiguity is resolved. Our methodology leverages computational geometric analysis, graph algorithms, and optimization formulations to strategically incorporate landmarks into indoor route instructions. We propose a method to optimize landmark allocation in indoor navigation guidance systems, improving the clarity of route instructions at complex decision points that are inadequately served by turn-based instructions alone.

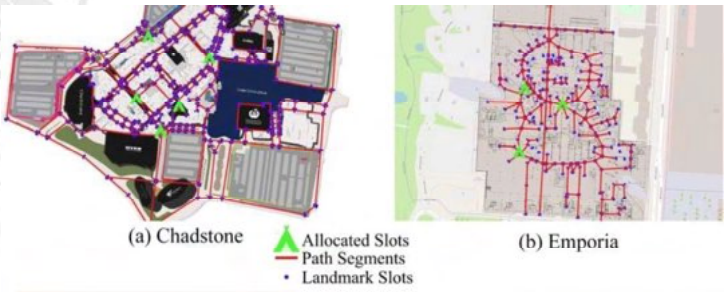
METHODOLOGY

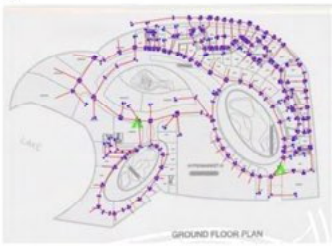
- Combining Techniques: The approach integrates computational geometry and optimization to allocate landmarks in indoor environments.
- Quantifying Uncertainty: Criteria are developed to quantify path segment uncertainty for effective landmark allocation.
- Optimization: An integer linear programming model is used to maximize uncertainty reduction while minimizing the number of landmarks.

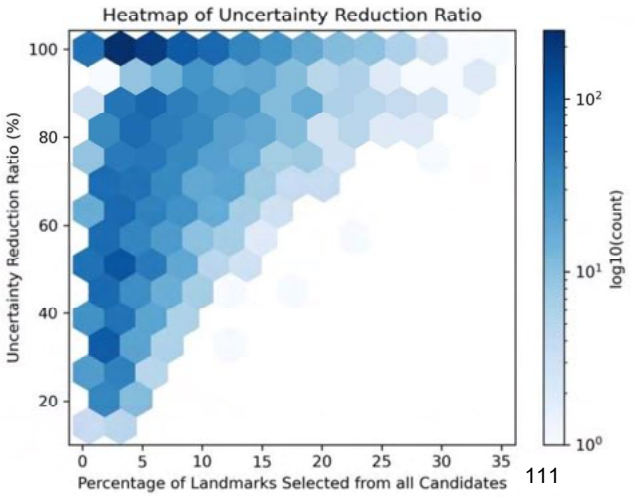


RESULTS & DISCUSSION

- Our results show that by strategically allocating landmarks, we reduced navigation uncertainty by 95% while using only 8% of available landmark slots across 742 complex indoor environments. This approach balances efficiency and clarity.







Zero Velocity Detection using Ultra Wide Band (UWB) and Inertial Sensors

Name: Ashwani Kumar
Email: askumar@student.unimelb.edu.au
Supervisors: A/Prof. Kourosh Khoshelham, Dr. Amir Khodabandeh, Dr. Salil Goel
Discipline: Geomatics

INTRODUCTION

Foot-mounted inertial navigation is a promising indoor positioning technique used for navigation, mapping, tracking first responders, and gait analysis. It employs Inertial Measurement Units (IMUs) on users' feet for location estimation but faces challenges like error accumulation and drift. To address these issues, Zero Velocity Update (ZUPT) identifies stationary intervals to update the Kalman filter. This stationary interval is referred to as zero velocity phase. we propose to integrate a foot-mounted IMU with dual foot-mounted Ultra Wide Band (UWB) sensors to perform zero velocity detection. UWB sensors provide inter-foot distance at each time instant which can be utilized to perform accurate zero velocity detection. The use of UWB sensors along with inertial sensors can help to remove limitations present in earlier methods like tedious process of threshold estimation, requirement of large amount of data and use of overly complex algorithms. To satisfy these requirements a new approach has been generated which uses dual foot mounted ultra-wide band (UWB) sensor along with the IMU to perform zero velocity detection.

METHODOLOGY

From previous studies and experiments, it has been found that during heel strike event and during heel off event the distance between the feet is maximum. To utilize this information UWB sensor is used. The approach leverages the distance measurements between two UWB sensors mounted on each shank of a user. The method identifies the number of steps by detecting minima points in the periodic UWB data, which correspond to foot movements during walking. These detected minima are used for step detection and are verified against ground truth observations for multiple subjects, showing accurate results. The UWB data is then smoothed using a 2nd order Savitzky-Golay filter, and maxima points between detected minima are extracted, representing heel strikes and toe-off events. These maxima points are further used to detect zero velocity by fusing this information with information obtained from IMU sensor. The accuracy of this approach is validated using ground truth labels from manual camera data annotation.

RESULTS & DISCUSSION

The method was evaluated in an experiment with four human participants at a single speed, yielding IoU scores ranging from 0.54-0.81, and F1 scores ranging from 0.70-0.90. These promising results indicate that the potential of UWB sensor-based zero velocity detection approaches warrants further exploration as a possible replacement for current inertial sensor-based methods.

Person	Gender	Height (cm)
Subject 1	Male	168
Subject 2	Female	154
Subject 3	Male	181
Subject 4	Female	160

Table 1: Characteristics of Subjects

Person	Steps Taken (Ground Truth)	Steps Taken (UWB Data)
Subject 1	75	75
Subject 2	164	166
Subject 3	106	106
Subject 4	102	102

Table 2: Number of steps taken by each subject in equal time

Person	Precsion	Recall	F1 score	IoU
Subject 1	0.99	0.74	0.85	0.73
Subject 2	0.91	0.57	0.7	0.54
Subject 3	0.92	0.88	0.9	0.81
Subject 4	0.85	0.85	0.85	0.74

Table 3: Results

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Open Mutual Learning: Ensemble of CNNs for urban building footprint extraction with open data

Bipul Neupane (bneupane@student.unielb.edu.au)
Supervisor: A/Prof. Dr Jagannath Aryal
Co-supervisor: Prof. Abbas Rajabifard
Discipline: Geomatics

INTRODUCTION

- Building footprint extraction (BFE) is important to create inventories for urban planning and monitoring, among other applications.
- Problem: Openly available building footprint data products such as Microsoft Building footprints (MBF) and OpenStreetMaps (OSM) are incomplete and are misaligned from actual footprints (see *Fig. 1*)
- Proposed solution: *Open Mutual Learning* to leverage from commercial data to enhance the models trained on open datasets.

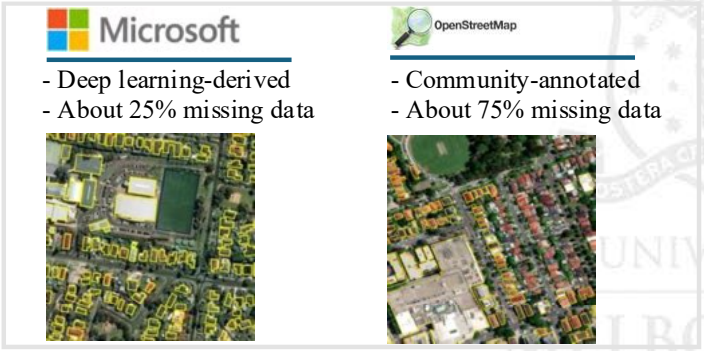


Fig. 1: Open building footprint data products in Australia and the number of missing building footprints in the study area of Chatswood, NSW.

PROPOSED METHOD

1. *Train Teacher:* Pre-train a deep learning model on a large building footprint dataset from Melbourne.
2. *Distil Students:* Distil three Students with smaller training data from OSM, MBF, and commercial GB dataset from Geoscape. During distillation, aggregate each Student's loss using a weighted average; weights being calculated as *Softmax* of penalties and rewards depending on the completeness of the small datasets.

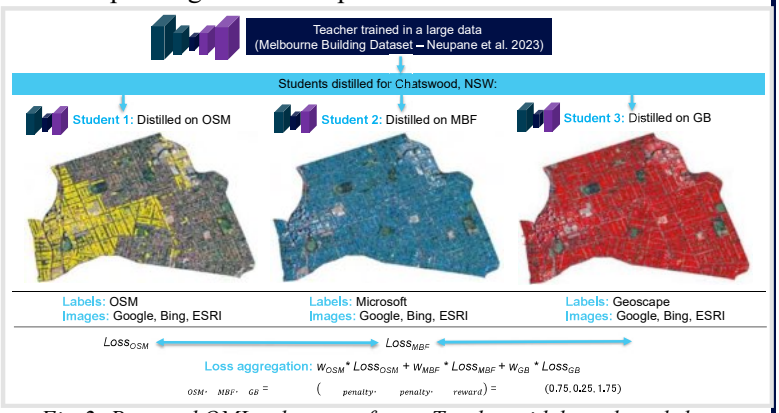


Fig. 2: Proposed OML to leverage from a Teacher with large knowledge base and a Student trained on an accurate commercial dataset (GB), among other Students trained on incomplete open datasets (OSM, MBF).

EXPERIMENTS

- Evaluate the performance of the Teacher trained on Melbourne Building Dataset (MELB).
- Experiment against existing deep mutual learning (DML). Evaluate OML with U-Net built upon state-of-the-art CNN networks: Large Teacher model of U-Net with EfficientNetv2L (from Google) and Smaller Student model of U-Net with MobileViT (from Meta).
- Investigate if the performance of Students can be increased with OML

RESULTS & DISCUSSION

Teacher (U-EfficientNetv2L) is pre-trained on Melbourne Building Footprint dataset with IoU of 85.6% and F1 score of 91.6%. The samples are shown in *Fig. 3*.

Fig. 3: BFE from Teacher on the MELB dataset.

OML between Teacher and Students (OSM, MBF, and GB) dataset resulted in (1.4, 6.6, 5.8%) gain in IoU and (1.0, 6.0, 4.5%) gain in F1 score respectively, when compared to DML. The output sample are shown in *Fig. 4*.

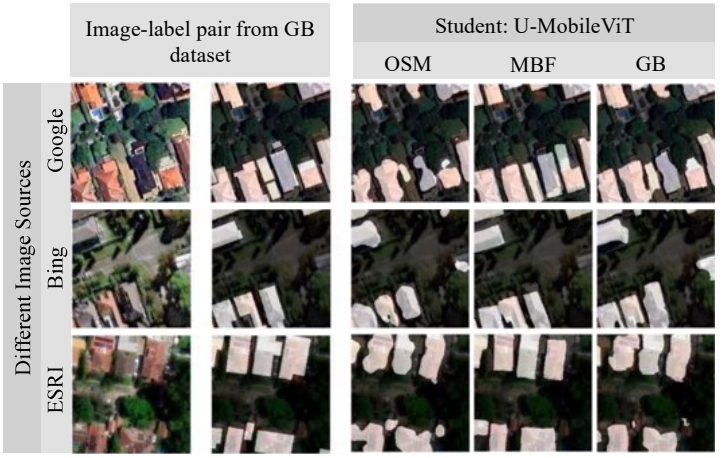


Fig. 4: BFE from Students distilled on OSM, MBF, and GB datasets.

CONCLUSION: Accurate building footprint was achieved with OML by leveraging from existing large datasets and accurate commercial dataset. The Student distilled on Microsoft's dataset gained the most (6.6% gain in IoU) from the proposed OML.

Full paper:

Open World Object Detection with Vision-Language Model

Name: Zizhao Li
Email: zizhao.li1@student.unimelb.edu.au
Supervisors: A/Prof. Kourosh Khoshelham, A/Prof. Joseph West
Discipline: Geomatics

INTRODUCTION

Traditional object detection methods operate under the closed-set assumption, where all object categories encountered after deployment are known during training. This assumption is unrealistic and potentially dangerous for applications like autonomous driving. Open World Object Detection (OWOD) enables an object detector to identify unknown objects and incrementally learn new classes. Existing OWOD methods are typically based on a two-stage object detector, which first generates class-agnostic object proposals for all foreground instances and then uses an open-set classifier to distinguish known classes and reject unknown ones. During incremental learning, the replay strategy is employed to prevent catastrophic forgetting. However, the rise of vision-language models has introduced a new approach to OWOD. For instance, CLIP-based models make predictions by matching the cosine similarity between text and image embeddings. Large-scale pre-training enables these models to extract high-quality embeddings, making it possible to reject unknown inputs and learn new classes by adjusting text prompts or embeddings.

METHODOLOGY

We propose a novel OWOD method based on Yolo-World. Specifically, we design a contrastive learning module (MSCAL) to reject unknown objects. The object detection process is divided into the following steps: 1. Define N known classes as prompts and use the CLIP text encoder to extract text embeddings. 2. Use the image encoder to extract multi-scale image embeddings. 3. Fuse the text embeddings and multi-scale image embeddings in the multi-modal neck to create a feature pyramid. 4. Pass the feature pyramid through N MSCAL modules to compute OOD-ness. Each position in the feature pyramid is mapped into a lower-dimensional space and then compared with class anchors by computing the inner product. The model is trained to maximize the inner product between an embedding and its corresponding class anchor. Unknown objects, which do not belong to any class, are identified by a lower maximum inner product. 5. Refine the prediction based on the computed OOD-ness. For incremental learning, new text embeddings and MSCAL modules are added to accommodate new classes.

Figures / Results

Figure 1: Overall Architecture of our method. The model takes image and text as input, and outputs are dense predictions of class probabilities, OOD scores, and bounding boxes.

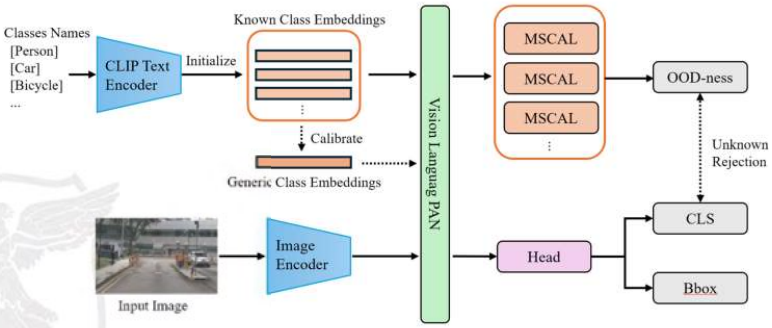


Figure 2: Details of the MSCAL module, which maps the feature pyramid to a lower-dimensional space and calculates OOD scores.

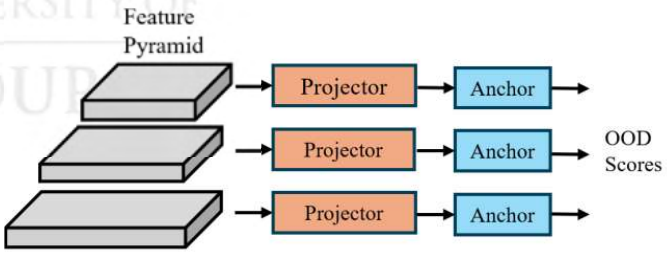
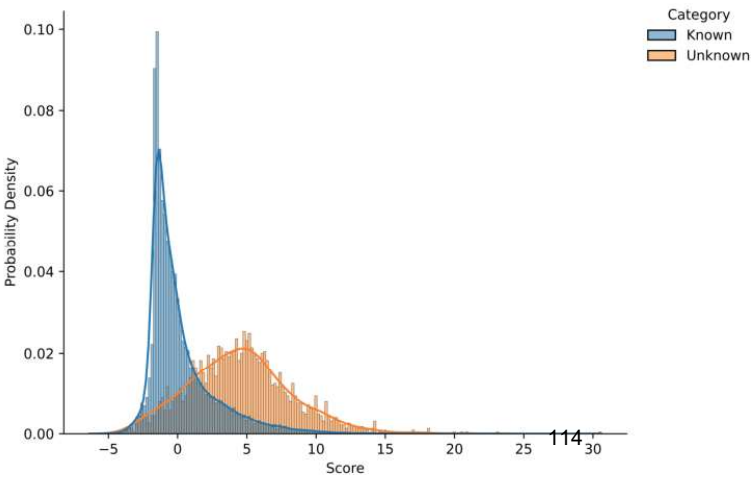


Figure 3: Probability density of known and unknown data. In OWOD, the model assigns an out-of-distribution (OOD) score to indicate how unknown an object is. As shown below, our method demonstrates clear separation between known and unknown classes..



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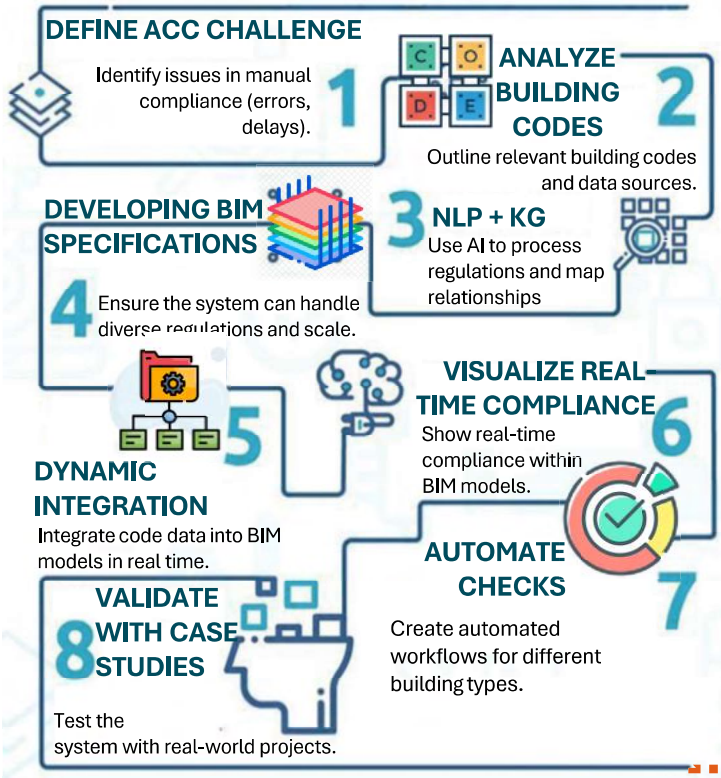
AI-Driven BIM Model Requirements for Automated Building Code Compliance

Nikoo Mirhosseini
Email: smirhosseini@student.unimelb.edu.au
Supervisors: Dr. Davood Shojaei, Dr. Soheil Sabri
Discipline: Geomatics

INTRODUCTION

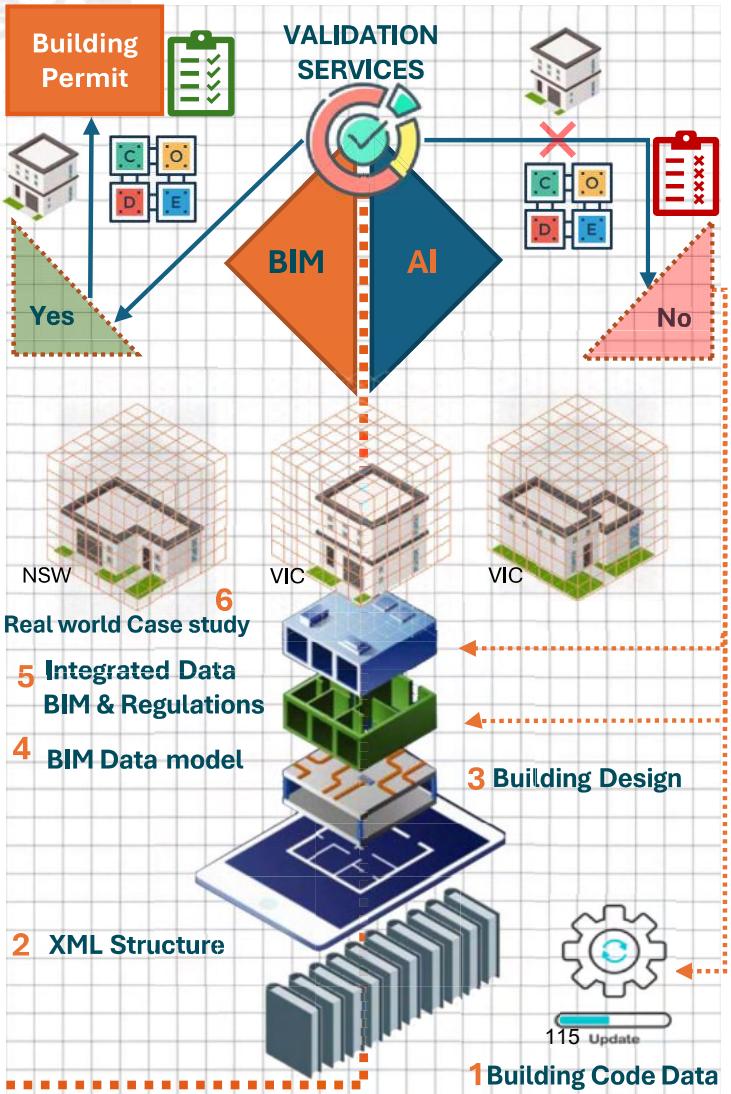
Manual building code compliance checks are time-consuming and error-prone, especially with increasing complexity in modern construction. This research presents an AI-driven framework integrating BIM, NLP, and Knowledge Graphs to automate building code interpretation. By enabling real-time compliance checks, the framework accelerates project timelines, reduces costs, and minimizes human errors.

METHODOLOGY



RESULTS & DISCUSSION

Significant improvements were observed with the AI-driven framework compared to traditional methods. Compliance accuracy increased, human errors were reduced, and project timelines were shortened due to real-time BIM model updates. The integration of NLP and Knowledge Graphs allowed for a deeper and more accurate interpretation of complex regulations, streamlining the process for various building classifications and regional adaptations. The framework's adaptability ensures a seamless compliance check across different projects, offering tangible improvements in cost savings and safety outcomes. Future work will focus on refining the framework for broader industry application and deeper integration with evolving regulations.



Above-ground biomass estimation using 3D synthetic data

Name: Habib Pourdelan
Email: Hpourdelan@student.unimelb.edu.au
Supervisors: A/Prof Khoshelham, A/Prof Tomko
Disciple: Geomatics

INTRODUCTION

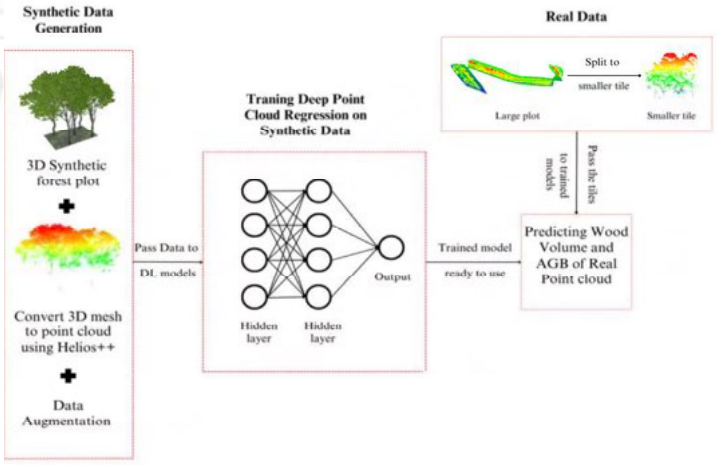
The increasing concentration of atmospheric carbon dioxide (CO_2) is a major contributor to global warming, and forest ecosystems play a critical role in mitigating this effect by serving as significant carbon sinks. Accurately estimating forest aboveground biomass (AGB) is essential for understanding carbon sequestration, as forests store nearly half of the Earth's terrestrial carbon. However, traditional methods for biomass estimation, while accurate, are labor-intensive and constrained by scale. This study addresses these limitations by employing synthetic LiDAR data combined with deep learning models to estimate AGB more efficiently. The use of synthetic data enables the creation of scalable, diverse training datasets, while deep learning techniques provide a powerful tool for directly estimating biomass from point clouds. This approach not only increases the accuracy of biomass estimation but also offers a more practical solution for large-scale forest monitoring and carbon accounting.

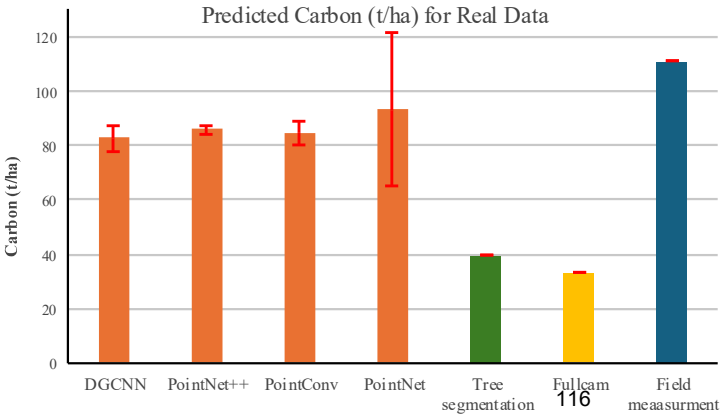
METHODOLOGY

To achieve the objective of accurately estimating AGB and carbon stocks, the study involved generating synthetic 3D forest plots that were converted into point cloud data. These point clouds were used to train deep learning models, including PointNet++, DGCNN, PointNet, and PointConv, which were specifically designed to estimate wood volume. This wood volume data was then converted into AGB and carbon using species-specific wood density values for eucalyptus trees. After models trained, we used the models on real-world data from the Melville Forest to predict wood volume and AGB and carbon. Point cloud data of this site was captured, and carbon stocks were measured through three distinct methods: indirect measurements, the FULLCAM model, and field measurements. By comparing the deep learning models' estimates against these traditional methods, we seek to evaluate the models' performance in real-world settings. This comprehensive comparison will help determine the accuracy and robustness of the deep learning approaches in providing reliable estimates of forest biomass and carbon stocks across diverse data types.

RESULTS & DISCUSSION

On synthetic data, PointNet++ achieved the best performance with a mean validation loss of 0.023 ± 0.005 and a MAPE of 1.44% ± 0.18%, followed by DGCNN with a validation loss of 0.038 ± 0.004 and a MAPE of 1.63% ± 0.06%. PointConv recorded a validation loss of 0.041 ± 0.007 and a MAP of 1.70% ± 0.14%, while PointNet had a validation loss of 1.069 ± 0.038 and a MAPE of 9.00% ± 0.19%. In terms of carbon estimation on real data, PointNet++ (85.80 ± 1.38 t/ha), DGCNN (82.65 ± 4.92 t/ha), PointConv (84.63 ± 4.33 t/ha), and PointNet (93.32 ± 28.09 t/ha) all outperformed traditional methods like indirect measurement and FullCAM, which underestimated carbon stock by 64.4% and 70.3%, respectively. The use of synthetic data enabled the generation of diverse and scalable datasets for model training, though domain shift between synthetic and real data remains a challenge.





Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 05 – Morning session- Ocean Engineering + Energy +Engineering Management

Session chair: Dr Joey Voermans

Presentation title	Presenter
Optimizing Sea State Estimates from Vessel Motion	Anran Duan
Transfer Function for Adaptive Methods of Estimating Directional Spectra Using a Fully Nonlinear Wave Model	Omar Zain Torres Rios
Numerical simulations of ocean surface waves along the Australian coast with a focus on the Great Barrier Reef	Xianghui Dong
Evaluating Hindcast Accuracy for Swell Arrival Times in the Indian Ocean	Xiaoyu Sun
Submerged Floating Tunnel High-Potential Energy System	Wei Lin
Advancing Retrofit Building Designs: A Multi-Objective Optimization Approach for Climate Change Adaptation	Duc Minh Le
Mult-objective Optimisation of Pre-treatment Process for Anaerobic Digestion of Household Food and Garden Waste	Kexin Hu
Depth-Varying Non-Uniform Corrosion effects on Marine Concrete Pile structures	Rishwanth Darun A S
Effects of gait at different walking speeds on bone fracture healing in patients with various body weights	Qianjun Ding
Toward Engineering Education Transformation with Threshold Learning in First Nations Australian Engineering	Aurora Greane

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Forum 05 – Afternoon session- Transport

Session chair: Prof Russel Thompson

Presentation title	Presenter
Modelling the effects of travel time use on mode choice and the value of travel time savings	Ana Luiza Santos de Sa
ETA Predictions for Physical Internet Hubs	Anshul Vijay
AI-Driven Audio Signal Processing Applied in Intelligent Transportation Systems	Hossein Parineh
Investigation on the effects of road pricing on road safety	Humberto Barrera-Jimenez
Electric Vehicle Charging Access: User Perspectives and Implications to Accessibility	Isrrah Malabanan
Feature-Aware Unsupervised Detection of Important Nodes in Graphs	Mohammadreza Ghanbari
AI-Powered transit simulator: Integration between microscopic simulation and machine learning	Mustafa Rezazada
General algorithm of assigning raster features to vector maps at any resolution, size or scale	Nan Xu
Developing a hyperconnected and resilient logistic network design for peri-urban freight transportation	Simon Anthony Lorenzo
Modelling the effects of travel time use on mode choice and the value of travel time savings	Ana Luiza Santos de Sa
ETA Predictions for Physical Internet Hubs	Anshul Vijay
AI-Driven Audio Signal Processing Applied in Intelligent Transportation Systems	Hossein Parineh

Optimizing Sea State Estimates from Vessel Motion

Name: Anran Duan
Email: anrand@student.unimelb.edu.au
Supervisor: Prof. Alessandro Toffoli
Discipline: Ocean Engineering

INTRODUCTION

Studying the interaction between ocean waves and sea ice cover is essential for ensuring safety operations within the polar region and investigating the effects of climate change. However, while spectral wave modelling in open ocean areas has achieved high accuracy, modelling in the marginal ice zone remains challenging and is associated with relatively large errors. This challenge primarily stems from the limited availability of observations of waves in sea ice.

In this study, extensive ship motion datasets collected from on-board inertial measurement units (IMU), during voyages in the Southern Ocean are utilized to derive wave spectra for analysing wave-in-ice properties. This extensive dataset offers an opportunity to calibrate wave models in simulating wave attenuation within the MIZ.

METHODOLOGY

The encounter spectra, directly observed from the advancing ship, are corrected for two sources of distortion to restore the wave spectra:

1. The First source of distortion to the wave spectrum is the Doppler effect, which occurs due to the relative motion of the ship with respect to the ocean waves. Therefore, the spectrum in the encounter domain, observed from an advancing ship, needs to be transformed to the absolute domain, corresponding to observations from a fixed point.

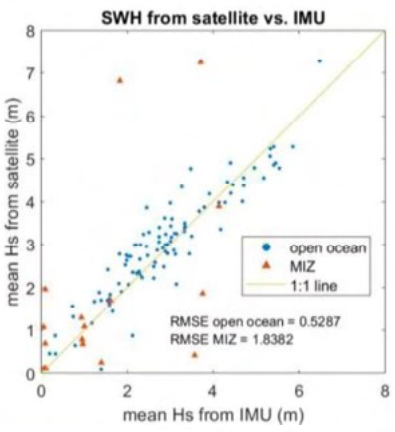
2. The second challenge in reconstructing the full wave spectrum is that the ship acts as a filter for high-frequency components of the actual wave, preventing accurate measurement of high-frequency waves. To address this, we adopt the wave-buoy analogy (WBA) method to restore high-frequency waves.

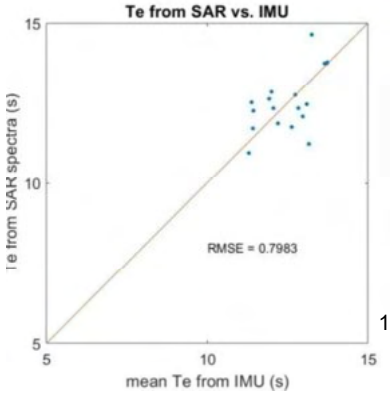
RESULTS & DISCUSSION

After a trial-and-error process to estimate the RAO by adjusting the ship's draft, we achieved the minimum RMSE between Hs^{IMU} and Hs^{sat}. The figure below shows the comparison of Hs^{IMU} and Hs^{sat} over open ocean and MIZ separately, based on the ice concentration from the satellite. The RMSE of Hs is 0.53m over the open ocean and 1.84m within the MIZ. The classification of measurements from open ocean or MIZ may not be entirely accurate, as the ice concentration measurements from satellites may not be precise.

Additionally, SAR spectra from satellites are used for validating the energy wave period (Te) from our measurement. However, due to the scarcity of SAR spectra, only a few matches the measured spectra. As shown in Figure 6, the comparison of both datasets shows a good correlation, with an RMSE of 0.8s.

In the next stage, the wave spectra will be used to analyse wave-in-ice properties. Wave attenuation within the MIZ will be examined and correlated with ice characteristics.





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Transfer Function for Adaptive Methods of Estimating Directional Spectra Using a Fully Nonlinear Wave Model

Name: Zain Torres
Email: otorresrios@student.unimelb.edu.au
Supervisors: Prof. A. Babanin, Prof. Sannasiraj, Dr. I. Young
Disciple: Ocean Engineering

INTRODUCTION

- The directional-frequency wave spectrum (DWS) describes ocean waves and is vital for navigation safety, offshore structure design, wave energy converters optimization, and understanding climate impacts due to wave dynamics. However, estimating the DWS is still a challenge due to ocean variability and limited surface data measurements. Commonly employed methods that rely on punctual measurements, such as buoys and gauge arrays, often depend on assumptions that may limit the accuracy of estimations, particularly in estimating wave propagation distribution. This study evaluates these methods by comparing them against the true spectrum obtained from Fourier analysis of a simulated surface generated by a fully nonlinear wave model. The model captures realistic nonlinear interactions in the wave field making it ideal to simulate different sea states. The aim is to assess the performance of different estimation methods specifically in estimating the spreading distribution. Based on the resulting spreading coefficients, we propose a transfer function for each method analyzed in the present study.

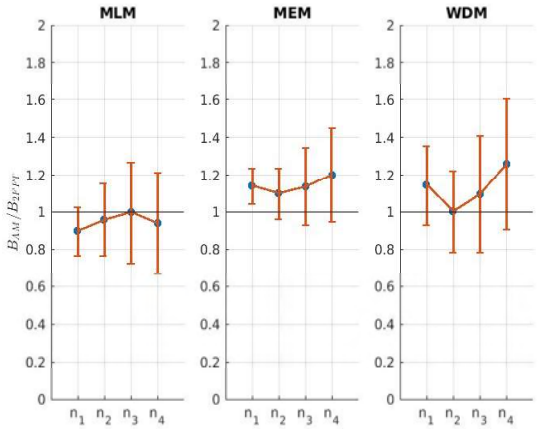
METHODOLOGY

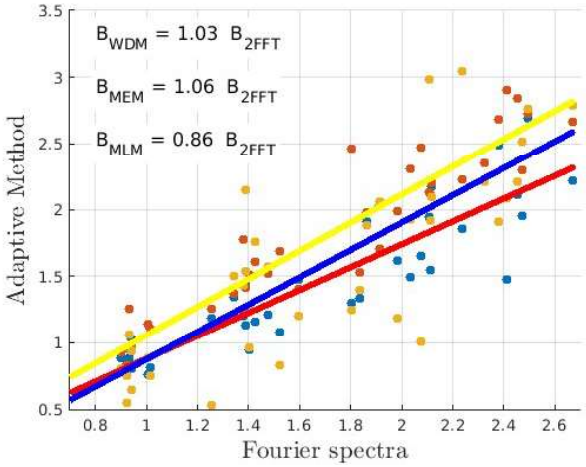
- The estimations of the DWS are conducted using adaptive methods, including the Maximum Likelihood Method (MLM), Maximum Entropy Method (MEM), and Wavelet Directional Method (WDM). These are applied to timeseries extracted from the simulated surface at various locations. We used the Fourier transform of the simulated surface as a reference for evaluating the efficacy of these methods. Our focus is on spreading coefficient *B*, which quantifies the distribution of wave propagation directions in the DWS. This coefficient allows us to estimate and quantify the differences in spreading distribution obtained from the adaptive methods in contrast with the Fourier spectra, from which we develop a transfer function to represent the performance of each method.

RESULTS & DISCUSSION

- Our findings highlight the importance of method selection for an accurate spectral analysis. Our Fourier analysis revealed that the directional distribution broadens along peak frequency due to nonlinear effects, particularly in narrow spectra, and the effect increased with wave steepness.

- Comparisons with the 2D Fourier Transform (2FFT) as the standard spectrum we found that the Maximum Likelihood Method (MLM) overestimated the spreading coefficient by 14%, while the Maximum Entropy Method (MEM) and Wavelet Directional Method (WDM) produced narrower spectra, with reductions of 6% and 3%, respectively. These results highlight the necessity for careful method selection to achieve accurate and reliable spectral analysis of wind waves.





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Numerical simulations of ocean surface waves along the Australian coast with a focus on the Great Barrier Reef

Name: **Xianghui Dong**
Email: xiandong@student.unimelb.edu.au
Supervisors: Prof. Alexander Babanin, A/Prof. Qingxiang Liu
Disciple: Ocean Engineering

INTRODUCTION

The accuracy of global wave simulations generally degrades considerably in coastal waters primarily due to coarse global bathymetric grids (usually 0.25°-0.5°) and more complex physical settings (e.g., emerging bottom processes; Cavaleri et al., 2018). Liu et al. (2021) reported that the error in wave height, from their global simulations is much larger on the Australian coasts than that in deep oceans (scatter index of 0.2 - 0.4 vs 0.15).

Notably, our investigation pinpointed the Great Barrier Reef (GBR) as the most challenging area for wave modeling along the Australian coast. Previous field experiments showed that barrier reefs would induce substantial loss of incident wave energy due to the combined effect of depth-induced wave breaking and bottom friction (Hardy & Young, 1996; Lowe et al., 2005; Young, 1989). Thus, it was shown that wave energy in the GBR was seriously overestimated by spectral wave models without accounting for these dissipative effects of barrier reefs (e.g., Hardy et al., 2000; Hemer et al., 2017; Liu et al., 2021). To address this issue here, we proposed a two-step modeling strategy.

METHODOLOGY

- **WAVEWATCH III**
- **Implicit Scheme**: Time step = 1200s
- **Domain Decomposition Parallelization**
- **Unstructured Grid**
  Max_reso = 1 km Nodes = 88995
  Min_reso = 15 km Elements = 157240
  Min_reso_nearshore = 3 km
- **Subgrid scale reef parameterization**

Step 1: Reef as land

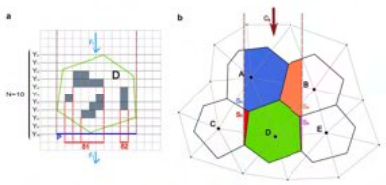
treated individual reefs in the GBR as unresolved islands

Step 2: The unresolved obstacles source term (UOST)

$$S_{uo} = S_{ld} + S_{se},$$

$$S_{ld} = -\psi_{ld}\frac{1-\beta_l}{\beta_l}\frac{c_g}{\Delta L}F(k,\theta),$$

$$S_{se} = -\psi_{se}(\frac{\beta_u}{\alpha_u}-1)\frac{c_g}{\Delta L}F(k,\theta).$$



RESULTS & DISCUSSION

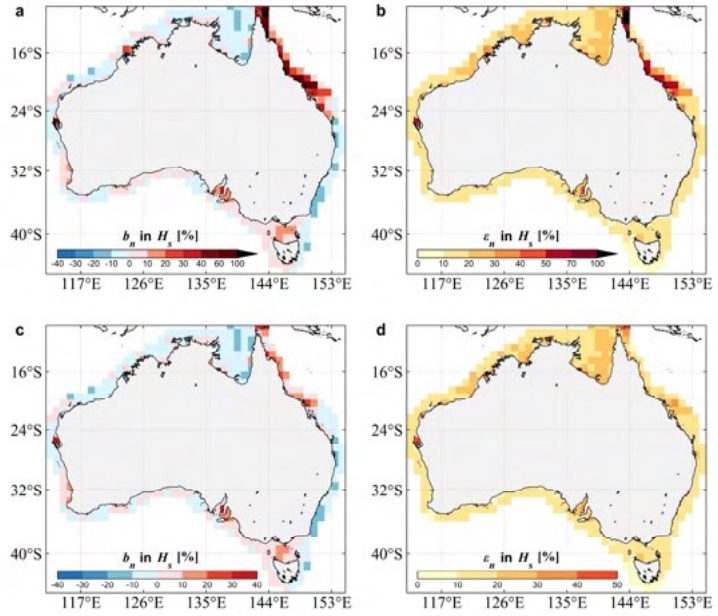


Fig. 1. Error statistics of H_s gridded in 1°×1° bins for the WW3 (**a**, **b**) Run 4 (without UOST) and (**c**, **d**) Run 5 (with UOST) relative to the altimeter wave records.

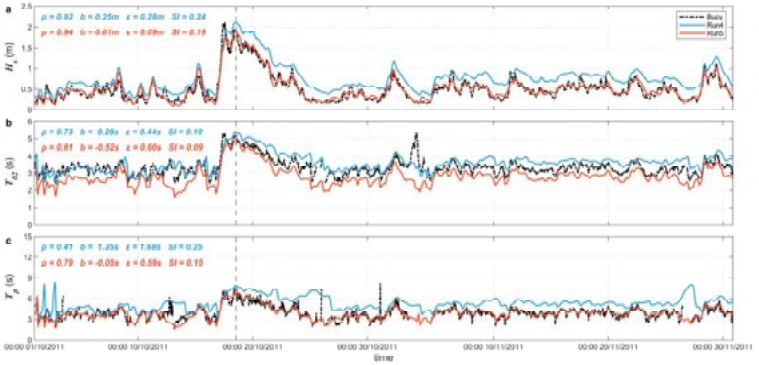


Fig. 2. Comparison of the (**a**) H_s, (**b**) $T_{0,2}$ and (**c**) T_p between observations and the WW3 simulations (Run 4 without UOST and Run 5 with UOST) for a two-month period (Oct. – Nov. 2011) at Hay Point wave buoy (55032; water depth of 9 m), respectively.

- Our subgrid scale reef parameterization enhances the wave model performance in the GBR dramatically, reducing the wave height bias from above 100% to below 20%.
- Overall, the WW3-ST6 physics (Liu et al., 2019), together with subgrid scale reef parameterization and other relevant source terms, perform reasonably well in the Australian coastal waters. This clearly demonstrates its applicability and reliability of simulating ocean waves, even in the complex reef matrix.

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Evaluating Hindcast Accuracy for Swell Arrival Times in the Indian Ocean

Name: Xiaoyu Sun
Email: xiasun5@student.unimelb.edu.au
Supervisors: Prof. Alexander V. Babanin and Prof. Jian Sun
Disciple: Ocean Engineering

INTRODUCTION

- Ocean swells, often originate from strong ocean storms, can carry energy and travel across ocean basins with slight dissipation. Swells can pose threats to navigation safety because the intensity of swells is often not directly related to the local wind speed, leading to potential underestimation of their danger.
- To improve the accuracy of swell hindcast, two key aspects need to be focused on: the energy decay rate and the swell arrival time. However, while existing research has extensively studied about energy decay, there has been relatively less attention on swell arrival time. A recent study shows that the average error of model hindcast in swell arrival time prediction is about 4 hours (earlier than observations), but the underlying causes remain to be investigated further.
- Here we examine the situation in the Indian Ocean and made some comparisons between the two oceans. This study provides new insights for better understanding the factors that influence the accuracy of swell arrival time hindcasts.

METHODOLOGY

- The observed sea surface elevation data used here is from the NRA laser array located near the western coast of Australia, covering the period from 2014 to 2016. Quality control is conducted to the laser observations before constructing the wave spectra.
- The laser and CAWCR wave model wave spectra are both partitioned, then the wave parameters are calculated.
- Swell events originating from the same storm source are identified by analysing the temporal trends of wave parameters in both datasets.
- The time series of the cross-correlation coefficient (CC) and NRMSD are calculated to help determine the time lags between the hindcast data and laser data, and the distribution of lags across seasons are analysed.
- A few cases are back-traced to verify their existence in the real ocean.

RESULTS & DISCUSSION

- 37 swell events are matched.
- In over 1/3 of the cases, there is no lag between the arrival time of hindcast and observations.
- When there's an error, the error is always negative (hindcast earlier).
- Larger errors are observed in winter and spring compared to summer and autumn.
- All the swells originate from the Southern Ocean.

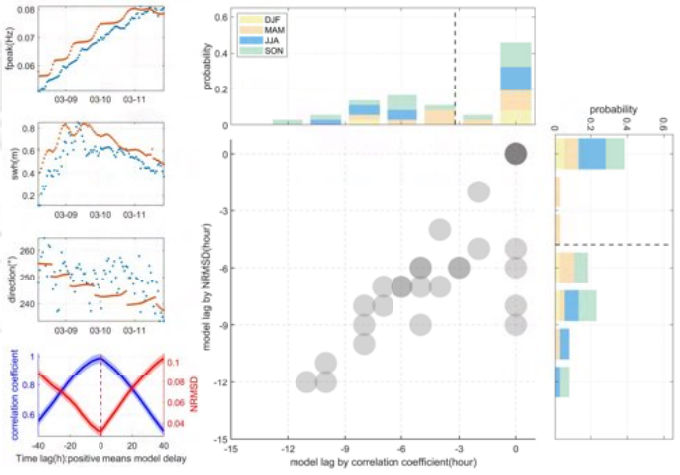


Fig. 1 The left column shows an example of the matched swell event. The right column shows the distribution of time lags between the hindcast and observations.

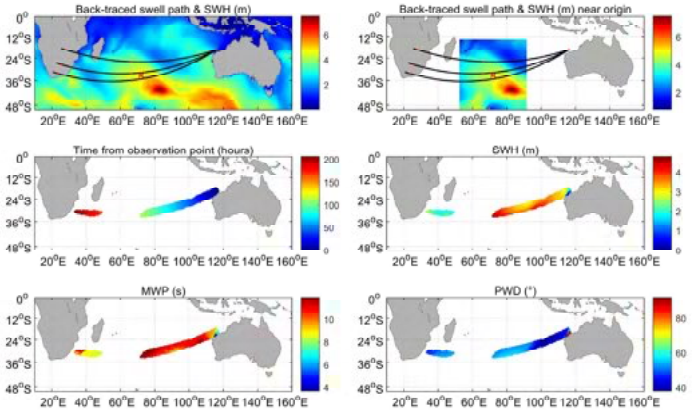


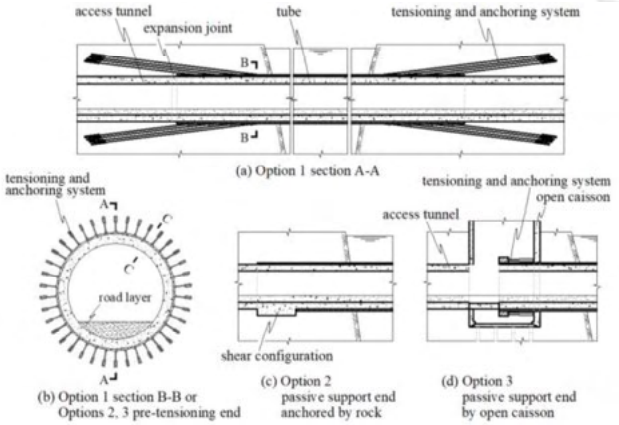
Fig. 2 An example of the backtracked swell path (black line), the location of swell origin (red cross), and the scatter plots of wave parameters.

Submerged Floating Tunnel High-Potential Energy System

Wei Lin, linwl2@student.unimelb.edu.au
Mark Cassidy, Yinghui Tian
Ocean Engineering

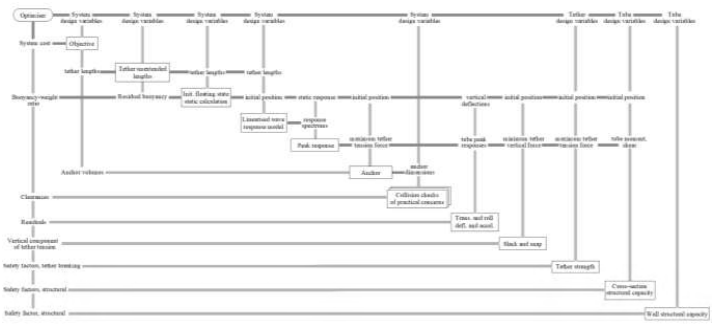
INTRODUCTION

Although proposals to build submerged floating tunnels (SFTs) have existed for over a century, their history is littered with well-meaning suggestions of form and type, but very few have been built. More recently, however, their potential as a highly cost-effective and sustainable crossing has rejuvenated industry interest. With the investigation of a novel high-potential energy system, the benefit of providing axial tension along a tether-supported SFT is studied.



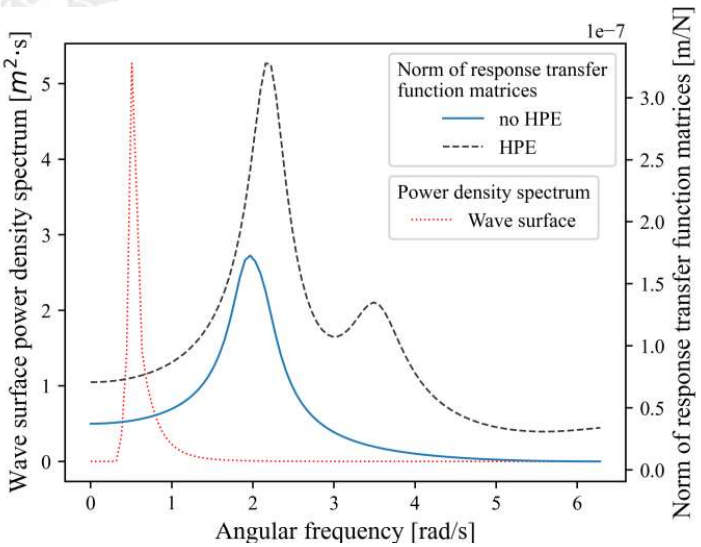
METHODOLOGY

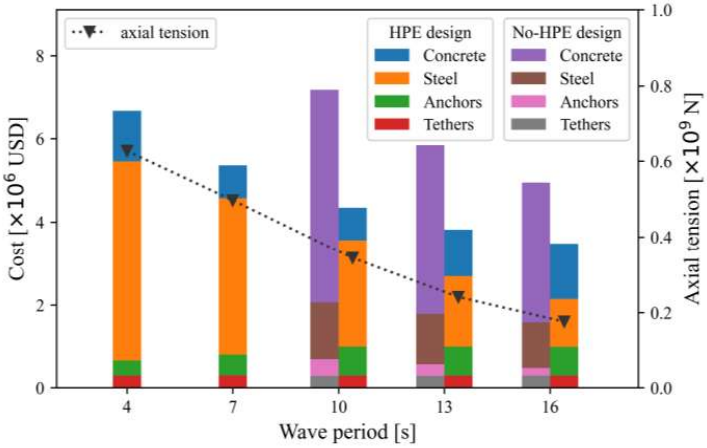
- Equation of motions are assembled in Rayleigh-Ritz form
- Response computation was in the frequency domain with three hours peak responses derived
- Gradient-based optimisation was adopted with design objective of minimising cost.



RESULTS & DISCUSSION

- Design optimisation results show that the SFT design with HPE has a higher chance of yielding a possible design to survive in unfavourable wave conditions
- Always yields a more cost-effective scheme.
- The approach has potential for engineering contractors to quickly and reliably develop a potential design concept, on which detailed assessment.





Building Envelope Retrofitting: An Optimization Approach for Climate Change Adaptation

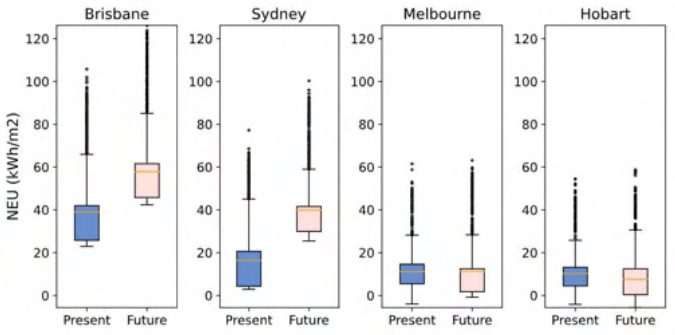
Duc Minh Le
Supervisors: Dr. Phillip Christopher, Dr. Tuan Nguyen, Prof. Tuan Ngo
Email: ducminh@student.unimelb.edu.au
Discipline: Energy

INTRODUCTION

- This research aims to investigate a whole-building model in varied climates for the most populous Australian cities. The study integrates comprehensive parameters for retrofitting the building envelope, including passive, active, and renewable design elements. Their impact on building performance under climate change scenarios is examined, particularly in the context of achieving the zero energy target by 2050. To this end, the study employs a simulation-based optimisation approach with three objectives: (1) building energy use, (2) thermal comfort, and (3) life-cycle cost. Ultimately, an optimal design for each climate region will be determined, supported by a heuristic Multiple Criteria Decision-Making (MCDM) framework. The analytical findings and optimisation data supplied seek to aid architects and engineers in making the most informed retrofitting decisions for building envelopes and determining optimal designs that enhance resilience and adaptation to inevitable future climatic changes.

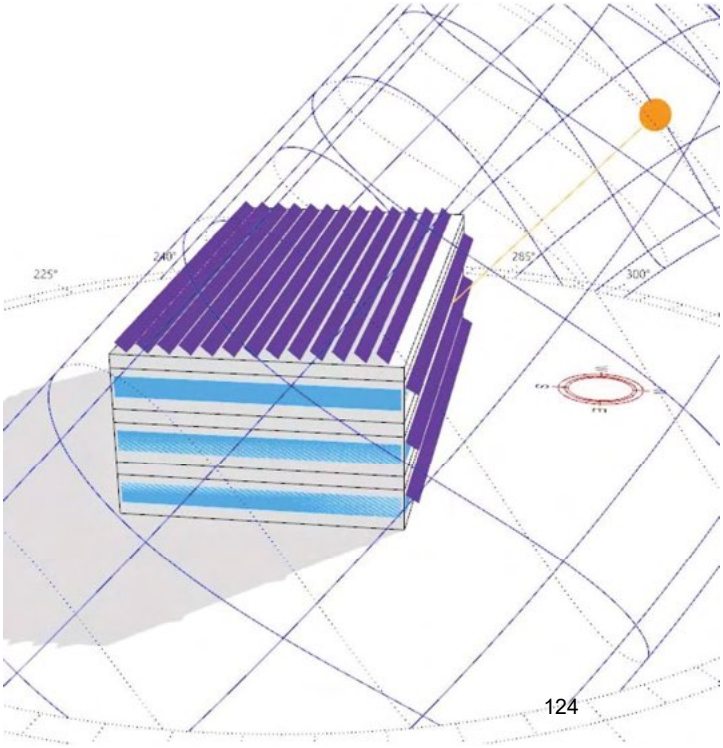
RESULTS & DISCUSSION

- The results show significant implications of climate change, especially in Brisbane and Sydney. In these areas, average NEU increases by 48.21% and 143.21%, respectively, due to higher cooling demands associated with rising temperatures. On the other hand, Melbourne's NEU remains relatively steady, with a slight increase from 11.13 kWh/m² to 11.31 kWh/m², a negligible rise of 1.58%. Meanwhile, Hobart shows a decrease in NEU, dropping from 10.23 kWh/m² to 7.55 kWh/m², reflecting a reduction of 26.14%.



METHODOLOGY

- Firstly, the future climatic data is identified, and then a midsized office model is developed, including passive, active, and renewable design strategies for building envelope retrofit based on parametric integrated simulation. The third stage, centred on optimisation, considered three key objectives: Net-Energy Use (NEU), Overheating Hours (OH), and Life-Cycle Cost (LCC). To this end, the optimisation processes were conducted on a personal workstation featuring an Intel® Core™ i7-4800MQ processor and 8GB RAM. In the final stage, the study examined optimisation data and employed the MCDM framework by conducting sensitivity weight analysis to explore the implications of parametric envelope design on building retrofit performance; eventually, each climate region's unique recommendation was determined to compare results between the present and future weather conditions.



Depth-Varying Non-Uniform Corrosion effects on Marine Concrete Pile structures

Name: **RISHWANTH DARUN A S**
Email: rannamalaisa@student.unimelb.edu.au, rishwanth.darun@kuleuven.be
Supervisors: Prof. Lihai Zhang, Prof. Yinghui Tian, A/Prof. Xuemei Liu
Discipline: Engineering Management, Structural

INTRODUCTION

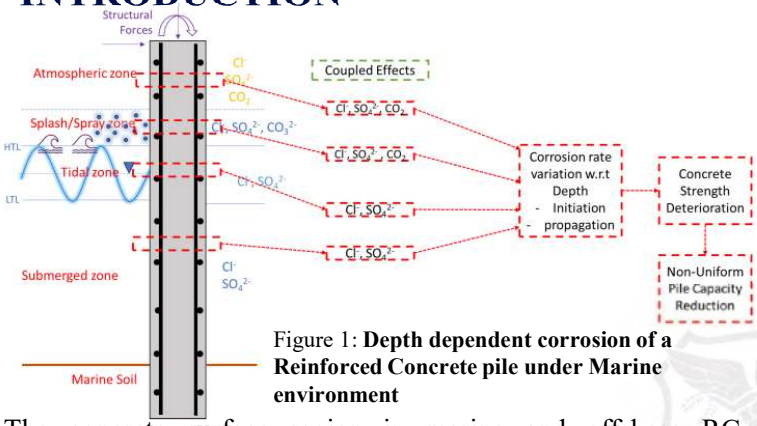


Figure 1: **Depth dependent corrosion of a Reinforced Concrete pile under Marine environment**

The concrete surface region in marine and offshore RC structures can be separated into submerged, tidal, splash/spray and atmospheric zones. As the transport of corrosive ions is highly variable and in addition the effect of external pressures in each zone is different.

The combination of various corrosive ions (Chloride [Cl^-], Sulphate [SO_4^{2-}] and Carbon-di-oxide [CO_2]) present in the seawater and atmosphere have varied mixed reactions in the reinforced concrete section. The mechanism of corrosion in concrete cover region is much different from the reinforcement degradation processes.

METHODOLOGY

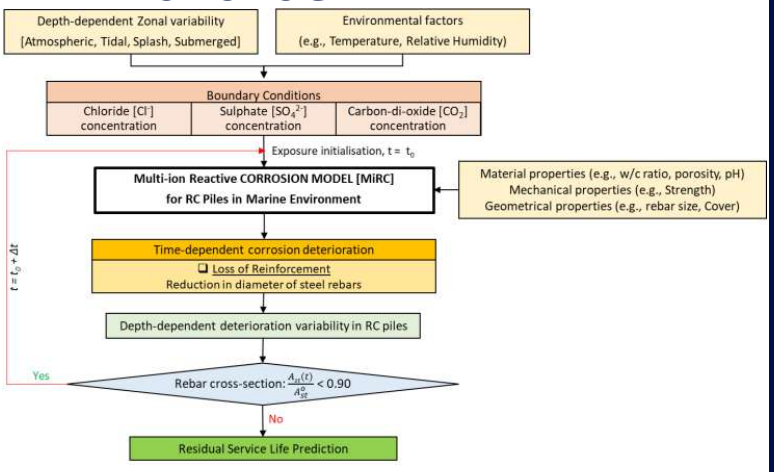
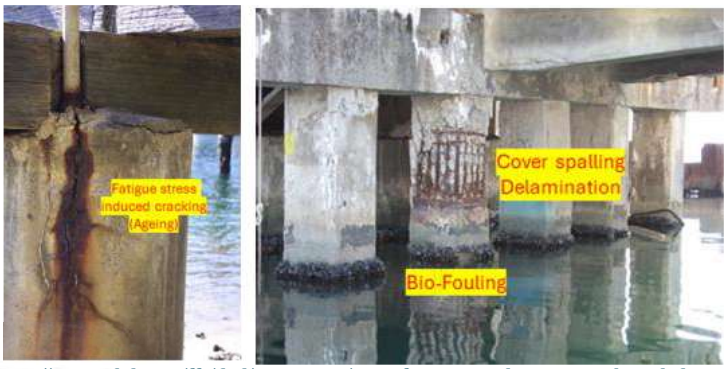


Figure 2: **Details of the Multi-ion Reactive Corrosion model for predicting residual service life of a RC pile under marine environment**

Corrosion due to multiple corrosive ions can be characterized as Multi-ion Coupled chemo-mechanical model, with reactive-transport process of ions into the concrete modelled based on Poro-elastic media theory at meso-scale. This is integrated with mechanical time-dependent elastic deformation behaviour of concrete to numerically model the stress induced internal cracking due to expansive corrosion products, thereby leading to structural strength deterioration.



https://www.wbdg.org/ffc/dod/cpc-source/waterfront-coastal-structures-knowledge-area

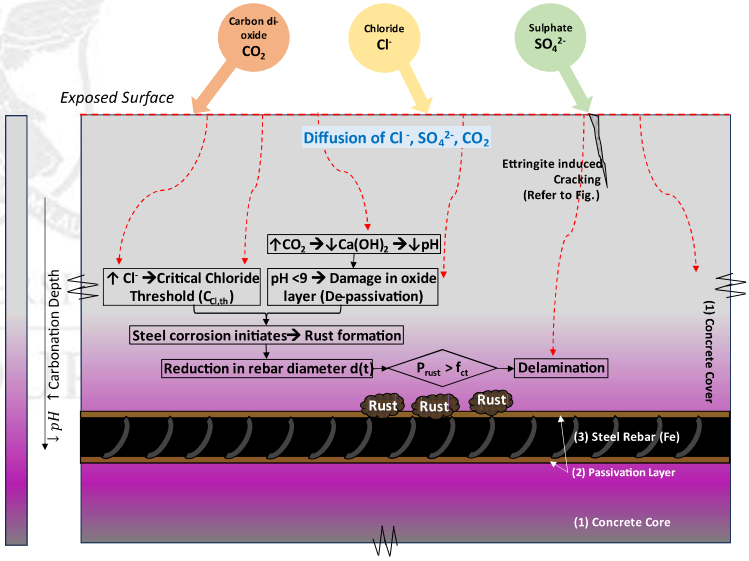


Figure 3: **Corrosion mechanism of Steel reinforcement bar in a concrete pile under Marine environment**

RESULTS & DISCUSSION

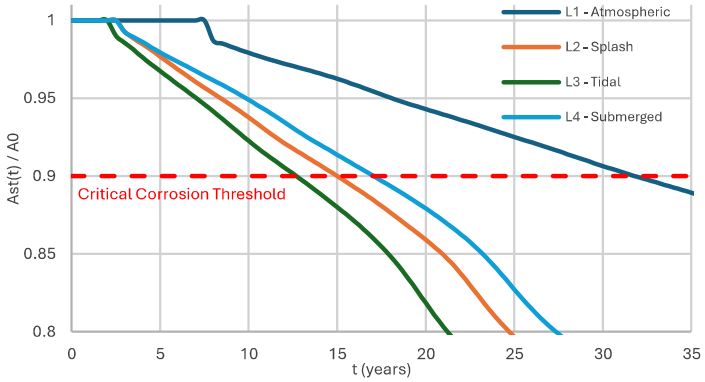


Figure 4: **Time-dependent reduction of steel reinforcement cross-section area (Normalised)**

- Corrosion severity: Tidal > Splash > Submerged > Atmospheric
- Rebar in Tidal zone deteriorates and reaches Threshold limits 61% earlier than in Atmospheric region

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Effects of gait at different walking speeds on bone fracture healing in patients with various body weights

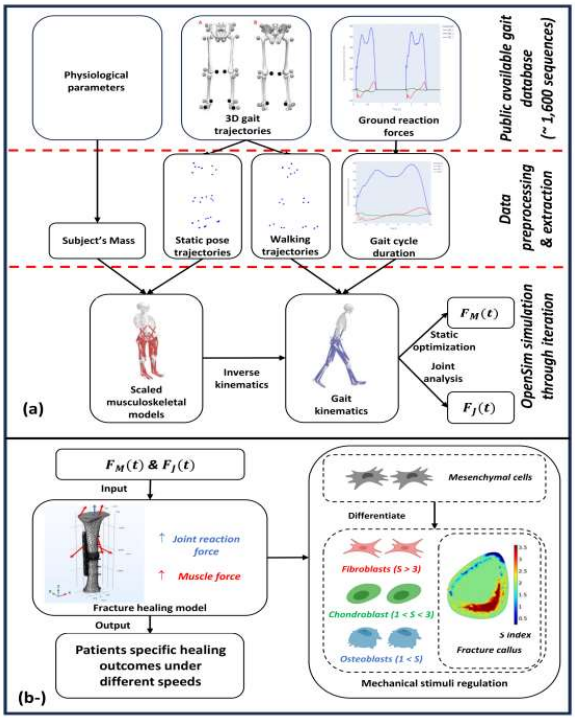
Name: Qianjun Ding
Email: qianjund@student.unimelb.edu.au
Supervisors: Prof. Lihai Zhang, Dr. Saeed Miramini
Disciple: Project management

INTRODUCTION

It is well known that applying locking fixation method under various physiological conditions of patients influences the mechanical microenvironment at the early stage of fracture healing. However, current studies mostly use deterministic approaches by conducting experiments on static standing poses from a single subject.

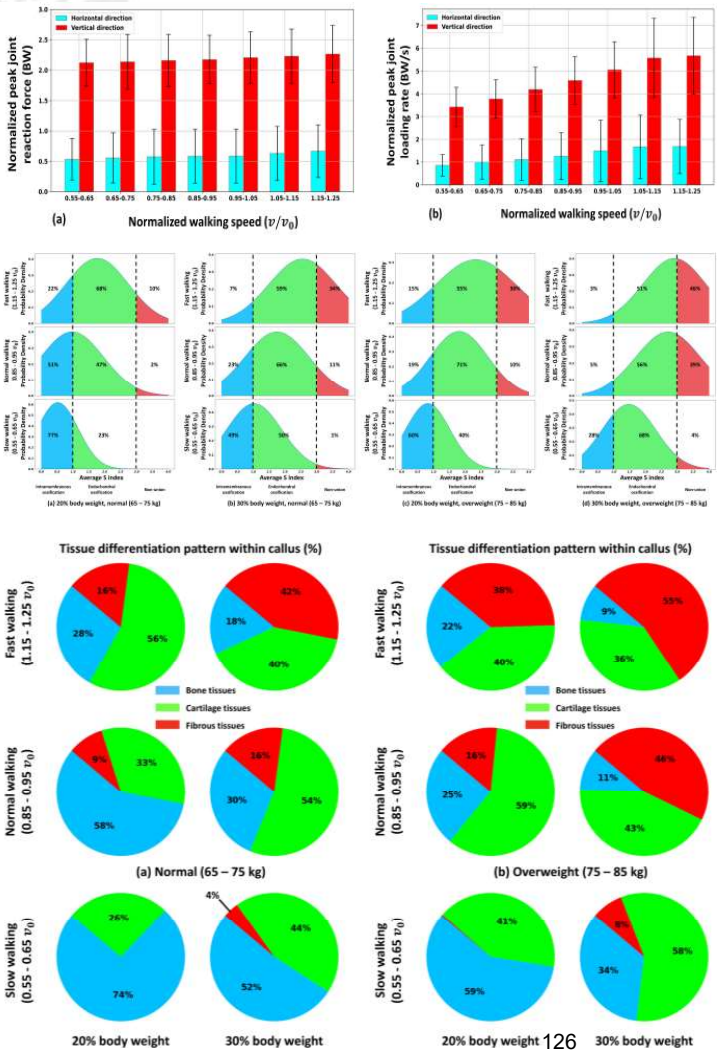
The key objective of this study is to develop a computational framework that simulates muscle and joint contact forces from publicly available gait databases using musculoskeletal models, and subsequently predicts rehabilitation outcomes under combinations of various physiological at the early healing stage. Our specific goal is to conduct a probabilistic approach to compute the probability of a favourable healing pathway from normal distributions and the average percentage of tissue differentiation patterns under different conditions. This research can provide a more comprehensive analysis of how patients' physiological conditions influence their fracture microenvironments, offering a remarkable reference for clinicians and orthopaedic surgeons.

METHODOLOGY



RESULTS & DISCUSSION

- The gait speed is positively correlated with forces and loading rates of knee joints in vertical and horizontal directions, which could significantly impact the biomechanical microenvironment during the early stage of healing. (e.g., an increase in gait speed can result in a higher probability of non-union healing).
- The model uses a probabilistic approach to show that the appropriate combination between the ranges of speed and partial weight-bearing can promote mechanical stimuli of successful and uniform healing for groups with different body masses, while minimizing the possibility of delay or non-union healing at the fracture site.



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Transforming Engineering Education with Threshold Learning in First Nations Australian Engineering

Aurora Greane, Indigenous Engineering (a.greane@unimelb.edu.au)
Supervisors: A/Prof Juliana Kaya Prpic, Susan Beetson, Professor Sally Male, and Dr Craig Cowled

Background

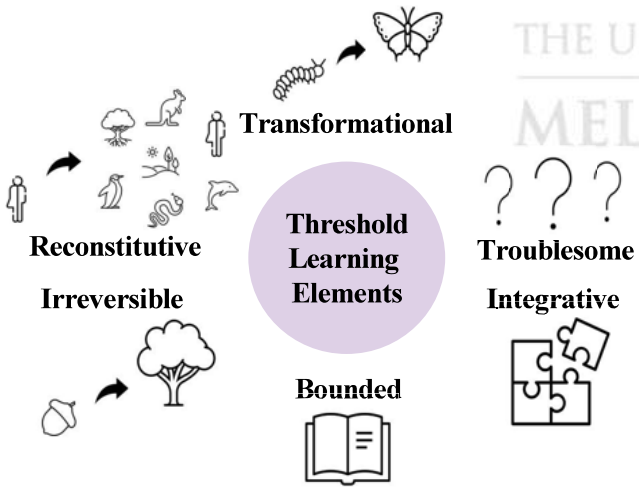
Australian professional organisations and universities have committed to embedding First Nations Australian engineering Knowledges, perspectives, and value systems in the engineering curriculum [1], [2].

Threshold learning describes discipline-specific learning elements that students find most transformative and troublesome. Designing curricula to focus on these elements enables educators to best facilitate transformational learning [3], [4].

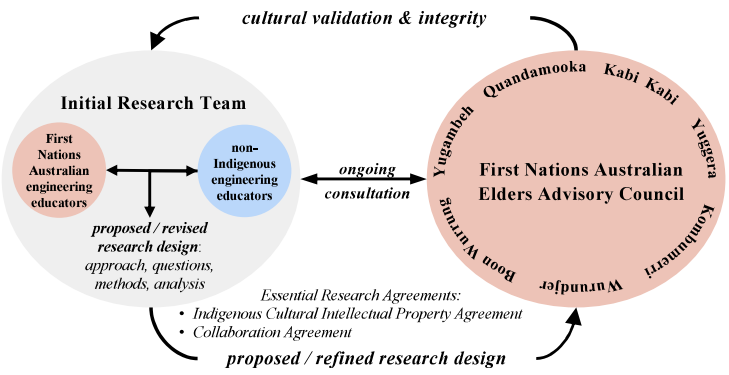
This project seeks to identify threshold learning elements in First Nations Australian engineering. It also aims to design threshold learning experiences and assessment methods to educate emerging engineers who understand and appreciate First Nations Australian engineering Knowledges, perspectives, and value systems.

Threshold Learning Elements

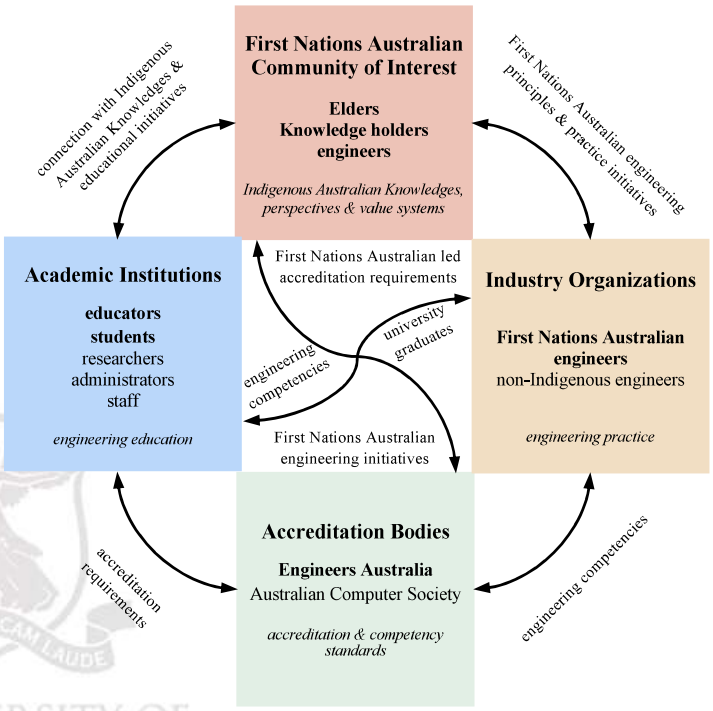
(Concepts [4], [5], Capabilities [3], and Values)



Research Approach

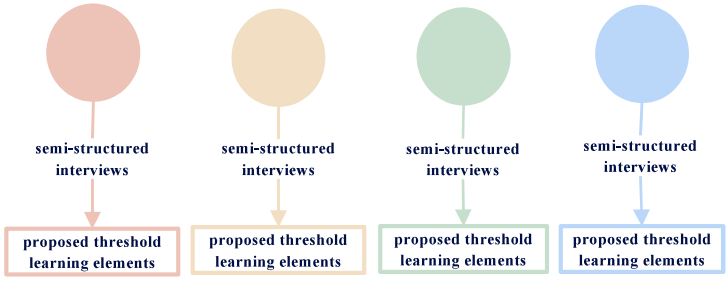


Stakeholders

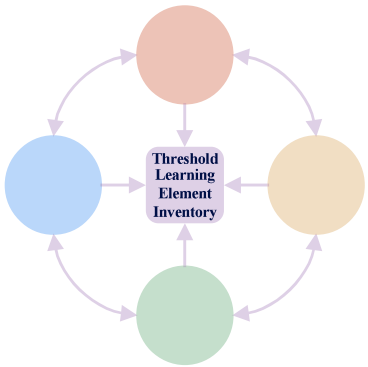


Proposed Research Design

Diverging Phase [10]: Separate semi-structured interviews with stakeholders from each group to gather diverse perspectives and identify a broad range of potential threshold learning elements.



Integrating Phase [10]: Focus groups with stakeholders from all groups to discuss and develop a cohesive threshold learning element inventory.



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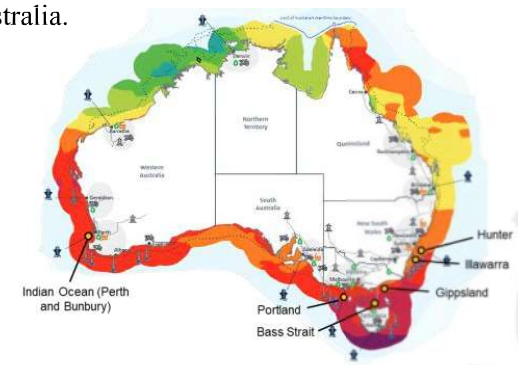
Multi-scale Modelling of Calcareous Sands

Name: Fei Liu
Email: feil3@student.unimelb.edu.au
Supervisors: Prof. Yinghui Tian, Dr. Jay Black, Dr. Hongyuan Liu
Discipline: Ocean Engineering

INTRODUCTION

BACKGROUND

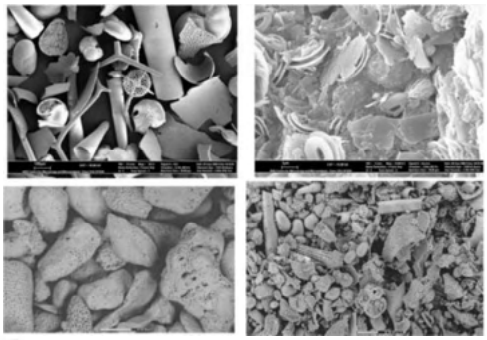
- The calcareous sand seabed poses a significant challenge to the development of wind power in Australia.



Six priority areas for offshore wind in Australia

UNIQUE PROPERTIES OF CALCAREOUS SANDS

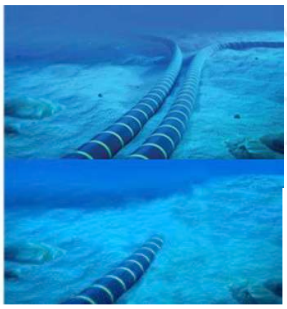
- Unique composition
- Irregular shape
- High porosity
- Relatively low hardness
- High compressibility
- Easily crushable



SEM for calcareous sand particles

ENGINEERING CHALLENGES

Pile running during pile driving



Cable bending and self-burial

- The challenges in engineering applications largely arise from limited research on the internal microscopic mechanisms of calcareous sands.

KNOWLEDGE GAPS

Single particle (Micro)

- Single particle: limited understanding of the mechanisms behind morphological changes and particle breakage.

Particle assembly (Meso)

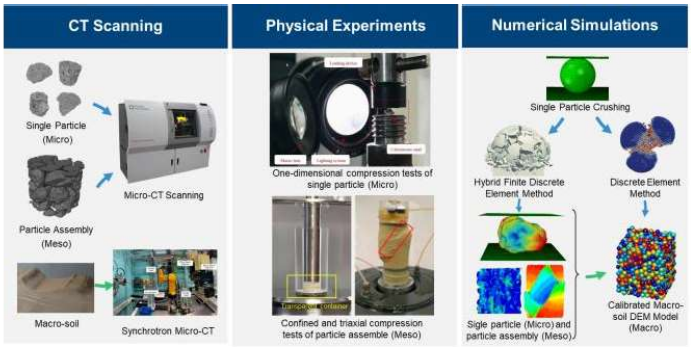
- Particle assembly: limited understanding of particle interactions, behavior, and contact issues.

Macro soil (Macro)

- Macro soil: limited understanding of how micro-scale particle breakage and meso-scale contact behavior affect macroscopic engineering performance.

METHODOLOGY

- Three research methods are employed to achieve a multi-scale study of calcareous sand, and to develop numerical models suitable for the macro-scale soil.



CONCLUSIONS & FUTURE PLANS

- Based on the available literature, a multidisciplinary, multi-scale integrated research approach is shown to be a feasible method for studying the crushing mechanisms of calcareous sand.
- Current research focuses on the relationship between the microscopic morphology of calcareous sand particles and their crushing characteristics.
- Plans are in place to develop a numerical model for calcareous sand compression tests, followed by parameter calibration and model validation.

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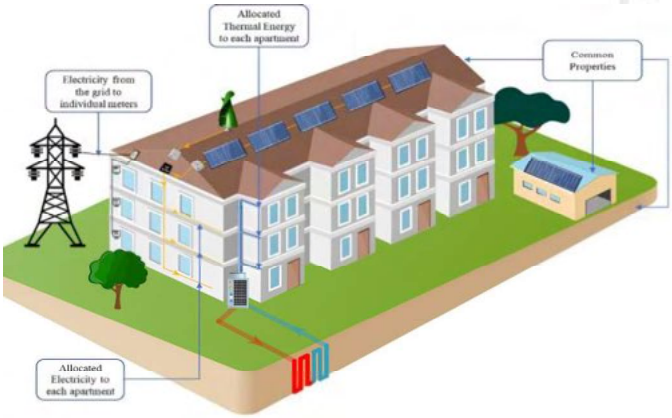
Energising Apartments: Role of 'Energy Entitlement' for Renewable Energy Transition

Aravind Poshnath
e-Mail: aposhnath@student.unimelb.edu.au
Discipline: Renewable Energy & Energy Efficiency
Supervisors: Dr Behzad Rismanchi, Prof. Abbas Rajabifard

INTRODUCTION

Despite the increasing focus on renewable energy, adoption within Multi-Owned Buildings (MOBs) remains disproportionately low compared to detached homes. This discrepancy exacerbates energy and revenue allocation challenges among apartment owners sharing Common Properties. Legal scrutiny reveals a critical gap in energy allocation principles, inadequately tailored to the unique social and physical landscapes of MOBs. Introducing the innovative 'Energy Entitlement' concept, our research aims to address this gap by delineating renewable energy ownership within each apartment of the MOB.



METHODOLOGY

Identified factors influencing energy allocation

↓

Performed dispute analysis of existing allocation models

↓

Defined potential novel allocation models

↓

Evaluated the suitability of models analytically

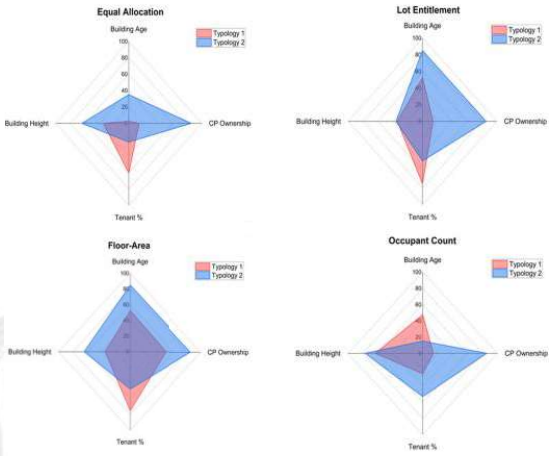
↓

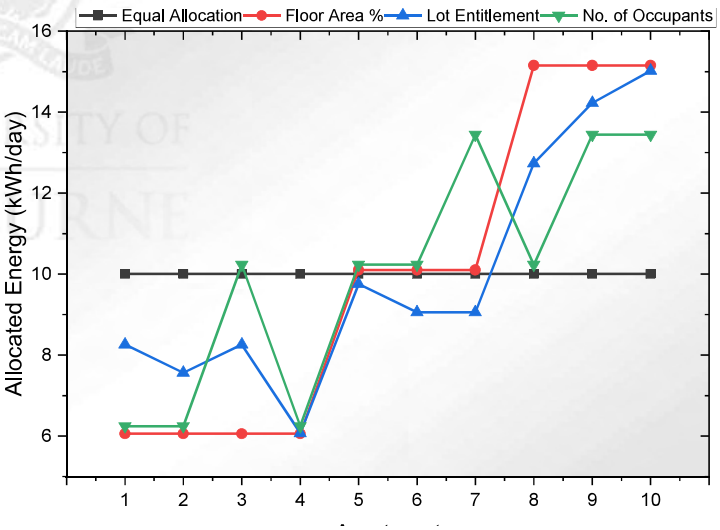
Conducted TOPSIS Analysis

↓

Aggregated to an evidence-based decision-making framework

RESULTS & DISCUSSION





- The efficacy of each allocation model varies considerably across the building typologies
- The 'one-size-fits-all' approach may prove ineffective for energy allocation in residential Multi-Owned Buildings (MOBs).
- The physical and social characteristics of each building influence the suitability of energy allocation models, underscoring the need for tailored approaches.
- Energy entitlement can foster a sense of ownership and encourage responsible energy consumption.

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Dynamic and Circular Life Cycle Sustainability Assessment for Prefabricated Buildings

Name: Megha Sindhu Pradeep
Email: msindhuprade@student.unimelb.edu.au
Supervisors: Dr Behzad Rismanchi, Prof. Tuan Ngo
Discipline: Energy

INTRODUCTION

The significant impact of building sector in the environment, economy, and society underscores the urgent need to adopt Prefabricated Buildings (PBs). However, to address the challenges in their adoption, quantitative assessments of their life cycle sustainability performance is essential. To achieve this, a holistic approach is crucial, as evaluating individual sustainability pillars in isolation during a particular phase(s) leads to skewed perspectives and sub-optimal risk management, potentially resulting in project failure. Furthermore, as stakeholders increasingly design PBs for disassembly and deconstruction, assessing their circularity during design becomes critical. However, static assessments may produce inaccurate estimates, as they overlook the temporal aspects of buildings' longer life cycles. As researchers have focused only in addressing only one or more of these limitations, this study aims to (i) Analyse the gaps and challenges in current life cycle sustainability studies of the building sector, & (ii) Develop an integrated framework for Dynamic and Circular Life Cycle Sustainability Assessments (DC-LCSAs) tailored for PBs.

METHODOLOGY

As a first step toward these objectives, relevant articles of past 10 years were selected using the PRISMA framework (Fig. 1) through keyword search in established databases. Articles were eligible for full-text review if they:

(1) Presented a sustainability assessment for PBs with case studies and results, or

(2) Addressed TBL pillars, dynamism, or circularity in any life cycle stage(s) as per EN15804.

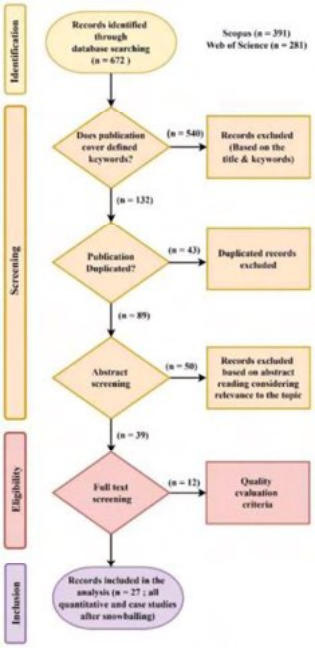

Fig. 1. PRISMA

RESULTS & DISCUSSION

The first objective of systematic gap analysis in the current literature resulted in the identification of existing frameworks that have evolved in this field, as illustrated in Fig. 2, along with the relevant studies.

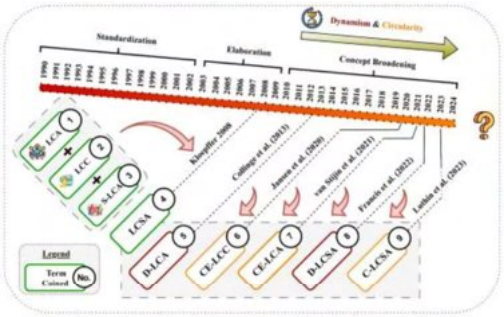

Fig. 2. Existing frameworks

These frameworks addressed limited aspects due to data constraints and uncertainties, highlighting the need for a DC-LCSA framework for PBs. In response, a comprehensive assessment framework based on ISO 15392 (2019) was developed in Objective 2, integrating systems thinking, dynamism, and circularity (Fig. 3).

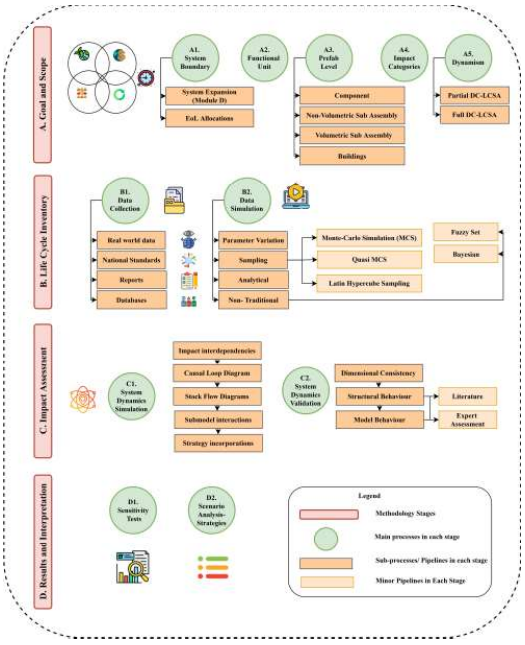

Fig. 3. DC- LCSA

Future researches can couple the framework with MCDM techniques for informed decision-making. Further, the impacts of the decisions in future life trajectories can be analysed through scenario analysis using EoL allocations.

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Leveraging Open Innovation in Infrastructure: Co-Creation, Risk Mitigation, and Knowledge Sharing in the Level Crossing Removal Project

Name: Robert Moehler
Email: moehler@student.unimelb.edu.au
Supervisors: Prof. Dr. A, Western, Prof. Dr. C. Duffield
Discipline: Project Management

INTRODUCTION

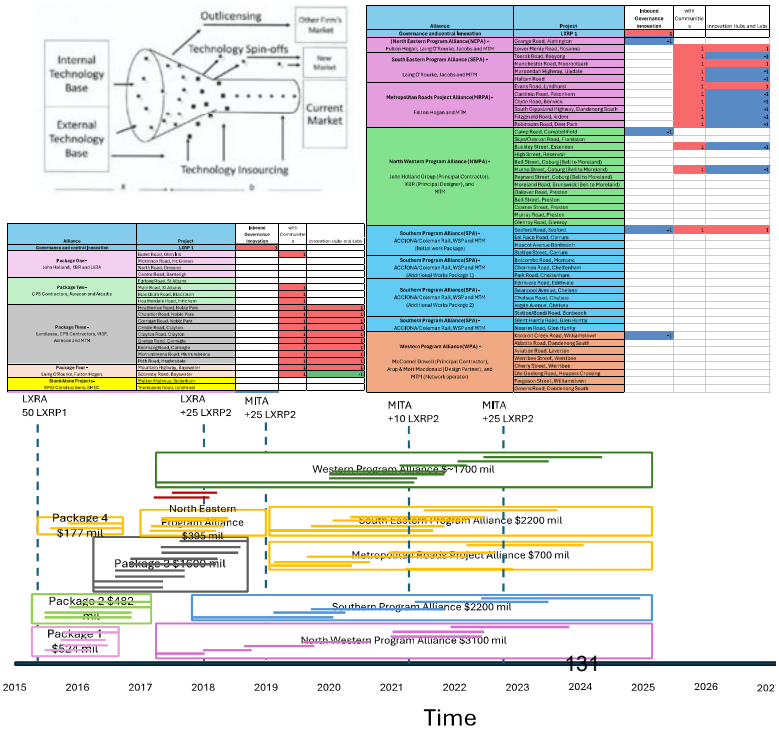
- In infrastructure mega projects and programs like the Level Crossing Removal Project (LXRP), the delivery model's lifecycle phases are instrumental in shaping what the final product or service can become, often in response to complexity. Open Innovation has been a core theorem to inspire for Collaborative Networks and Stakeholder Engagement, Crowdsourcing and Co-Creation, Adaptability and Flexibility, Knowledge Sharing and Technological Integration or Risk Management through Distributed Innovation. The Level Crossing Removal Project (LXRP) leverages innovative alliance structures, collaborative risk management, and community engagement to deliver infrastructure outcomes. This abstract presents the evaluation of inbound and outbound open innovation within the mega program, as well as among the 104 projects within alliances and across alliances based on the analytical model. The goal is to draw out when to use open innovation, how to implement it, and what successful open innovation entails to encourage broader industry adoption.

METHODOLOGY

- This research employs a case study methodology to analyse the Level Crossing Removal Project (LXRP), focusing on open innovation in large-scale infrastructure projects. The dataset was developed using publicly available information from LXRA sources, which is in the process of validation through expert interviews with both project stakeholders and scholars specializing in open innovation and infrastructure management. The case study allows for theoretical generalization by drawing broader conclusions from this specific project, enabling insights that may apply to similar infrastructure programs. The analysis evaluates the integration of open innovation in key areas, such as collaborative networks, risk management, and technological integration, across the 110 individual projects within the LXRP. The study also explores how political commitments, such as the expansion from 50 to 110 level crossings and budgetary increases, underscore the importance of adaptive innovation in responding to growing project complexity and managing stakeholder expectations The analysis of the dataset combines qualitative data from interviews with quantitative project outcomes to provide a comprehensive understanding.

RESULTS & DISCUSSION

- Inbound innovation governance, inspired by **CrossRail**, established a dedicated innovation capability by integrating the project pipeline into a programmatic structure.
- The dataset shows co-creation played a critical role in mitigating risks and adding community value, evolving from individual project input (1st announcement) to broader collaboration across programs (4th announcement).
- Early-stage innovations like **MatX** and **Reconophalt** were enhanced by community-driven design, particularly at **Lilydale** and **Mooroolbark** stations.
- While the **Innovation Register** saw limited use, cross-alliance knowledge-sharing persisted, including **Indigenous co-design** through an **Aboriginal Reference Group**.
- Successful open innovation relies on **permeable boundaries** for idea flow, cross-boundary collaboration, and managing complex relationships across organizational ecosystems. Essential OI capabilities include partnership management, IP governance, supply chain integration, and market adaptability.



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Assessment of Long-Term Trends and Variability of Wind Energy Density off the Coast of Australia

Name: Rui Li
Emali: rl6@student.unimelb.edu.au
Supervisor: Alexander V. Babanin
Discipline: Ocean Engineering

INTRODUCTION

The offshore wind resources possess immense scale and remarkable dispersion owing to the vast coverage of oceans and seas compared to landmasses. Offshore locations experience significantly higher wind speeds compared to onshore areas due to the absence of land obstacles and the smoother water surface. The Australian government declared an area in the Bass Strait off Gippsland as suitable for offshore renewable energy in 2022. This declaration will help enable Australia's energy transition towards renewable power and cleaner, cheaper and more secure energy. It will help Australia reach net zero by 2050.

METHODOLOGY

- Data Sources: ECMWF-ERA5 reanalysis data from 1980 to 2019, wind speed data at both 10 meters and 100 meters heights
- Methodology: The Gumbel distribution, The variability index.

RESULTS & DISCUSSION

- **Long-term trends of WED**

Based on the monthly WED data spanning 40 years, Figure 4 illustrates the trends of zonal and meridional WED. In terms of zonal direction, WED in the Southern Ocean demonstrates an increasing trend, with a maximum rate of 1.40 W/m^2/year. A clear boundary line can be observed at 30°S, distinguishing the increasing and decreasing areas. North of 30°S, WED growth is consistently positive. Moving on to the meridional direction, two areas with high growth rates in WED stand out - one in the western Australian seas and the other in the northeast Australian seas. The maximum growth rates recorded are 0.52W/m^2/year and 0.79W/m^2/year, respectively.

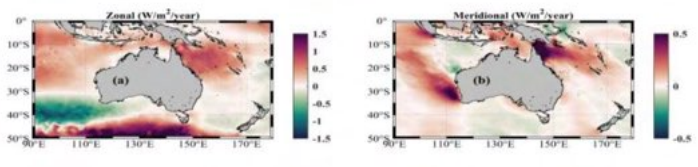

Figure 1. Trends of (a) zonal and (b) meridional WED.

- **Distribution of the wind energy density**

The spatial distributions of the mean WED over 40 years are illustrated in Figure 1. The spatial distribution and seasonal variation of WED are closely linked to the fluctuation of wind speed. The Southern Ocean consistently experiences high wind energy due to its elevated wind speeds. In January, the WED reaches its peak off the coast of western Australia, surpassing 400W/m^2. Conversely, the northeastern Australian seas exhibit the lowest annual WED in January. Meanwhile, the WED along the southeast coast remains relatively stable. Although Bass Strait is influenced by prevailing westerly winds in July, resulting in an increase on WED during the winter (austral), the values of mean WED consistently remain below 200 W/m^2.

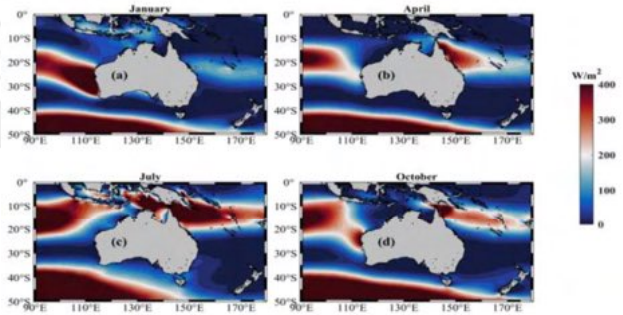

Figure 2. Mean WED over the 40 years calculated using 10m wind speed.

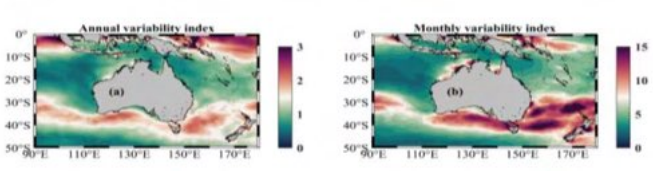

Figure 3. (a) Annual, (b) monthly variability indexes of WED.

FUTURE RESEARCH

- Further analysis on short-term WED fluctuations is crucial for a comprehensive understanding of wind energy potential.

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Passengerisation of travel? Modelling the effects of travel time use on mode choice

Ana Luiza Santos de Sa (asantosdesa@student.unimelb.edu.au)

Supervisor: Dr Patricia Sauri Lavieri

Co-supervisors: Dr Jacek Pawlak (Imperial College London) and Prof Russell G. Thompson

INTRODUCTION

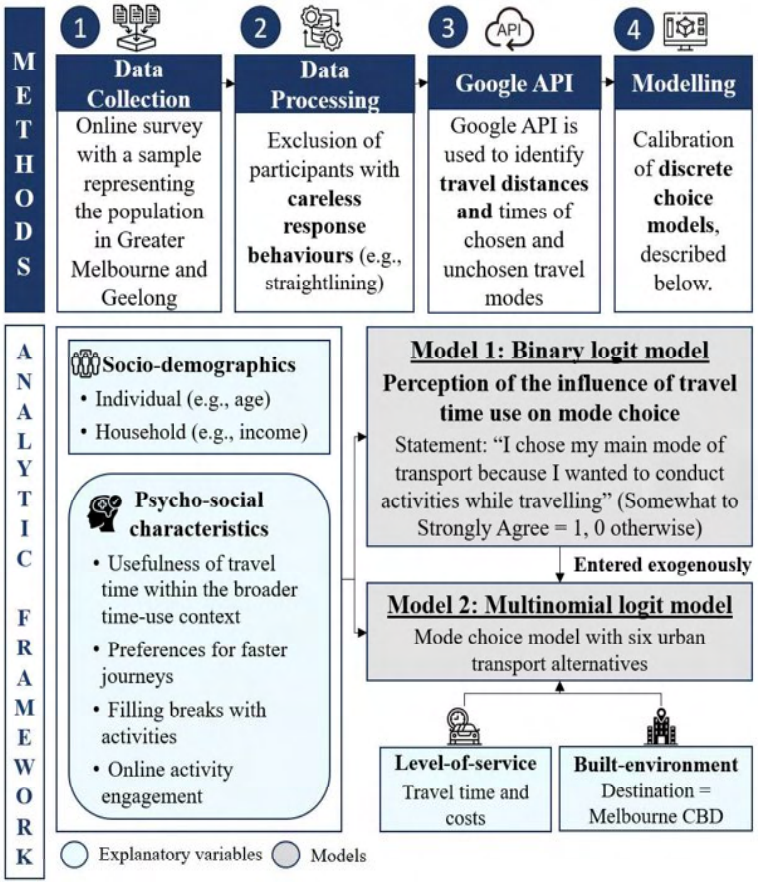
Travel time use (i.e., conducting activities while travelling) has often been hypothesised to influence one of the most crucial dimensions of activity-travel behaviour: **travel mode choice**. The predominant hypothesis is that individuals who have *preferences for travel time use* will seek travel modes that better accommodate their activity needs, especially those where they travel as passengers (e.g., public transport and automated vehicles), leading to the "passengerisation of travel" (Mokhtarian, 2018). Despite that, transport research is yet to **understand the causal relationship between travel time use and mode choice**. This is what the current research aims to tackle. This research's objectives are two-fold:

(a) Examine the characteristics of travellers who perceive travel time use as a decisive factor in their mode choices.

(b) Model the effects of travel time use on mode choice.

The findings of this study can inform transport planners and policymakers on (i) how to design more attractive public transport systems, which is crucial for building a sustainable transport system, and (ii) unravel a future with automated vehicles when travel time use will be more commonplace.

METHODOLOGY



RESULTS & DISCUSSION

Model 1: Binary Logit Model

Who perceives travel time use as a decisive factor in mode choice?

Psycho-social factors are the **most relevant**

The **more valuable and useful travel time use** is in the **individual's daily schedule**, the **more likely** travellers are to perceive travel time use as a decisive factor for mode choice.

Socio-demographics also **matter**

Young (21 – 29), students, and mid-income travellers are **more likely** to perceive travel time as a decisive factor. Conversely, women and highly educated individuals are **less likely** to think so.

Model 2: Multinomial Logit Model

Does travel time use *really* influence mode choice?

Yes, with an **indirect effect**. The best model had **significant positive interactions** between the *perception of the influence of travel time use on mode choice* and *travel time* for "walk" and "rail" options. This means that **individuals with such a perception of travel time use have lower resistance to travel longer journeys by such modes** (i.e., lower value of travel time savings), and it does not fully confirm the "passengerisation of travel" hypothesis.

Explanatory variable	Estimates	
	Est	t-ratio
Constants (ommitted from the table)		
Level-of-service		
Travel time (TT)	-1.15	-7.21
Travel cost (TC) (log transformation)	-0.71	-7.04
Psycho-social		
Car driver: Preferences for faster journeys	1.49	4.70
Interactions: Travel time x Psycho-social		
Rail: Travel time use influences mode choice x TT	0.35	2.05
Walk: Travel time use influences mode choice x TT	0.77	4.03
Socio-demographic		
Car passenger: Female	1.20	4.89
Car passenger: Employed/Self-employed	-0.95	-4.50
Bus & Rail: Studying	0.41	2.21
Built-environment		
Rail: Destination is in Melbourne CBD	2.31	13.01
Walk & Cycle: Destination is in Melbourne CBD	1.75	5.88
Car passenger: Destination is in Melbourne CBD	0.67	2.31
Goodness-of-fit		
Rho-squared vs equal shares	0.4447	

ETA Prediction using ML for PI-Hubs

Anshul Vijay
Email: anshul.vijay@unimelb.edu.au
Supervisors: Prof. Russell G. Thompson & Dr. Neema Nassir

INTRODUCTION

- Within an everchanging urban environment, multiple parties interact, including pedestrians, domestic and commercial traffic, leading to variability in travel times. Moreover, with limited alternative routes, greater congestion and therefore uncertainties in travel times arise through the day (McKinnon, 2015). This stochasticity subsequently impacts a transit center's operations, where goods are transhipped from one vehicle to another. Variability in vehicle arrival times can adversely impact slot scheduling at docks, causing greater queue lengths, vehicle idle times and emissions at the loading bays.
- Despite the high degree of uncertainty involved, literature has predominantly approached the slot scheduling problem from a deterministic rather than a stochastic perspective (Nasiri et al., 2022). Further, within the Physical Internet paradigm, where high degree of collaboration occurs among network participants, there has been limited consideration of this problem.

METHODOLOGY

- Within the proposed Slot Rescheduling System Framework for PI-Hub facilities, carriers operating the inbound vehicles delivering goods to the facility use the PI-hub's online booking platform to book a slot. They then proceed to share their vehicle's real-time location with the PI-Hub Orchestrator.
- Meanwhile, outbound vehicles tasked with transporting goods from the facility are determined via an auction mechanism. From multiple auction participants, the winning carrier proceeds to share its' vehicle's real-time location with the PI-Hub Orchestrator. Subsequently, the Orchestrator makes a slot booking on behalf of the winning carrier.

RESULTS & DISCUSSION

- Carriers (of both inbound and outbound vehicles) sharing the real-time fleet location data with the PI Hub Orchestrator. It is responsible for all operational decision making within the facility.
- Upon receiving the real-time fleet location data, the Orchestrator shares this data with the machine learning based predictive model that, based on historical data, provides the probability of the vehicle arriving at the expected time. Based on this probability, the schedule is adjusted using the optimisation model.

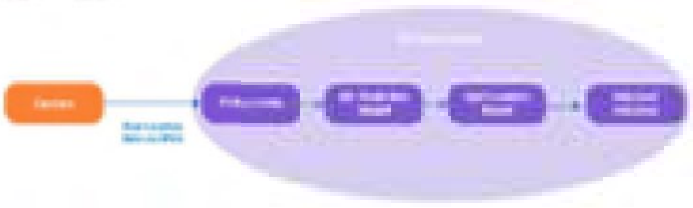


Figure 1 - PI-Hub Slot Rescheduling System Overview

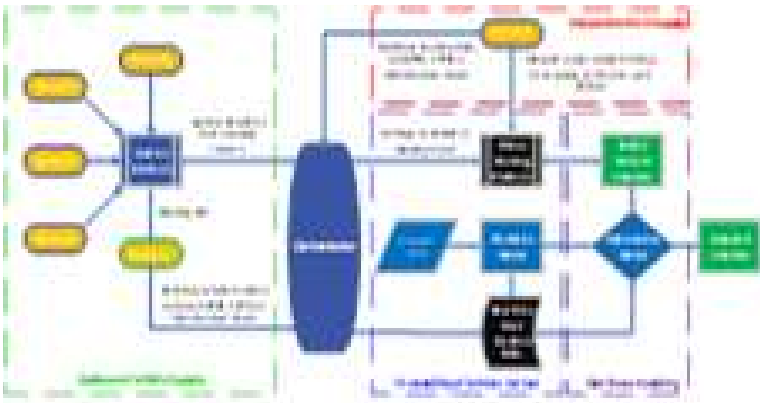


Figure 2 - Proposed PI-Hub Slot Rescheduling System Framework, adapted from Prakoso et al. (2022)

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Infrastructure Engineering Graduate Research Conference 2024

AI-Driven Audio Signal Processing Applied in Intelligent Transportation Systems

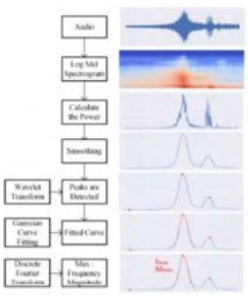
Presented by: Hossein Parineh – hparineh@student.unimelb.edu.au
Supervisors: Prof Majid Sarvi, Dr. Saeed Asadi Bagloee
Transport Group- Department of Infrastructure Engineering- University of Melbourne

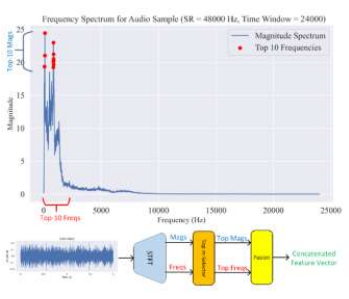
INTRODUCTION

The efficiency of intelligent transportation systems (ITS) Strongly relies on the quality of data collected by traffic monitoring sensors. Conventional traffic monitoring sensors such as cameras and radar require expensive infrastructure and are limited in the types of data they can capture. In contrast, acoustic sensors emerge as a cost-effective alternative capable that provide a wide range of traffic data, such as vehicle counting, type classification, speed estimation, etc. Prior research in this field use the audio data collected in controlled environments, with a limited type of vehicles and datasets small in size. This research addresses these limitations by: 1) introducing the first real-world dataset collected across 20 locations in Melbourne. 2) This dataset is then used for a comprehensive analyses of the audio, using various feature extraction methods and AI models, including 1D-CNN, 2D-CNN, few-shot learning, and LSTM. These approaches help to extract valuable information such as vehicle detection, count, type classification, speed estimation, traffic monitoring, and emergency vehicle detection.

METHODOLOGY

Each task in this research requires a specific feature vector. Some tasks can be addressed by using a standard approach such as Log Mel-spectrograms (which transforms audio from the time domain to the time-frequency domain). However, tasks with more complexity, such as speed estimation and multi-vehicle detection in a single sound profile, require more advanced feature extraction methods. So, we develop heuristic feature vectors for each task and process them using suitable deep learning models, including 1D-CNN, 2D-CNN, few-shot learning, and LSTM, each selected to best suit the specific task at hand.





RESULTS & DISCUSSION

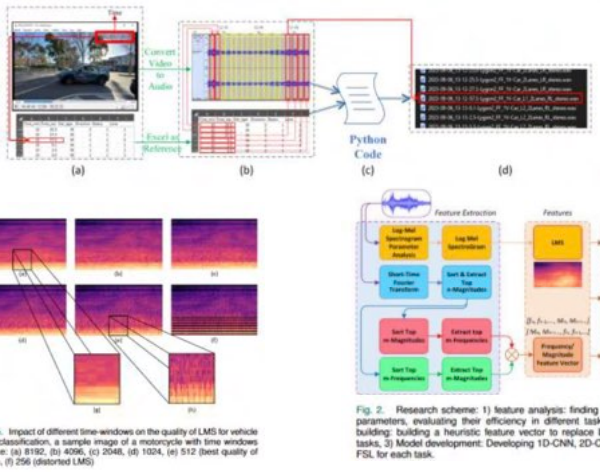
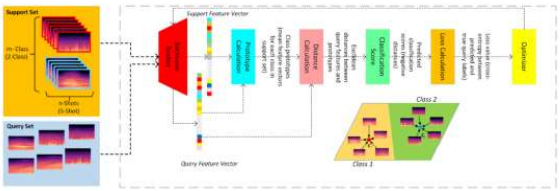
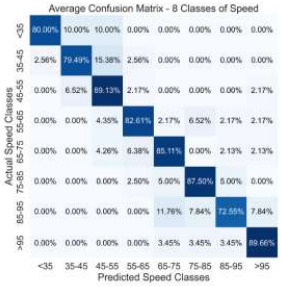


Fig. 5. Impact of different time-windows on the quality of LMS for vehicle type classification, a sample image of a motorcycle with time windows of size: (a) 8192, (b) 4096, (c) 2048, (d) 1024, (e) 512 (best quality of LMS), (f) 256 (distorted LMS)

Fig. 2. Research scheme: 1) feature analysis: finding the best LMS parameters, evaluating their efficiency in different tasks, 2) Feature building: building a heuristic feature vector to replace LMS for some tasks, 3) Model development: Developing 1D-CNN, 2D-CNN, DNN and FSL for each task.





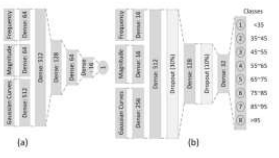


Fig. 3. Deep-learning models. (a) Regression model. (b) Classification model.

No.	Model	Feature	DS Info	Ref	Accuracy
1	CNN	LMS	MELAUDIS	This Study	99.96%
2	DNN	LMS	MELAUDIS	This Study	98.02%
3	VGG16	LMS	MELAUDIS	This Study	97.61%
4	MobileNet	LMS	IDMT	[20]	98.34%
5	SVR	HFP+LMS	VC-PRG	[29]	>98%
6	VCNN	HFP+LMS	VC-PRG	[30]	99.48%

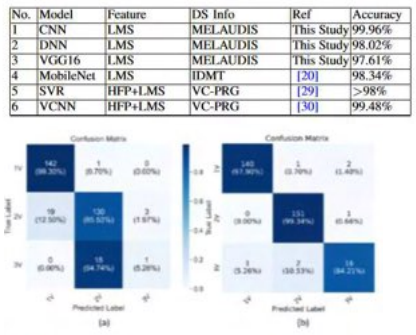


Fig. 9. Effectiveness of features and models in multi-vehicle detec ask: (a) LMS and 2D-CNN: overall accuracy = 63.36%, (b) TMF 1D-CNN: overall accuracy = 93.82%.

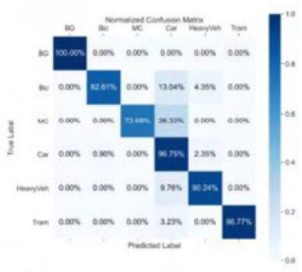


Fig. 14. Confusion matrix of vehicle type classification

Fig. 15. Confusion matrix of traffic monitoring

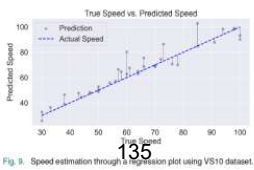


Fig. 9. Speed estimation through a regression plot using VS10 dataset.

Investigation on the effects of road pricing on safety.

Name: Humberto Barrera-Jimenez
Email: h.barrerajimenez@student.unimelb.edu.au
Supervisors: Prof. Mark Stevenson, Dr. Patricia Sauri Lavieri
Discipline: Transport

INTRODUCTION

Road pricing has been proven one of the most effective and efficient interventions to reduce the externalities of urban transport from a demand management perspective (Kuss & Nicholas, 2022; Rye & Ison, 2008). It has been observed that road pricing also improved road safety (Singichetti et al., 2021, 2022), despite never being an explicit design and policy principle of existing road pricing schemes (Lassiter, 2016; Naumann et al., 2020). The determinants of such effects are yet to be determined

This investigation explores individual, network and governance levels potential effects of road pricing on safety. Individual motorists' decision-making and behavioural responses on safe driving, mode choice, route choice and time-of-departure is explored through Discrete Choice and Driving Simulation experiments. Network effects are studied through Agent-Based Models. Governance is proposed through a theoretical policy framework.

It is hypothesised that, if explicitly included,, road pricing can be used as a systemic road safety strategy.

METHODOLOGY

This project is structured as an exploratory investigation. It spans the discrete, continuous and high-level decision-making, using 4 intertwined methods to integrate behavioural science, transport planning, economics and governance.

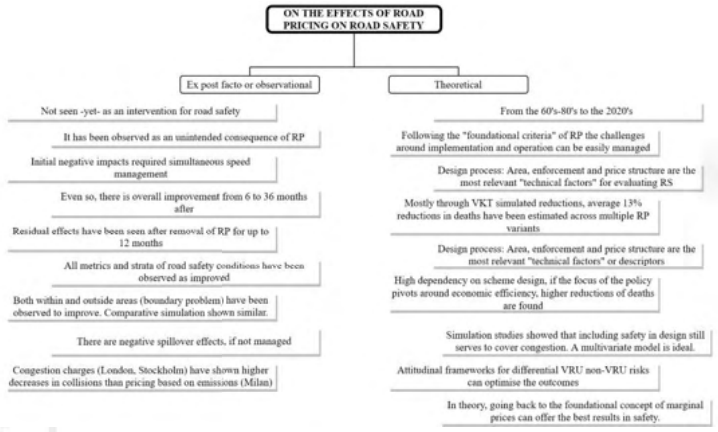
<u>Discrete Choice & Driving Simulation</u>
Mode + Route + Time-of-departure +
Safe driving (Manoeuvring, Awareness, Distraction)

<u>Agent-based modelling and simulation</u>
Exposure reduction (less vehicles, less driving, saferdriving), demand and traffic re-balance

<u>Governance frameworks</u>
Unveil true costs of car usage, hidden inequities, change discourses, innovate policy-making, sustainability (social, environmental, financial + resilience)

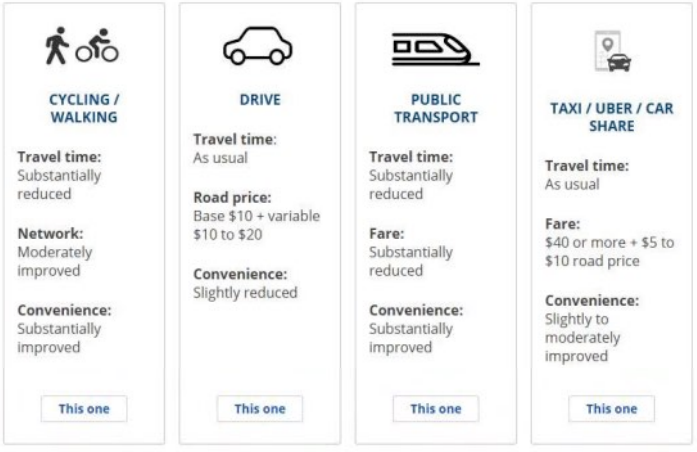
WORK IN PROGRESS

Literature review.



Driving simulation

Discrete choice



Infrastructure Engineering
Graduate Research Conference 2024

Electric Vehicle Charging Access: User Perspectives and Implications to Accessibility

PhD candidate: **Isrrah Malabanan** [i.malabanan@unimelb.edu.au]
Supervisors: Patrícia Sauri Lavieri[a], and Iderlina Mateo-Babiano[b]
Discipline: Transport
[a] Department of Infrastructure Engineering, FEIT, [b] Melbourne School of Design, ABP

INTRODUCTION

Charging disadvantage refers to the challenges in accessing and using electric vehicle (EV) charging technologies and services. It occurs when EV charging is:

- not always readily available
- physically distant
- systematically more expensive
- takes a significant time to fit into routines
- not inherently user-friendly
- does not enable other uses of battery energy

It not only affects EV purchase decisions but, more importantly, could influence users' travel behaviour and energy consumption patterns.

Current literature on EV charging provision often overlooks the diversity of users' charging needs and contexts, and the link between charging access and transport and energy accessibility.

To increase user-focused considerations in charging provision and to better understand the impacts of charging access in transport and energy perspectives, we proposed a conceptualisation of charging access as a user's capability and developed the **EV charging capabilities (EVCC) framework** based on the capabilities approach.

Additionally, we empirically explored the nuanced challenges that certain charging disadvantaged users face through qualitative research strategies.

METHOD

This study is funded by the University of Melbourne's ABP-FEIT Research Collaboration Grant and approved by the University of Melbourne Human Research Ethics Committee (Ethics ID 2023-28096-47638-3).

RESULTS & DISCUSSION

By shifting the viewpoint of charging access from spatial infrastructure distribution to the provision of capabilities, we identify the roles of:

- financial capacity
- personal conditions
- social roles and relationships,
- physical environment,
- wider structural conditions

on charging disadvantage and its consequences.

Additionally, our analysis identifies **renters and multi-unit dwelling (MUD) residents** as vulnerable to charging disadvantage due to their difficulties accessing home charging and limited public charging opportunities.

Their lack of home charging forces reliance on public charging, requiring routine changes and deliberate trip planning.

"We would wait until 10 or 11 at night and then … move our car from [public charging space] to our secure car spot."

"Is it in an area where I actually wanna sit around and are there things to do nearby?"

Furthermore, not all users can productively wait for charging due to the nature of household responsibilities and occupations.

"I can't do 'work from a charging station' because my work is office-based."

"…especially with a 5-year-old who doesn't want to sit and wait, wanting to charge is quite frustrating."

Our analysis highlights the multifaceted nature of charging disadvantage, highlighting the need for infrastructure planning that goes beyond mere physical proximity towards a holistic approach considering users' diverse circumstances.

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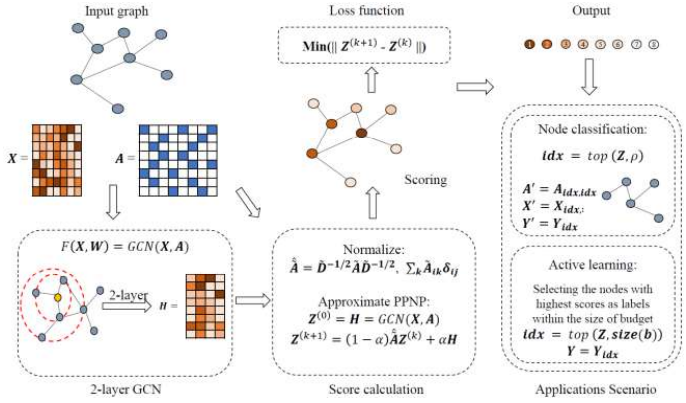
Feature-Aware Unsupervised Detection of Important Nodes in Graphs

Mohammadreza Ghanbari,
ghanbarim@unimelb.edu.au
Supervisors: Prof. Majid Sarvi, Dr. Jianzhong Qi, Dr. Saeed Asadi
Discipline: Transport

INTRODUCTION

- The significance of graph-structured data has increased in domains such as transportation networks, social networks, and molecular structure, emphasizing their adaptability in understanding complex relationships in today's information-rich landscape. A key task in such graphs is identifying critical nodes that are of particular importance, however, the absence of ground truth makes it challenging. Most existing methods either ignore node features or rely on supervised learning. This work introduces FadiGNN, a trainable, unsupervised model that combines node features and graph structure using Graph Convolutional Networks (GCNs) and personalized PageRank. FadiGNN is evaluated on tasks such as node classification and active learning. The experiments are conducted on different real-world datasets including large graph data and demonstrates high accuracy improvement over state-of-the-art models in node classification.

METHODOLOGY



Structure of our model FadiGNN. The model starts by applying a 2-layer GCN model on the adjacency matrix A and feature matrix X to compute the initial node embeddings. The generated embeddings are then used in the adapted personalized PageRank algorithm for score initialization. In the end, the loss function is used to reduce the difference between consecutive outputs.

RESULTS & DISCUSSION

Dataset	ρ	GCOND	Coarsening SCAL	FGC	K-center	Traditional Centrality	PPR	CUL	FadiGNN	#G Nodes	#G' Nodes
Cora	0.3	81.56±0.6	79.42±1.71	85.79±0.24	84.00±1.35	71.06±0.52	84.74±0.17	86.23±2.27	**86.69±1.13**	2,708	812
	0.1	81.37±0.40	71.38±3.62	81.46±0.79	72.16±3.96	25.15±1.75	77.05±0.62	80.07±2.27	**82.05±0.30**		270
	0.05	79.93±0.44	55.32±7.03	**80.01±0.51**	58.12±4.50	16.00±0.17	73.75±1.51	71.79±2.45	74.24±3.20		135
Citeseer	0.3	72.43±0.94	68.87±1.37	74.64±1.37	71.24±1.20	64.08±0.86	74.13±0.78	71.04±1.37	**76.52±1.73**	3,327	998
	0.1	70.46±0.47	71.38±3.62	73.36±0.53	66.37±1.23	29.85±2.17	67.56±1.76	66.99±1.65	**73.63±1.23**		332
	0.05	64.03±2.4	55.32±7.03	**71.02±0.96**	64.28±4.09	20.40±0.14	59.10±1.12	60.84±3.03	67.46±0.97		166
Co-phy	0.05	93.05±0.26	73.09±7.41	94.27±0.25	94.24±0.71	50.51±0.00*	94.01±0.17	94.95±0.31	**95.61±0.18**	34,493	1724
	0.03	92.81±0.31	63.65±9.65	94.02±0.20	93.82±0.67	50.51±0.00*	93.56±0.36	94.66±0.42	**95.33±0.30**		1034
	0.01	92.79±0.4	31.08±2.65	93.08±0.22	92.32±1.70	50.51±0.00*	90.36±0.67	93.06±0.56	**93.60±0.27**		344
Pubmed	0.05	78.16±0.30	72.82±2.62	80.73±0.44	79.42±0.98	43.01±0.15	83.66±0.80	84.41±0.77	**85.27±0.98**	19,717	985
	0.03	78.04±0.47	70.24±2.63	79.91±0.30	76.22±0.94	42.37±0.77	81.31±0.23	83.28±0.67	**83.65±0.69**		591
	0.01	77.2±0.20	54.49±10.5	78.42±0.43	75.13±2.95	43.08±1.18	76.90±0.60	77.23±0.89	**80.49±0.41**		197
Co-CS	0.05	86.29±0.63	34.45±10.0	89.60±0.39	86.00±6.65	74.73±0.58	88.24±0.27	88.04±0.82	**91.49±0.24**	18,333	916
	0.03	86.32±0.45	26.06±9.29	88.29±0.79	80.20±12.96	63.50±0.21	84.87±0.57	84.42±0.92	**88.66±0.22**		549
	0.01	84.01±0.02	14.42±8.5	**86.37±1.36**	67.08±22.35	40.56±1.03	79.04±0.29	67.55±0.15	83.28±0.57		183

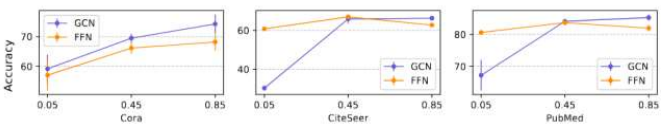
Node classification accuracy of models on different datasets. The best results are highlighted in boldface.

Dataset	G' (PPR)	G' (**FadiGNN**)	Full graph G
Cora	73.75±1.51	74.24±3.20	89.50±1.23
Citeseer	59.10±1.12	67.46±0.97	79.10±1.68
Co-phy	94.01±0.17	95.61±0.18	96.22±0.72
Pubmed	83.66±0.80	85.27±0.98	88.89±0.59
Co-cs	88.24±0.27	91.49±0.24	92.83±0.11

The table shows how well our model performs compared to the original Graph (No Coarsening).

Model/ρ	0.01	0.03	0.05
Centrality	19.47±1.25	22.34±1.31	25.31±0.68
PPR	15.48±0.14	27.07±1.42	31.45±0.58
CUL	52.75±1.52	59.78±0.23	59.77±0.25
FadiGNN	**53.83±1.16**	**59.87±0.28**	**59.91±0.23**

Accuracy of models on OGB-arxiv dataset.



The influence of teleport probability on model accuracy is examined across three datasets. The GCN model is used for node classification. The plots represent the GCN and FFN as function approximation $F(X, W)$, which are assessed for their performance under varying teleport probability.

Infrastructure Engineering
Graduate Research Conference 2024

AI-powered transit simulator: integration between microscopic simulation and machine learning

Mustafa Rezazada
Mustafa.rezazada@student.unimelb.edu.au
Dr. Neema Nassir and Prof. Egemen Tanin
Transport

INTRODUCTION

Modelling public transport (PT) operations is challenging due to fluctuating demand, supply variations, and external disruptions, and varying behaviour of passengers and drivers. Traditional research using macro and mesoscopic simulation or microscopic simulators struggle to replicate day-to-day variability, and they fail to capture the cumulative impact on overall system performance and service reliability.

This study introduces a hybrid AI-powered simulation that integrates machine learning (ML) and deep learning (DL) with microscopic simulation to overcome these limitations. The methodological contribution is twofold: (1) it employs advanced ML and DL models trained on large-scale real-world data to learn variability and patterns, enabling more accurate inputs for simulation, and (2) it replaces certain simulation activities with AI agents, enhancing the scalability and computational efficiency of microscopic simulators.

Applied in a case study to one of Melbourne's largest tram route, to evaluate system reliability under multiple uncertainties related to demand, supply, and external factors. The results demonstrate that the causes of reliability issues vary temporally and spatially, and the AI-powered simulators successfully replicated historical patterns and variability in key performance indicators, such as headway, dwell time, departure discrepancies, and bunching, with an overall accuracy of over 95%, making them suitable for reliability analysis.

METHODOLOGY

The proposed framework integrates real-world data, advanced AI models, and microscopic simulations to model PT operations in a unified, holistic manner. It classifies system components into primary and secondary activities. Primary components directly impact reliability (e.g., vehicle and passenger movements) and are modelled with detailed microscopic simulations. Secondary components (e.g., demand fluctuations, signal delays) indirectly impact reliability and are modelled using ML and DL to learn patterns and variability from large datasets.

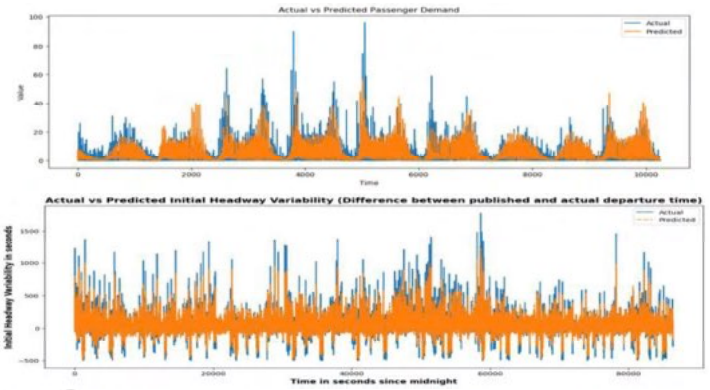
The framework includes three core engines:

1. **Data Processing and Fusion Engine (DPF-E)**: Automates data retrieval, processing, and integration for AI model inputs.
2. **AI Engine (AI-E):** Hosts ML and DL models that predict operational conditions before and during simulation, learning from historical patterns and spatio-temporal dependencies (Figure 2).
3. **Simulation Engine (SM-E):** Simulates primary components like vehicle and passenger movements, integrating predictions from AI-E to enhance accuracy and scalability. This flexible integration allows for varying simulation intervals to balance detail and performance.

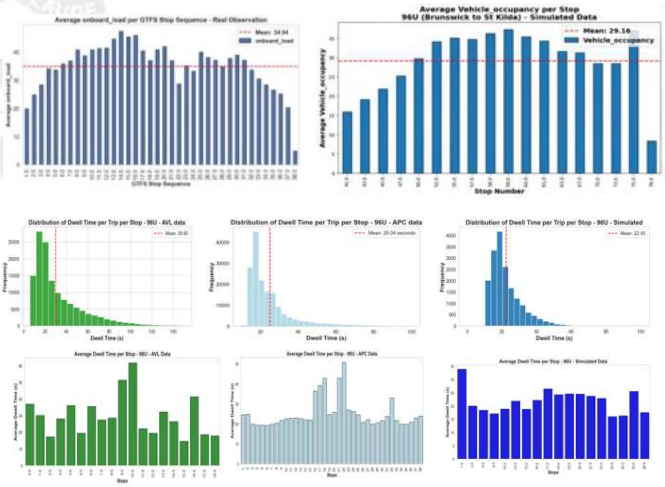
The framework optimises the strengths of AI models and microscopic simulations to provide a scalable and accurate tool for PT reliability analysis. It captures both local interactions and broader network effects, enabling the detailed analysis of complex PT systems. This hybrid approach can predict demand at stops, model downstream impacts, and simulate service reliability under diverse conditions, which is beyond the capabilities of existing simulators or AI models alone.

RESULTS & DISCUSSION

1. Variability of the underlying reliability causes



2. Replicating historical patterns and day-to-day variability for key performance indicators such as headway, dwell time, and onboard load.



Results demonstrate that our AI-powered simulator effectively captures both the variability of underlying causes and the overall reliability measures. Despite the challenges in measuring dwell time and headway variability, our innovative approach accurately represents their spatio-temporal variability and average values with over 95% accuracy.

This simulator is a powerful tool for reliability and variability analysis, offering unprecedented micro-level resolution at significantly larger network scales. We optimised the integration of ML and DL models with microsimulation, creating a unified holistic engine as opposed to existing hybrid models that execute tasks sequentially, using ML input for simulation or vice versa.

The proposed simulator has diverse applications, including identifying sources of reliability issues, distinguishing between systematic recurrent and non-recurrent bunching problems, and evaluating overall system performance and reliability. In this research, we focused on the overall reliability.

In conclusion, this AI-powered simulator represents a significant advancement in transportation modeling, offering high-resolution insights for complex network analysis and decision-making.

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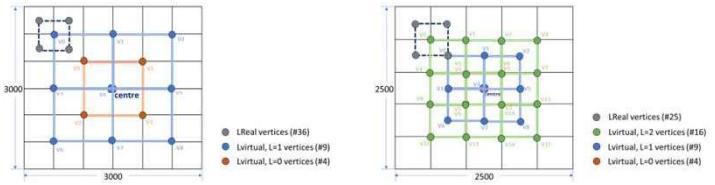
General algorithm of assigning raster features to vector maps at any resolution, size or scale

Nan Xu
naxu@student.unimelb.edu.au
Mark Stevenson, Kerry Nice, Sachith Seneviratne
Transport

INTRODUCTION

- The fusion of multi-source data is essential for a comprehensive analysis of geographic applications. In this study, we propose a general algorithm for assigning features from raster data (concentrations of air pollutants) to vector components (roads represented by edges) in city maps through the iterative construction of virtual layers to expand geolocation from a city centre to boundaries in a 2D projected map. The construction follows the rule of perfect squares with a slight difference depending on the oddness or evenness of the ratio of city size to raster resolution. We demonstrate the algorithm by applying it to assign accurate $PM_{2.5}$ and NO_2 concentrations to roads in 1692 cities globally for a potential graph-based pollution analysis. This algorithm could pave the way for agile studies on urgent climate issues by providing a generic and efficient method to accurately fuse multiple raster and vector datasets of varying scales and compositions.

METHODOLOGY



If $I_{totale(o)} > 1$,

$V_{vire(o)} = \{4, 9, 16, \ldots, (n+2)^2\}, n = 0, 1, 2, \ldots, I_{vire(o)} - 1,$

for s is even,

$$V_{reale} = 4 \times (n+2)^2;$$

for s is odd,

$$V_{reale} = ((n+1)+2)^2.$$

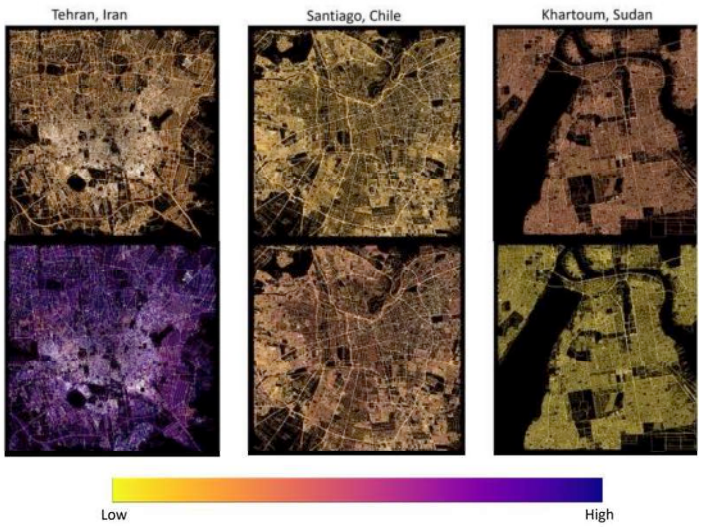
$V_{reale(o)}$ should be equal to the number of target grids G,

$$V_{reale(o)} == G.$$

RESULTS & DISCUSSION

- We applied the stated algorithm to the fusion of two raster datasets with different resolutions of $PM_{2.5}$ (r=500) and NO_2 (r=1000), and vector map data generated from OpenStreetMap for 1692 global cities. The combined is visualized as table and image as below.
- The technique is an automatic, efficient, low-cost, and open-source Python solution, which is convenient to adapt to other forms of fusion on the pixel or decision level.

u	v	key	osmid	highway	oneway	reversed	length	geometry	PM25	bridge	name	service	junction	access
22925	5367922921	0	556460807	service	False	False	158.519	LINESTRING (102.26213 -3.80733, 102.26181 -3.8..	15.9	NaN	NaN	NaN	NaN	NaN
	5367922929	0	556460807	service	False	True	143.456	LINESTRING (102.26213 -3.80733, 102.26229 -3.8..	15.9	NaN	NaN	NaN	NaN	NaN
	5367922112	0	556460805	service	False	True	51.385	LINESTRING (102.26213 -3.80733, 102.26245 -3.8..	15.9	NaN	NaN	NaN	NaN	NaN
22921	5367922925	0	556460807	service	False	True	158.519	LINESTRING (102.26099 -3.80652, 102.26134 -3.8..	15.9	NaN	NaN	NaN	NaN	NaN
40154	9436388692	0	[814548578, 814548579, 814548580]	service	False	True	1685.845	LINESTRING (102.26437 -3.81000, 102.26251 -3.8..	15.9	yes	NaN	NaN	NaN	NaN
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
39530	2441409518	0	235780173	residential	False	False	47.498	LINESTRING (102.28072 -3.77342, 102.28086 -3.7..	16.6	NaN	NaN	alley	NaN	yes
39518	2441409564	0	236070074	residential	False	False	184.046	LINESTRING (102.28097 -3.77307, 102.28104 -3.7..	16.6	NaN	NaN	NaN	NaN	NaN



Developing a hyperconnected and resilient logistic network design for peri-urban freight transportation

Simon Anthony Lorenzo
lorenzos@student.unimelb.edu.au
Supervisors: Prof. Russell Thompson, Prof. Greg Foliente
Discipline: Transport

INTRODUCTION

- In recent years, several disruptions of varying magnitudes have affected logistics networks across the country. From minor ones such as traffic jams and road disruptions, to major ones such as flooding and bushfires, these disruptions continue to cause delays and other negative consequences to logistics networks, resulting in waste in several forms such as excess costs and greenhouse gas emissions. The Physical Internet (PI) is paradigm that aims to address issues regarding efficiency and sustainability in global logistics, emphasizes interconnectivity of various aspects of the logistics networks. This can be leveraged to improve the resilience and robustness of logistics network, particularly in the peri-urban to regional scope.

RESULTS & DISCUSSION

- Initial results show that the adoption of PI, even partially, would provide a great range of benefits to various stakeholders involved. Economic gains, environmental and societal benefits, and a higher level of network resilience can potentially be achieved with the implementation of the PI-enabled structure. The next steps to advance both PI research and implementation are also provided.

METHODOLOGY

- A PI-enabled design of the logistics network is developed in the setting of Victoria through a discrete-events simulation model. A hyperconnected, open network is developed where retailers can leverage resource and information sharing to achieve various objectives. Key source and destination nodes are identified, and various instances of disruptions are explored. The frequency, severity, scope of impact and recovery time of these disruptions are also considered. Multi-objective assessment is undertaken to analyze different scenarios, with respect to financial projects for private companies, greenhouse gas emissions towards environmental sustainability, and resilience for the benefit of the general public. Different levels of PI incorporation are described, from the current, intermediate, and up to the ideal full PI-enabled setup, to aid in actual implementation.

Plot of source and destinations nodes across Victoria.

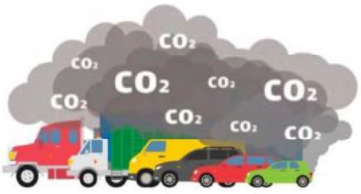
Infrastructure Engineering
Graduate Research Conference 2024

Sustainable Transport: A Multi-Task Approach for Predicting Emissions and Travel Delays at Signalised Intersection.

Name: Keya Roy
Email: keya@student.unimelb.edu.au
Supervisors: Dr. Neema Nassir, Dr. Xiaocai Zhang
Disciple: Transport

INTRODUCTION

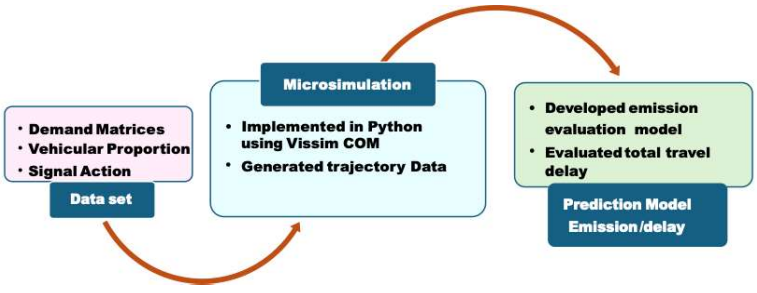
- Signalised intersections are the key hotspots of congestion which leads to increased **emissions** and significant **travel delays** which together undermine **urban sustainability**.
- In this study, **a novel multi-task** learning framework has been developed to **jointly predict** both **emissions** and **travel delays** at a signalised intersection.



- By using advanced **machine learning** and **deep learning** techniques and a **naturalistic dataset** that integrates **real-world traffic data** with **emission** and **delay** measurements, our approach aims to provide **accurate predictions** that can inform **smarter and sustainable traffic management**.

METHODOLOGY

- The **methodology** focuses on the development of various **machine learning** and **deep learning** techniques for the prediction of **emission** and **travel delays** at a **four-approach signalised intersection**.
- Total **16282 traffic scenarios** have been created using microscopic simulation technology.
- **Shapley Additive** has been performed for the **explainability** of the features.
- **Emission** at the microscopic level is measured by a physic-based method based on **vehicle trajectory** data **(**i.e., **velocity** and **acceleration**).



Research Methodology

RESULTS & DISCUSSION

- **Machine learning** and **2 Deep learning** baseline methods have been introduced for benchmarking the **joint prediction.**
- By comparing different techniques, the **TCN model** performs the **best** across various **evaluation metrics**.

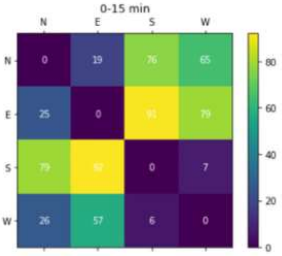
Error Comparison between different models (CO2 emission is in tonne)

Errors \ Models	SVR	CNN Model (1)	CNN Model (2)	TCN Model
RMSE	0.0482	0.0372	0.0364	**0.0348**
MAE	0.0384	0.0285	0.0284	**0.0265**
MAPE	7.6636	5.75%	5.63%	**5.30%**
R^2 Score	0.6078	0.7668	0.7767	**0.7964**

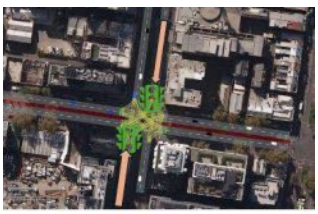
Error Comparison between different models (Total Travel Delays in min)

Errors \ Models	SVR	CNN Model (1)	CNN Model (2)	TCN Model
RMSE	405.77	305.0	285.43	**287.45**
MAE	318.17	235.47	221.20	**220.38**
MAPE	6.85%	5.11%	4.81%	**4.77%**
R^2 Score	0.6588	0.8072	0.8312	**0.8288**

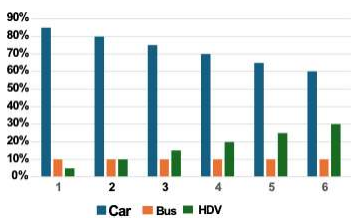
- Analysis of the **feature importance** reveals that for **emissions**, the **demand matrix** is the most significant, followed by the **vehicular proportion.**
- The **feature importance** analysis for **travel delays** shows that the **signal setting time** for the **N-S direction** is the most significant, followed by the **signal setting time** for the **E-W direction**.



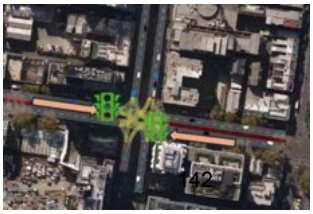
Demand Matrix



Signal Setting for the N-S through



Various Vehicular Proportions



Signal Setting for the E-W through

Advanced methods in discrete choice modelling

Name: Amir Ghorbani
Supervisors: Dr. Neema Nassir, Dr. Patricia Sauri Lavieri
Discipline : Transport

INTRODUCTION

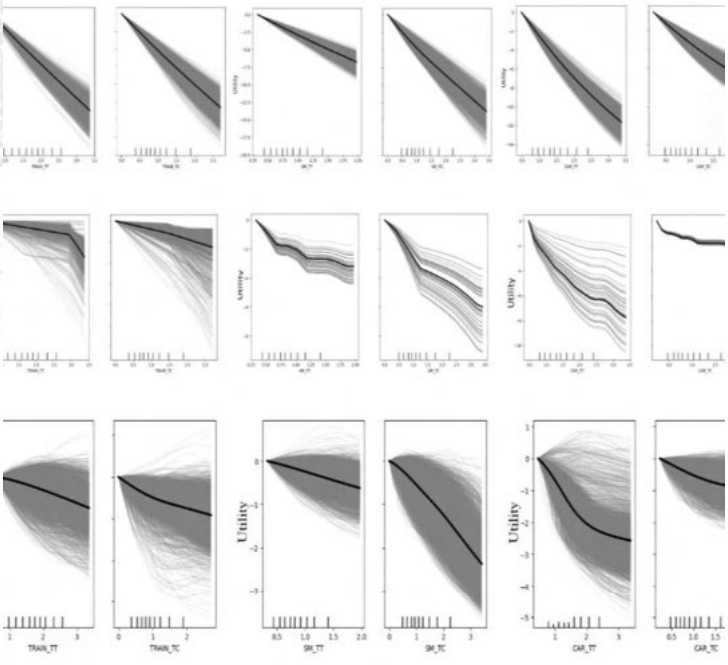
- Theory-driven discrete choice models (DCMs) are often built using manually crafted utility functions, which can lead to insufficient predictive accuracy, misrepresentation of key relationships, and a time-consuming specification process. In contrast, data-driven DCMs improve predictive accuracy by adopting more flexible and automated utility specifications. However, this flexibility comes at the cost of lower behavioural reliability, as these models frequently provide biased or misleading interpretations of critical metrics such as willingness to pay. Therefore, the challenge is to develop data-driven DCMs that can retain high predictive power while improving interpretability and ensuring credible behavioural insights. This research advances beyond state-of-the-art neural network-based DCMs by formulating a behaviourally Informed neural network (BINN) that is responsive to behavioural domain knowledge.

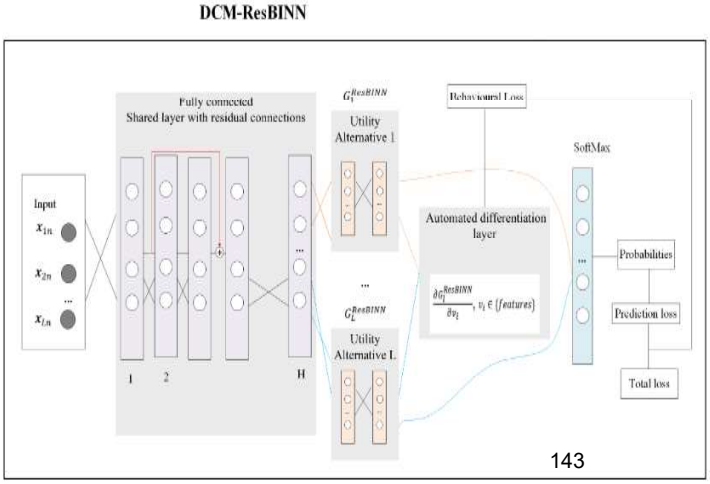
METHODOLOGY

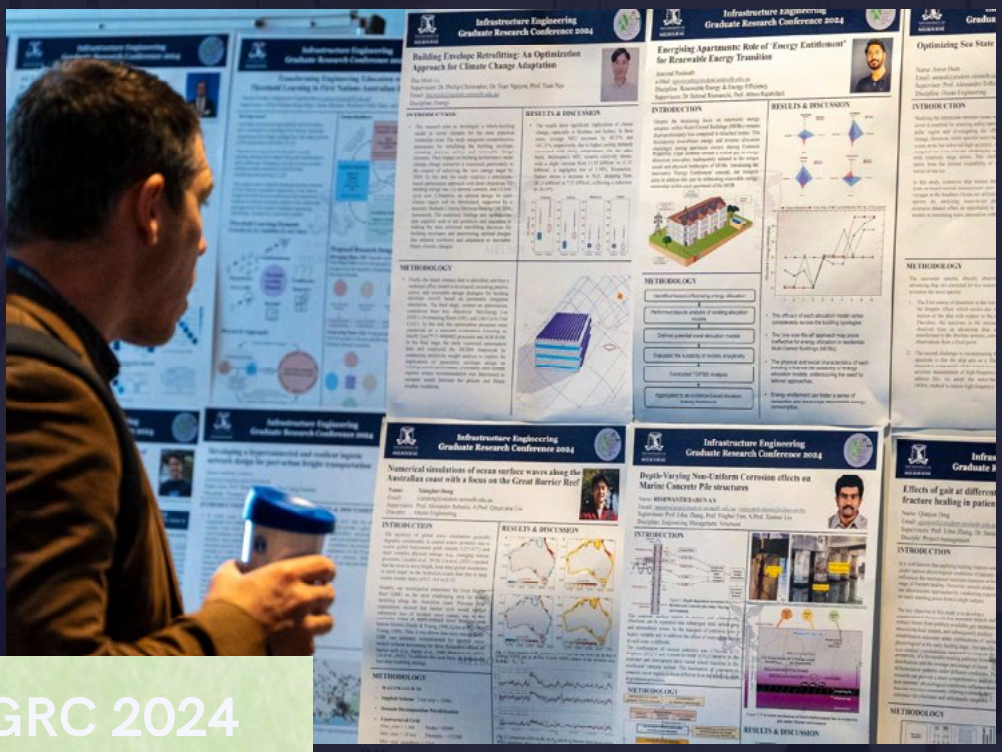
- We achieve this by introducing new terms in the loss function of the DCM-DNN inspired by the PINN framework proposed by Raissi et al(2019) . This approach leverages the high predictability of neural networks while steering the results toward more behaviourally consistent outcomes. Additionally, our model offers an advantage over LN by requiring fewer parameters to fine-tune while also incorporating WTP constraints alongside the monotonicity addressed in LN. By enhancing behavioural realism, the BINN model makes its policy-related outputs more credible.

RESULTS & DISCUSSION

- The results of this research promote the use of NN-based DCMs to enhance interpretability, a quality traditionally associated with manually crafted models. In this context, the paper presents a behaviourally consistent DCM concerning monotonicity and VOTT distribution by introducing behaviourally informed neural networks (BINN), incorporating the physics-informed neural network (PINN) framework.







IEGRC 2024 SPLENDID CAPTURES OF THE DAY

21 October 2024

IEGRC 2024 SPLENDID CAPTURES OF THE DAY

21 OCTOBER 2024

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Evening session- Panel discussion – Bridging the Gap by Transforming Research into Industry-Ready Sustainable Solutions

Dr. Kiernan Fowler - Moderator

Senior Lecturer, IE Department

"The success of research is not just gauged by the innovation it introduces, but significantly by its practical applicability and adoption in real world scenarios"

Dr. Serryn Eagleson

Digital Advisory Lead, Arup

"Through any challenges, remember to keep moving forward, stay communicative keep dial on open at whatever the positions you get or networking you involved with, add a little bit of value and be curious on them"

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Prof. Alex Felson,

Elisabeth Murdoch Chair of Landscape Architecture

"Human society is driven by innovation, making creative thinking essential for professionals. Breaking away from conventional structures through open-minded approaches is most effective when academia and industry collaborate"

Dr. Patricia Sauri Lavieri

Senior Lecturer, IE Department

"Researchers are a kind of knowledge entrepreneurs; you might need to sell your ideas convincingly for all to gain support to build your career and strengthen your position."

IEGRC 2024 SPLENDID CAPTURES OF THE DAY

21 October 2024

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Evening session- Award Ceremony – Best presentation at IEGRC 2024

Forum – Presentation title	Presenter
Structural Engineering - Numerical Modelling of Liquid Hydrogen Boil-off	Susiri Costa
Geotechnical Engineering - Numerical assessment of ground heat exchangers performance in a pit lake environment	Mauricio Carcamo Medel
Environmental Hydrology and Water Resources - Assessment of surrogate models for flood inundation: The physics - Community priorities for climate change adaptation	Madeline Grupper
Geomatics Group - Developing 3D Spatial Graph Database for Underground Utility Networks	Ensiyeh Javaherian Pour
Ocean, Energy, Engineering Management, and Transport - Electric Vehicle Charging Access: User Perspectives and Implications to Accessibility	Isrrah Malabanan

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Evening session- Award Ceremony – Best journal papers of the year

Paper title	First author
Nonlinear analysis and design of high strength concrete filled steel tubular columns under non uniform fires	Lalita Lama
Crowdshipping for sustainable urban logistics: A systematic review of the literature	Seyed Sina Mohri
Assessment of surrogate models for flood inundation: The physics – guided LSG model vs. state-of-the-art machine learning models	Niels Fraehr
Identifying global parameters for advancing Land Administration Systems	Fatemeh Jahani Chehrehbargh

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Evening session- Award Ceremony – Best poster at IEGRC 2024

Poster title	Presenter
Open Mutual Learning: Ensemble of CNNs for urban building footprint extraction with open data	Bipul Neupane
Integrating vegetation dynamics into conceptual hydrological modelling	Gabrielle Burns
Electric Vehicle Charging Access: User Perspectives and Implications to Accessibility	Isrrah Malabanan

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Evening session- Award Ceremony –Logo competition for IEGRC 2024 - Winner

Logo Theme	Designed by
Beyond Green: Transforming research into sustainability	Pramod Dilashan

Evening session - Lucky draw - Winners

Infrastructure Engineering Graduate Research Conference (IEGRC) -2024

Evening session - Vote of Thanks

Prof. Lihai Zhang

Research Higher Degree Coordinator,
Infrastructure Engineering Department

"Thank you all for your invaluable contributions. A conference is more than just a gathering, it's a transformation of ideas, innovation, and education. Let's carry the spirit of this event forward into the year ahead"

Thank you
IEGRC 2024

21 October 2024 at Rydges Melbourne CBD