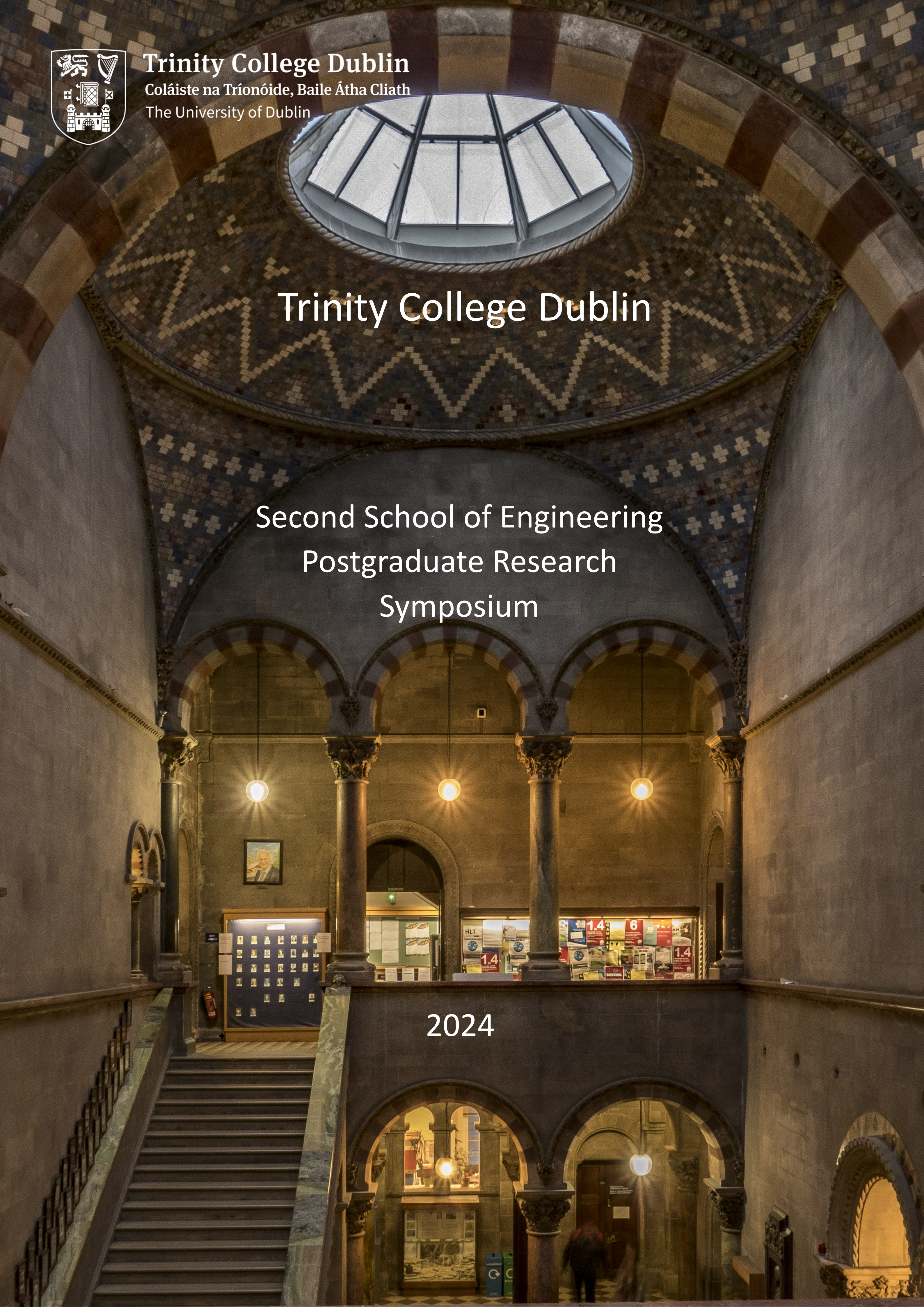

Trinity College Dublin
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# Trinity College Dublin

## Second School of Engineering Postgraduate Research Symposium

2024

*Cover image:*

*Museum Building Atrium, Trinity College*

# UNIVERSITY OF DUBLIN

# TRINITY COLLEGE

# BOOK OF ABSTRACTS

Second School of Engineering Postgraduate Research Symposium

Tuesday, 22nd October 2024

School of Engineering

TCD

# SECOND SCHOOL OF ENGINEERING POSTGRADUATE RESEARCH SYMPOSIUM

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## Introduction

Welcome to the Second PhD Research Symposium of the School of Engineering, a celebration of innovation, exploration, and the pursuit of knowledge in the field of engineering. We are delighted to present this book of abstracts, a compendium of the remarkable research undertaken by our talented PG researchers in the School.

Within these pages, you will find a snapshot of the diverse and cutting-edge research that defines our School of Engineering. Our researchers have dedicated countless hours to complex problems, developing novel solutions, and pushing the boundaries of what is possible in the world of engineering.

Each abstract is representative of the passion, dedication, and expertise of our PhD researchers. Their work not only contributes to the academic excellence of our School but also holds the promise of transforming industries, improving lives, and making a positive impact on society for a sustainable future.

We thank the researchers who have shared their work in these pages, to their mentors, advisors and supervisors who have guided them on this intellectual journey, and to the faculty and staff who support and facilitate their research.

As you explore this book of abstracts, we encourage you to engage with the research, to foster dialogue, and to seek opportunities for collaboration and innovation. Together, we can address the challenges of today and shape a more sustainable tomorrow.

We hope that the research showcased here inspires you as much as it has inspired us.

*Prof Breiffni Fitzgerald*

*Director of Postgraduate Teaching and Learning*

*School of Engineering*

## School of Engineering

The School of Engineering owes its establishment to the leadership of Humphrey Lloyd, with valuable support from mathematicians James McCullagh and Thomas Luby. This pivotal moment in the history of Trinity College occurred on June 15, 1841, when the Board publicly announced their intention to create a School of Civil Engineering and sought to appoint two professors. As part of the application process, students interested in the two-year civil engineering course had to have successfully completed the Junior Freshman year of the Arts program at the university.

Engineering lectures commenced on November 16, 1841, with Humphrey Lloyd delivering a *praelection* the day before to mark the official opening of the School. In his address, Lloyd articulated the significance of teaching engineering within a university context. He emphasized the opportunities provided by the University for students' education and professional development. He underscored the transformation of engineering from a field primarily concerned with engines to one that had risen to the forefront of the liberal professions. With extensive public projects underway, the responsibilities of engineers were numerous and substantial, demanding a wide-ranging and comprehensive knowledge.

Lloyd encouraged students to take full advantage of the educational opportunities presented to them, to be diligent in their studies, take comprehensive notes during lectures, and combine the knowledge they acquired with their personal reading. He emphasized that students had ample motivation to excel in their studies, as the path towards becoming a professional engineer was fascinating and appealing. The subsequent career in engineering offered an opportunity to serve their country with distinction, earn a respectable livelihood, and attain an honourable reputation. He concluded by extolling the virtues of the engineering profession, encouraging students to pursue its study, and offered insights that remain relevant today.

Throughout its history, the strategic mission of the School of Engineering has consistently centred on the pursuit of excellence in both teaching and research in engineering. The primary goal has been to produce graduate engineers with the capability for independent and creative problem solving, analytical thinking, and innovative design. This unwavering commitment to nurturing skilled and forward-thinking engineers remains the school's enduring mission.

Cox Ron, ‘1841-2016: A Brief History of Engineering at Trinity’, 2016, School of Engineering. TCD.

Cox Ron, ‘Engineering at Trinity’, 1993, School of Engineering. TCD.

## Program

Tuesday, 22$^{nd}$ October 2024

**Time:** 9:15am

**Venue:** Science Gallery, Paccar Theatre (Presentations),

Science Gallery, Main Space (Posters).

**Agenda:**

9:15: Arrivals

9:30: Opening Address: Professor Alan O'Connor PhD, FTCD, CEng FIEI.

*Head of School of Engineering*

9:40: Presentations Start (each presentation lasts 7 minutes including Q&A)

10:55: Coffee Break

11:25: Presentations Recommence

12:15: Guest Speaker: Dr David Corrigan

*Senior Research Scientist at Huawei Ireland*

12:30: Lunch and Poster Presentations

13:45: Prize Awarding: Provost Linda Doyle

14:00: Closing Address

# ABSTRACTS

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**mm - Wave Radar Technologies for Digitizing Biodiversity**

Linta Antony[1] , Adam Narbudowicz[2], Ian Donohue[1], and Nicola Marchetti

[1] Trinity College Dublin, Dublin, Ireland, [2] Tyndall National Institute, Ireland

Insects are both numerous and varied, playing a significant role in our ecosystem and impacting human activities. The global decline in insect populations has severe and irreversible effects on the environment, however existing Insect monitoring methodologies are incapable to provide sufficient resolution. To address this issue, we propose a near-field radar device supported by machine learning processing. This research utilizes simple experimental setups to analyse the micro-Doppler effects caused by an insect passing within antenna's near-field, to accurately classify its species. The experimental setup and the proposed classification algorithm synergize to not only discern insect presence, absence, and wing beat patterns but also proficiently classify insects into distinct categories. These combined efforts mark a significant stride towards innovative, non-destructive radar-based techniques for enhanced biodiversity monitoring.

## References

[1] Linta Antony, Nicola Marchetti, and Adam Narbudowicz. "Modelling of Micro-Doppler Effect in mm-Wave Antenna Due to Near-Field Insect Fly-By." 2023 IEEE International Symposium On Antennas And Propagation (ISAP). IEEE, 2023.

[2] Linta Antony, et al. "Angle of Arrival Estimation Methods Using Spherical-Modes-Driven Multiport Antennas." 2024 18th European Conference on Antennas and Propagation (EuCAP). IEEE, 2024.

[3] Linta Antony, et al. "Virtual Spherical Modes for AoA Estimation with Small Sub-Wavelength Antennas." IEEE Antennas and Wireless Propagation Letters (2024).

[4] Linta Antony, Maryam Norouzi, Adam Narbudowicz, and Ian Donohue. "Detection and classification of flying insects by using micro-Doppler signatures of wing movement. " UK Patent Application 2411645.1.

## Transforming the Skies: How HAPS-RIS is Shaping the Future of UAV Networks

Arman Azizi[1], Mustafa Kishk[2], and Arman Farhang[1]

[1] Department of Electronic & Electrical Engineering, Trinity College Dublin, Dublin, Ireland

[2] Department of Electrical and Electronic Engineering, Maynooth University, Maynooth, Ireland

The advancement of wireless networks is steering towards achieving universal, reliable, and cost-effective connectivity for users globally, especially in remote and underserved regions where establishing conventional infrastructure is challenging or prohibitively expensive [1-4]. This research investigates the use of unmanned aerial vehicles (UAVs) as aerial base stations in these challenging areas, addressing a critical issue—the limitation imposed by the number of deployable UAVs, which constrains the achievable coverage. To overcome this limitation, this study introduces a novel framework that integrates high-altitude pseudo-satellites (HAPS) with reconfigurable intelligent surfaces (RIS), forming a HAPS-RIS system that leverages the stratosphere as a "smart mirror." This framework aims to minimize the need for UAVs while ensuring comprehensive network coverage [2]. The methodology employed in this research combines a multi-level optimization approach with advanced machine learning techniques, such as K-means clustering, integer programming, and RIS clustering. These methods facilitate efficient zone association and clustering of RIS elements to reduce computational overhead. Additionally, by applying the RIS clustering technique, the proposed framework offers a low-complexity solution to optimize RIS phase shifts, even in scenarios involving a massive number of RIS elements. The impact of this research is twofold: first, it provides practical, low-complexity solutions for deployment in the telecommunications industry, which may expedite the adoption of HAPS-RIS integrated systems. Second, it significantly reduces the reliance on large fleets of UAVs, making the network architecture more efficient and sustainable. Overall, this study demonstrates that by optimizing the integration of HAPS with RIS, it is possible to extend coverage effectively and affordably, offering a promising solution for future wireless networks in remote and underserved areas [2].

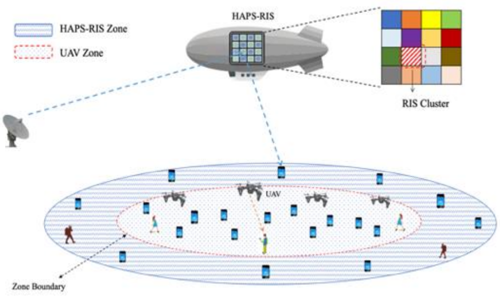


*Fig. 1. Proposed low-complexity architecture [2].*

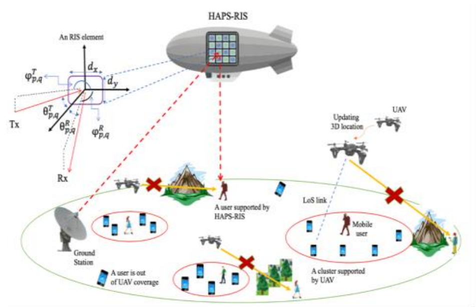


*Fig. 2. Integration of HAPS-RIS and UAV Networks [3].*

### References

[1] A. Azizi, A. Farhang, "RIS Meets Aerodynamic HAPS: A Multi-objective Optimization Approach," IEEE Wireless Communication Letters (WCL), 2023.

[2] A. Azizi, M. Kishk, and A. Farhang, "Exploring the Impact of HAPS-RIS on UAV-based Networks: A Novel Architectural Approach," arXiv preprint arXiv:2409.17817, 2024.

[3] A. Azizi and A. Farhang, "What Will Be The Network Architecture For Next Generation Networks?" ADVANCE CRT Research Colloquium, Tralee, Ireland, 2024. Available: https://doi.org/10.5281/zenodo.13898250.

[4] A. Azizi, S. Parsaeefard, M. R. Javan, N. Mokari, and H. Yanikomeroglu, ''Profit maximization in 5G+ networks with heterogeneous aerial and ground base stations,'' Vol. 19, No. 10, IEEE Trans. Mobile Computing, 2022.

**Investigating Brain Synchronisation Metrics as a Marker for Detecting Social Disengagement**

J.K. Bradshaw[1]

[1] Neural Engineering Group, Department of Electronic and Electrical Engineering, Trinity College Dublin, Dublin, Ireland

Social disengagement is the process by which an individual withdraws or reduces their participation in social interactions or activities. This process has been associated with hearing impairments and psychological disorders, and it is a known risk factor of mild cognitive impairments (MCI) and even dementia in later life. [1][2] Although it has traditionally been considered a normal consequence of aging, nowadays it is accepted as a modifiable risk factor. Electroencephalography (EEG) measures brain activity using non-invasive electrodes. While scalp-EEG is the standard method, ear-EEG is emerging as a more comfortable, naturalistic alternative using earbud-like devices. [3] This project focuses on measuring brain activity of multiple individuals simultaneously. This technique, named hyperscanning, detects brain synchronisation patterns between individuals and, therefore, potentially recognises disengaging behaviours. [4] Unfortunately, there is no understanding of the underlying neural mechanisms that lead to social disengagement, or how social interventions reduce patient's withdrawal. This line of research intends to understand these neural mechanisms to improve social therapies for disengaging patients, and to develop markers to avoid social disengagement. Therefore, the aim of this project is to study whether brain synchronisation activity is a good metric for detecting social disengagement. Accordingly, four studies will be carried out: (1) disentangle the contributions of task versus context in neural metrics of brain synchronisation, (2) investigate the modulatory effects of a hearing impairment in familiar versus unfamiliar social contexts in task performance based in brain synchronisation, (3) explore brain synchronisation in individuals with MCI, and (4) investigate the use of novel-unobtrusive ear-EEG systems towards the development of a social facilitation monitoring framework for real-life scenarios. An objective metric to detect withdrawal is necessary to design effective social therapies and to avoid the negative effects of social disengagement.

## References

[1] Motala A, Johnsrude IS, Herrmann B. A Longitudinal Framework to Describe the Relation Between Age-Related Hearing Loss and Social Isolation. Trends Hear. 2024;28:23312165241236041. DOI: 10.1177/23312165241236041

[2] Luchetti M, Terracciano A, Aschwanden D, Lee JH, Stephan Y, Sutin AR. Loneliness is associated with risk of cognitive impairment in the Survey of Health, Ageing and Retirement in Europe. Int J Geriatr Psychiatry. 2020;35(7):794-801. DOI: 10.1002/gps.5304

[3] Kaongoen N, Choi J, Woo Choi J, Kwon H, Hwang C, Hwang G, et al. The future of wearable EEG: a review of ear-EEG technology and its applications. J Neural Eng. 2023;20(5). DOI: 10.1088/1741-2552/acfcda

[4] Farrell S, Valdes AL. 'The Mind' promotes brain synchronization: an ecological evaluation of brain synchronization in co-operative tasks. Annu Int Conf IEEE Eng Med Biol Soc. 2023;2023:1-4. DOI: 10.1109/EMBC40787.2023.10340212

**Nucleate Pool Boiling Enhancement on Ti64 Cold Spray Additive Manufacturing Coatings**

Yan Chen[1], Alekos Ioannis Garivalis[2], Evgeny Shatskiy[1,3], Anthony Robinson[1],

Paolo Di Marco[2], Shuo Yin[1] and Rocco Lupoi[1]

[1] Department of Mechanical, Manufacturing, and Biomedical Engineering, Trinity College, University of Dublin, Ireland

[2] Department of Energy, Systems, Territory and Constructions Engineering, University of Pisa, Largo Lucio Lazzarino 1, 56122, Pisa, Italy

[3] Present address: University of Illinois at Urbana-Champaign, 901 West Illinois Street, Urbana, IL 61801, US

This study elucidates the effectiveness of a metal additive manufacturing technique, cold spray deposition, used to prepare enhanced boiling surfaces consisting of Ti-6Al-4V (Ti64) coatings on aluminium substrates. The process was specially tuned to produce highly inhomogeneous porous Ti64 coatings. By adjusting key cold spraying parameters such as transfer speed of nozzle, temperature and powder feeder rate, reproducible porous coating fabrication was successfully achieved.

After the coating deposition was completed, some samples were systematically tested for heat transfer in a specially designed pool boiling apparatus. Boiling curves of the enhanced cold sprayed surfaces were experimentally measured and compared to bare surfaces used as benchmarks to assess the enhancement. Data analysis showed that some of the tested surfaces exhibited significant enhancements in both heat transfer coefficients and critical heat flux. By analysing the coatings with a variety of characterisation techniques (e.g. scanning electron microscopy, white light interferometry, etc.), it was found that this enhancement could be attributed to an increase in nucleation points due to the porosity and high roughness of the surfaces. However, excessively thick coatings may lead to a decrease in heat transfer performance.

The Ti64 coating developed using the cold spraying technique has great potential for industrial applications where efficient boiling heat transfer performance is required. More importantly, the fabrication process has the capability of industrial production to rapidly cover large surface areas at relatively low cost, which is a significant advantage over subtractive manufacturing and other metal additive manufacturing methods.

## References

[1] Assadi H, Gärtner F, Stoltenhoff T and Kreye H 2003 Bonding mechanism in cold gas spraying Acta materialia 51(15) pp 4379-4394

[2] Li W, Cao C and Yin S 2020 Solid-state cold spraying of Ti and its alloys: A literature review Progress in Materials Science 110 p 100633

[3] Sohag F A, Beck F R, Mohanta L, Cheung F B, Segall A E, Eden T J and Potter J K 2017 Enhancement of Downward-Facing Saturated Boiling Heat Transfer by the Cold Spray Technique Nuclear Engineering Technology 49 pp 113 -122

[4] Yeom H, Gutierrez E, Jo H, Zhou Y, Mondry K, Sridharan K and Corradini M 2020 Pool boiling critical heat flux studies of accident tolerant fuel cladding materials Nuclear Engineering and Design 370 p. 110919

**Strategies for decentralised UAV-based collisions monitoring in rugby**

Yu Cheng and Harun Siljak

Department of Electronic and Electrical Engineering, Trinity College Dublin, Dublin, Ireland

Recent advancements in unmanned aerial vehicle (UAV) technology have unlocked new possibilities for dynamic data collection in challenging environments, such as sports fields during high-impact events[1]. Collisions in contact sports like rugby pose significant risks of traumatic brain injuries (TBIs), prompting a need for improved monitoring and safety measures[2]. However, existing solutions, including wearable technologies and video-based systems, face limitations such as reliance on manual input, sensitivity challenges, and occlusion issues, leading to inaccuracies and a lack of real-time proactive monitoring. This study aims to address these limitations by proposing a decentralized UAV fleet system for monitoring rugby collisions, with a focus on reducing TBI risks. Specifically, we ask: how can a decentralized UAV monitoring system enhance the accuracy and timeliness of TBI risk assessment in high-impact sports? To answer this, we implemented a UAV fleet system on the NetLogo platform, integrating custom collision detection algorithms and a decentralized collaboration framework. Our approach allows UAVs to autonomously track player movements, anticipate high-risk tackles, and provide early warnings to medical teams in real-time. Preliminary simulation results indicate that the proposed UAV system outperforms traditional TV-based coverage by enabling more precise and timely data capture. By allowing dynamic UAV repositioning and leveraging shared and local data, our system reduces occlusion and manual input issues, thus enhancing TBI prediction accuracy. These findings contribute to the field by presenting an innovative, scalable, and real-time monitoring approach that can proactively improve player safety in contact sports.

**Key words**

UAV Monitoring, Sports Collision Detection Algorithms, Decentralized real-time Data Processing

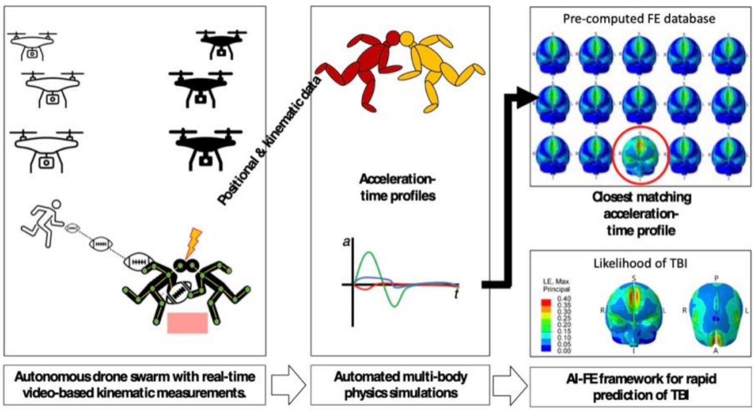


***Figure 1.*** Overall Idea of The UAV-TBI Project

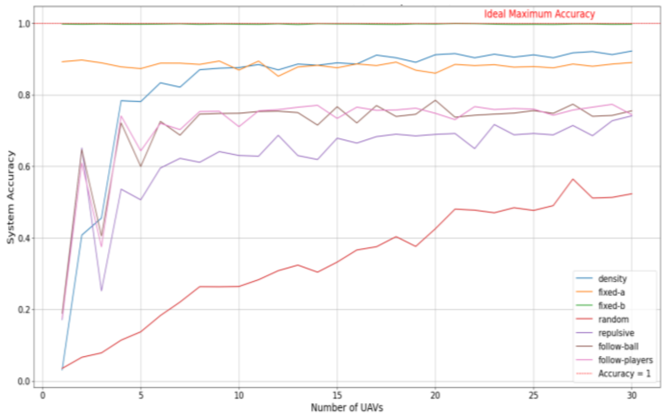


***Figure 2.*** System Accuracy Curve at Radius(5) and Speed(10)

## References

[1] R. Tucker, M. Raftery, G. W. Fuller, B. Hester, S.Kemp, and M. J. Cross, "A Video Analysis of Head Injuries Satisfying the Criteria for a Head Injury Assessment in Professional Rugby Union: a Prospective Cohort Study," British Journal of Sports Medicine,vol. 51, no. 15, pp. 1147-1151, Jun. 2017, doi: https://doi.org/10.1136/bjsports-2017-097883.

[2] Y. Celik, D. Powell, W. L. Woo, S. Stuart, and A.Godfrey. "A Feasibility Study Towards Instrumentation of the Sport Concussion Assessment Tool (iSCAT)," in 2020 42nd Annual Int. Conf. IEEE Eng. Med. Biol. Soc., pp. 4624–4627, 2020.

# Can elastin and collagen vascular microstructure be visualised specifically using 3D X-ray-based Histology?

F. Digeronimo[1-3], R. Johnston[1-3], G. Kerckhofs[4,5], B. Tornifoglio[1,2], C. Lally[1-3]

[1]Trinity Centre for Biomedical Engineering, Trinity College Dublin, Dublin, Ireland; [2]Department of Mechanical, Manufacturing and Biomedical Engineering, Trinity College Dublin, Dublin, Ireland; [3]Advanced Materials and Bioengineering Research Centre (AMBER), Royal College of Surgeons in Ireland and Trinity College Dublin, Dublin, Ireland; [4]Mechatronic, Electrical Energy and Dynamic Systems, Institute of Mechanics, Materials and Civil Engineering, UCLouvain, 1348 Ottignies-Louvain-la-Neuve, Belgium; [5]Pole of Morphology, Institute of Experimental and Clinical Research, UCLouvain, 1200 Woluwe-Saint-Lambert, Belgium.

**Introduction:** Histology is the gold standard for visualizing vascular microstructure but is destructive and limited to 2D views. 3D X-ray-based Histology (3DXH) offers a non-destructive alternative with full 3D imaging, which can also be used for real-time imaging alongside techniques such as mechanical testing [1-2]. For optimal 3DXH of vascular tissues, Contrast Enhancing Staining Agents (CESAs) which specifically target key vascular proteins, such as collagen and elastin, must be identified and utilised. Following native vascular tissue 3DXH, Phospho-Tungstic Acid (PTA) and 1:2 Hafnium-substituted Wells-Dawson PolyOxoMetalate (1:2 Hf-WD POM or Hf) were suggested to preferentially bind to collagen and elastin respectively [3-4], despite both proteins having similar microarchitectures in native tissue. This study further explores the binding specificity of the aforementioned CESAs to collagen and elastin.

**Methods:** Cryopreserved porcine carotid arteries were used to produce native (n=3), no elastin (n=3), and no collagen (n=3) tissue models using previously reported protocols [5-6]. Following fixation, the samples were stained with PTA or Hf and scanned at 2 µm isotropic resolution using a Phoenix Nanotom M (General Electric). 3DXH results were compared against gold-standard histological techniques for the visualisation of collagen and elastin. The effect of staining on subsequent histology was also evaluated.

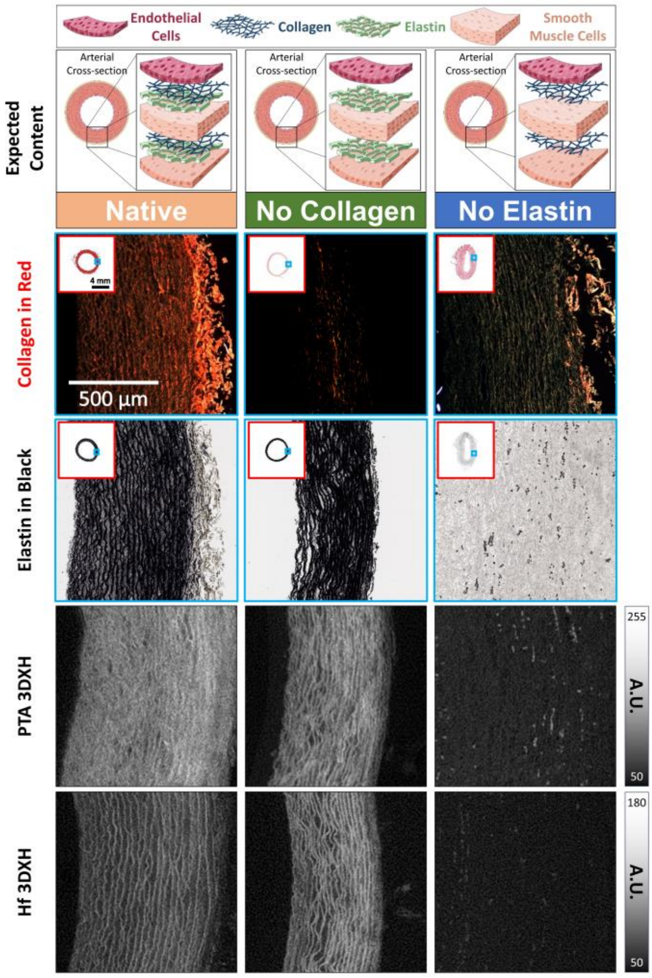


***Figure 1.** Histology and 3DXH for native, no-collagen and no-elastin arterial models. Row 1: Expected microstructural content; Row 2-3: **Full** and **zoomed in** views of picrosirius red-polarised light microscopy and Verhoeff's-brightfield histology sections; Row 4: Slice-view of PTA-stained 3DXH models. Row 5: Slice-view of Hf-stained 3DXH models.*

**Results and Conclusion:** As shown in Figure 1 above, contrast-enhancement was still detectable using both CESAs when either protein was removed, which confirms that the CESAs bind to both proteins. However, both CESAs show a much higher contrast-enhancement for elastin. Both CESAs allow visualization of the arterial microstructure, but Hf improves elastin contrast, due to a lower collagen contrast enhancement when compared to PTA. Future work will focus on quantitative comparison of the information from the acquired 3DXH data and histological images.

**References:** [1] Leyssens L et al, Int J Mol Sci, 22(6):3263, 2021; [2] Brunet J et al, Exp Mech, 61:147–157, 2021; [3] Hanly A et al, Front Physiol, 14:1057394, 2023; [4] Leyssens L et al, Acta Biomater, 164:303-316, 2023; [5] Tornifoglio B et al, Sci Rep, 10: 20718, 2020; [6] Stone A J et al, Magn Reson Med, 86(5):2512-2527, 2021.

**Acknowledgements:** This project is funded by the Centre for Doctoral Training in the Advanced Characterisation of Materials and Science Foundation Ireland (SFI) under award reference 18/EPSRC-CDT/3581.

**Development and Performance Optimisation of Large-Scale Plasmonic Luminescent Solar Concentrator Modules**

Aaron Glenn[1], Subhash Chandra[2], Sarah McCormack[1]

[1] Department of Civil, Structural & Environmental Engineering, Trinity College Dublin, Ireland

[2] Department of Geology, School of Natural Sciences, Trinity College Dublin, Ireland

Renewable energy alternatives to fossil fuels have become increasingly critical due to rising carbon dioxide levels and other harmful pollutants contributing to global warming. Solar energy in particular is promising as the amount of solar energy received by the Earth in just one hour is enough to meet global energy demands for an entire year [1]. This research focuses on a specific technology within the solar energy sector known as the Luminescent Solar Concentrator (LSC). Both LSCs and Plasmonic LSCs (PLSCs) present promising avenues for enhancing solar efficiency. These devices function by capturing photons and directing them to photovoltaic (PV) cells positioned at the edges, as illustrated in Figure 1.

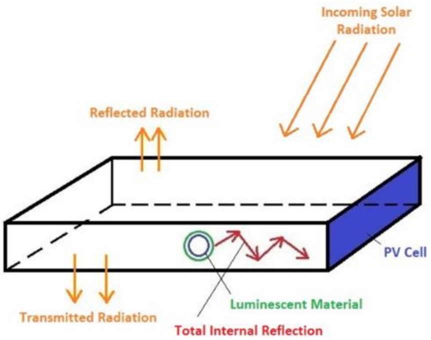


***Figure 1** – Operating principles of an LSC* [2].

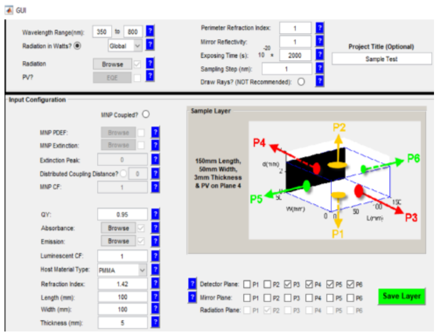

***Figure 2** – Graphical user interface of model.*

***Figure 3** – Outdoor panel.*

One of the key advantages of LSC designs is their ability to perform effectively in both direct and diffuse light conditions without the need for solar tracking systems, unlike traditional solar concentrators. Additionally, the size, shape, colour, and transparency of LSCs can be adjusted to meet specific functional requirements. Their solar concentration ratio is not limited, and they can target specific wavelengths of the solar spectrum, making them suitable for integration in both new and existing buildings.

This study explores the scalability and real-world application challenges of LSC/PLSC technologies by developing and validating an integrated optical-electrical model to optimise large-scale modules (Figure 2). We examine the effects of dye concentrations, metal nanoparticles (MNPs), and device dimensions on power output and efficiency. Using 3D resin printing and polydimethylsiloxane (PDMS)-based waveguides, we successfully fabricated large-scale PLSCs, achieving up to an 88.6% improvement in power output under varying conditions (Figure 3). The modular design facilitates seamless integration into building-integrated photovoltaics (BIPV), providing a scalable solution for urban energy demands.

**References**

[1] UC Davis. (n.d.) *How is solar power generated?* Available at: https://www.ucdavis.edu/climate/definitions/how-is-solar-power-generated (Accessed: 3 October 2024).

[2] Glenn, A., Chandra, S., McCormack, S.J., 2023. Design, fabrication and preliminary testing of plasmonic luminescent solar concentrator devices. Sustainable Buildings 6, 10. URL: https://doi.org/10.1051/sbuild/2023009, doi:10.1051/sbuild/2023009.

**An in vitro study on the pressure modifying impact of Balloon Guide Catheters on Aspiration Thrombectomy**

A. Glynn[1,2], C. Lally[1,3], B. Murphy[1,3], R. McCarthy[2]

[1]Trinity Centre for Biomedical Engineering & School of Engineering, Trinity College Dublin, Dublin 2, Ireland

[2]Cerenovus, Galway, Ireland

[3]Advanced Materials and Bioengineering Research Centre (AMBER), RCSI & TCD, Dublin, Ireland

**Purpose:** Aspiration Thrombectomy is an effective treatment for acute ischemic stroke (AIS) caused by large vessel occlusions (LVOs), however, a proportion of patients who experience poor clinical outcomes remain. Strategies to control blood flow during thrombus retrieval offer a potential solution, minimizing the risk of thrombus embolization and maximizing likelihood of thrombus retrieval. A well-established strategy is the inflation of a balloon guide catheter (BGC) in the internal carotid artery (ICA). However, use of a BGC is not universally adopted and debate exists regarding its benefit during aspiration thrombectomy. The aim of this study was to investigate the impact of BGCs on thrombus retrieval in the anterior circulation using an in vitro model of AIS.

**Materials and Methods:** A patient specific silicone model with physiological blood pressure and flow was used to recreate in vivo conditions. LVOs of varying sizes were created in the middle cerebral artery (MCA), using thrombus analogs prepared from ovine blood. Aspiration catheters with a range of inner diameters (ID) (4F, 5F, 6F & 8F) were used. Proximal flow arrest was achieved via inflation of a BGC in the ICA. Intraluminal pressures local to the thrombus were recorded, in addition to flow through each intracranial vessel outlet and through the aspiration catheter. Measurements were taken prior to device introduction, following device placement and during device use. Aspiration was applied through the catheter with a negative vacuum for a duration of 60 seconds.

**Results:** Inflation of a BGC during aspiration independently lowered the pressure at the clot face in the M1-MCA ($p<0.001$). This average reduction in pressure of 17mmHg reduces the pressure gradient across the LVO and thereby facilitates transmission of higher aspiration forces during retrieval. The average pressure gradient recorded across an LVO is approximately 60mmHg, thus, the impact of a BCG can reduce this gradient by almost one-third. The ability to reduce the LVO pressure gradient results in a higher likelihood of procedural success. The pressure reducing effect of the BGC was lessened when the outer diameter of the aspiration catheter was more closely matched to the internal diameter of the occluded vessel. A catheter-to-vessel diameter ratio close to parity reduces antegrade flow around the catheter, which also acts to reduce the pressure gradient across the LVO.

**Conclusion**: Inflation of a BGC has a measurable impact of pressure at the clot face in the M1-MCA, influencing the pressure drop across the clot, which enhances the likelihood of thrombus removal and limits the embolization of distal fragments.

## An Index-Based Methodology for Multi-Hazard Risk Assessment of Existing Bridge Portfolios

Ludovico Alberico Grieco & Fulvio Parisi

Department of Structures for Engineering and Architecture, University of Naples Federico II, Naples, Italy

In recent years, several catastrophic collapses of existing bridges have highlighted the need for rapid risk analysis methods aimed at supporting infrastructure managers in the prioritisation of detailed assessments and, if any, risk mitigation actions. A large percentage of existing road bridges were built between the 1960s and 1980s, having thus already reached or even exceeded their design lifetime. Several studies have also shown that bridges often collapse due to either natural or human-related events, such as floods, collisions or overloading that, in addition to earthquakes, should be duly considered in risk assessment. This calls for multi-hazard approaches that provide an integrated perspective of the risk of bridge portfolios, to identify critical structures to support decision-makers. This study proposes a multi-hazard risk-based prioritisation methodology for application to a large number of bridges under limited level of knowledge. Specifically, the risk level is quantified through indices, accounting for uncertainties, that are used for comparative purposes among bridges. The methodology is applied to a highway bridge portfolio located in northern Italy, producing a risk-based ranking that is critically discussed. Analysis results are then compared with the outcome of the current Italian guidelines for safety assessment and maintenance of existing bridges.

### References

[1] Scattarreggia N., Grieco L.A., Monteiro R., Parisi F. (2023). A preliminary methodology for multi-hazard risk assessment of large bridge portfolios using quantitative indicators. *Proceedings of 14th International Conference on Applications of Statistics and Probability in Civil Engineering, ICASP14*, Dublin, Ireland.

[2] Grieco L.A., Scattarreggia N., Monteiro R., Parisi F. (2024). An index-based methodology for multi-hazard risk assessment of bridge portfolios. *Proceedings of 18th World Conference on Earthquake Engineering, WCEE2024*, Milan, Italy.

[3] Grieco L.A., Scattarreggia N., Monteiro R., Parisi F. (in press). An index-based multi-hazard risk assessment method for prioritisation of existing bridge portfolios. *International Journal of Disaster Risk Reduction*.

## Investigating the Relationship Between Calcification and Structural Damage of Porcine Pericardium to Improve Bioprosthetic Heart Valve Durability

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Aortic stenosis (AS) results from narrowing and stiffening of the aortic valve, restricting or preventing blood flow from the heart to the rest of the body. 12.4% of people above 75 experience AS [1], and without treatment 50% of patients with severe AS will not survive past two years [2]. Minimally invasive treatment for AS involves the implantation of a bioprosthetic valve with porcine or bovine pericardium leaflets. These leaflets eventually succumb to failure due to calcification and structural damage in the form of regurgitation or stenosis [3]. The aim of this work is to investigate and establish the relationship between calcification and structural damage of porcine pericardium (PP), and to identify screenable tissue features which minimise both factors. To achieve this, PP was screened for its collagen fibre architecture using small angle light scattering (SALS), and then loaded in the presence of calcification solution using a bi-directional bulge rig for 30 million cycles, see *figure 1(A)*. Structural damage and calcification were quantified at 0, 5 M, 10 M, 20 M, and 30 million cycles using digital image correlation and µCT imaging respectively. Calcified and damaged samples were compared to uncalcified PP loaded in the same conditions. By 30 million cycles, 16 ruptures occurred in calcified samples. No ruptures were observed in PP with the same loading conditions which were not exposed to calcification. Rupture did not always occur at the most calcified region of the samples, but instead appeared to be co-located with radially oriented fibres, see *figure 1(B)*. The findings suggest that calcification and structural damage are likely to be synergistic factors affecting bioprosthetic valve durability, and that the collagen fibre architecture of PP may influence its likelihood of failure. Future work will involve an investigation into the influence of spatially varying collagen fibre architecture and calcification distribution on PP leaflet stresses and strains using finite element analysis.

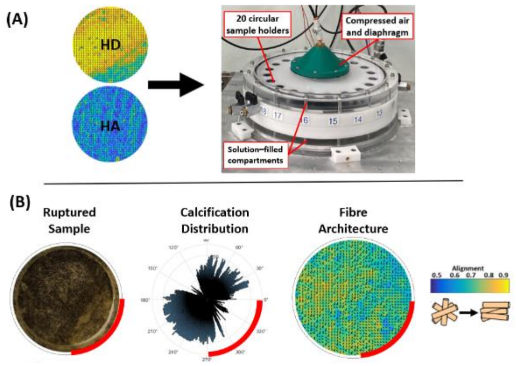


***Figure 1****: Tissue with highly aligned (HA) and highly dispersed (HD) collagen fibre architecture loaded for 30 million cycles in bulge rig [4] (A), ruptures appear in as little as 5 million cycles when calcification is present during loading, whose location appears to be influenced by collagen fibre orientation and not calcification distribution alone (B).*

### References

[1] - Osnabrugge, R.L.J. et al., J. Am. Coll. Cardiol., 2013

[2] - Clark, M.A. et al., Circ. Cardiovasc. Qual. Outcomes, 2012

[3] – Blackman, D.J. et al., J. Am. Coll. Cardiol., 2019

[4] – Whelan, A. et al., J Mech. Behav. Bio. Mater., 2021

**Analysing the Impact of Diesel Train Movements on Local Air Quality: Evaluating PM2.5 Concentrations at Dublin's Heuston Station using Random Forest Models**

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This study provides an in-depth analysis of the factors affecting particulate matter ($PM_{2.5}$) concentrations in Heuston Train Station in Dublin, focusing on the influence of diesel train movements.

Utilising hourly data collected from low-cost sensors at the platform, we applied Random Forest models to explore the relationship between $PM_{2.5}$ concentration and various contributing factors, including ambient conditions and train traffic. The model performed well, with a Root Mean Squared Error (RMSE) of 2.24 µg/m³ and an R-squared value of 0.78.

Background concentration is identified as the primary contributor to $PM_{2.5}$ level in the station by orders of magnitude more than other variables. Among traffic-related features, idling time in Region 1 (under the roof) is the most influential variable. Overall, idling times exert a greater impact on PM2.5 concentrations than components associated with individual train sets. For trains within the same set, the frequency of arrivals normally has a greater impact on PM2.5 levels than departures.

Partial dependency plots (PDP) were generated for all variables to visualise the effect of each feature on the predicted $PM_{2.5}$ levels, holding all other features constant. The slopes of the fitted lines reveal the variation in $PM_{2.5}$ concentrations in response to changes in predictor variables. PDPs indicate a strong correlation ($R^2 > 0.90$) between the partial dependence of background concentration and wind direction on PM2.5. Specifically, for every 1 µg/m³ increase in background concentration, the platform concentration similarly rises by 1 µg/m³. Although the slopes in the PDPs of idling time in regions 1 and 3 are relatively low, at 0.005 and 0.001, respectively, the impact remains significant given the units of cumulative idling time (minutes) and their distribution. For instance, a 5-car train idling for an additional 30 minutes in Zone 1 results in an increase in platform PM2.5 concentrations by 0.75 µg/m³. Consequently, minimising idle time is crucial for reducing air pollution at train stations. Additionally, the frequency of arrivals of either a 5-set or 3-set DMU train per hour corresponds to an average increase in PM2.5 of 0.02 µg/m³.

This study provides vital insights for station management and policymakers in designing targeted strategies for air quality improvements. By understanding the interactions between train traffic and variable environmental conditions, effective measures can be implemented to mitigate the impact of train movements and improve local air quality.

## Single camera view markerless pose estimation gait and upper limb movement in children with cerebral palsy

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Cerebral palsy (CP) is a common neurological disorder affecting movement, posture, and coordination in children. [1, 2] Therefore, movement assessment is essential for diagnosing CP and assisting clinical decisions. However, traditional movement analysis for CP diagnosis, though reliable, requires specialized clinical setups, which are costly and time-consuming. [3] Current solutions, such as 2D Human Pose Estimation (HPE), offer more accessible alternatives recognizing body movement and key points within short time. But these approaches have limitations in accuracy and recognize rotational movements, which are crucial for children with CP. To improve this, we propose to proceed with the study Long Short-Term Memory (LSTM) networks,[4] using heatmaps and inter-frame information from video data, leading to better assistance in clinical decision making.

### References

[1] Martin Bax et al. “Proposed definition and classification of cerebral palsy, April 2005”. In: Developmental Medicine amp; Child Neurology 47.8 (2005), pp. 571–576.

[2] Kevin D. McCay et al. “A Pose-Based Feature Fusion and Classification Framework for the Early Prediction of Cerebral Palsy in Infants”. In: IEEE Transactions on Neural Systems and Rehabilitation Engineering 30 2022), pp.8–19.

[3] Constance F Buran et al. “Family needs assessment in cerebral palsy clinic”. In: Journal for Specialists in pediatric Nursing 14.2 (2009), pp. 86–93.

[4] Scott D Uhlrich et al. “OpenCap: Human movement dynamics from smartphone videos”. In: PLoS computational biology 19.10 (2023), e1011462.

## A finite element-based framework for the development of 3D-printed bioinspired polymer heart valve leaflets

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Aortic stenosis is a prevalent and deadly disease carrying up to a 50% chance of mortality if left untreated [1]. Treatment is through prosthetic valve implantation; however, the devices used either require patients to take life-limiting anticoagulants or suffer from premature failure. Polymer heart valves have the potential of extended durability, ability to be used with minimally invasive techniques, and remove the need of anticoagulant therapy. If we would like to fully embrace these into future treatment we need to develop a directed approach to design and assess these devices. This research aims to deliver on that need, providing a framework for the development of 3D-printed polymer leaflets inspired by the native leaflet structure and mechanical response; this will assist engineers with material selection and leaflet structure for chosen leaflet shapes and applications.

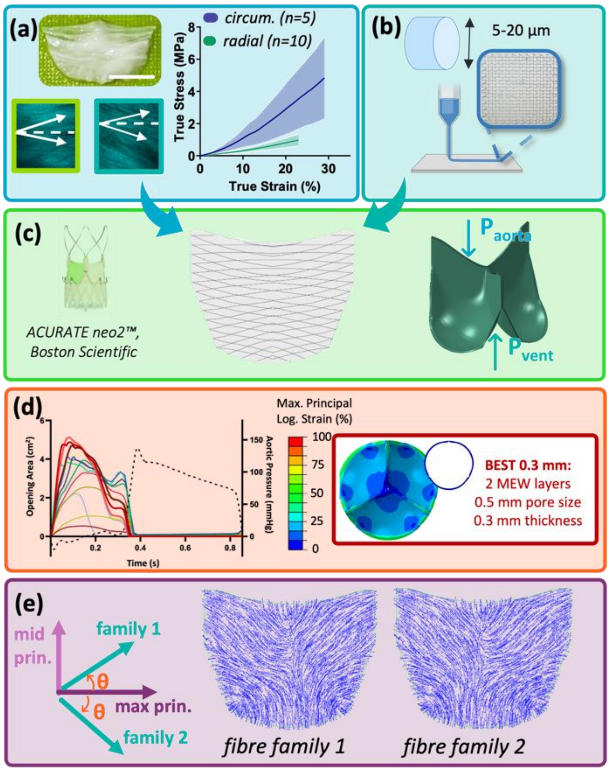


***Figure 1*** *(a) Mechanical testing and imaging of native porcine leaflets, (b) MEW diagram, (c) using a and b to inform fibre reinforced leaflet model, (d) using DOE to inform best structural combination, (e) using fibre remodelling to define optimal fibre orientations [4]. Scale: 1 cm*

This work investigates the mechanical response and structure of native aortic valve leaflets, and subsequently uses this knowledge to build a finite element model of a polymer leaflet valve with a bioinspired fibre structure manufactured using melt electrowriting (MEW) [2, 3]. Using design of experiments (DOE), the most effective combination of structural features were identified, and now, using a fibre remodelling algorithm, fibre orientation has been optimised for this particular valve leaflet geometry.

Overall, this work has lead to the creation of a customisable polymer leaflet development framework. This can be used to help identify ideal material combinations and structural features, and predict leaflet performance without needing to manufacture devices. This framework will enable effective development of novel, bioinspired, polymer heart valve devices that can outperform current commercial devices and improve patient outcomes.

### References

[1] Généreaux, *et al., JACC*, 2023

[2] Hughes, *et al., SSRN*, 2024

[3] Hughes, *et al.,* SERS, Dublin, Ireland, 2023

[4] Creane, *et al., Biomech. Model. Mechanobiol, 2011*

### Physical Boundaries to Direct Engineered Tissue Growth and Organization

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Engineering mechanically functional articular cartilage (AC) grafts is a challenging goal in tissue engineering. Recapitulating the arcade-like collagen organisation of AC, which is integral to the tissues' strength and stiffness, is integral to engineering truly functional grafts [1]. This motivates the need for innovative strategies to control collagen alignment in engineered tissues. Emerging 3D bioprinting strategies can be used to provide spatially defined cues to guide tissue growth. The overall goal of this study is to use embedded bioprinting to provide spatially defined boundary conditions to AC progenitor cells (ACPs) to direct collagen organization. Here two different approaches (either casting or 3D bioprinting) were used to physically constrain a cell-laden hydrogel (herein termed a bioink) with physical boundaries of differing widths (160, 250, 500, 750, or 900µm; see Fig. 1). These constructs were put into culture for 21 days, after which the composition and organization of the tissue produced by the cells in response to the different physical constraints was quantified. Polarised light microscopy revealed an increased collagen alignment in the thinner (250µm) casted and thinner (160µm) bioprinted filaments. These findings reveal that external boundaries can guide neotissue collagen alignment within high cell density bioinks. Future work on bioprinting functional AC will incorporate guiding structures with a 160µm spacing with a view towards achieving an arcade-like collagen architecture in bioprinted grafts.

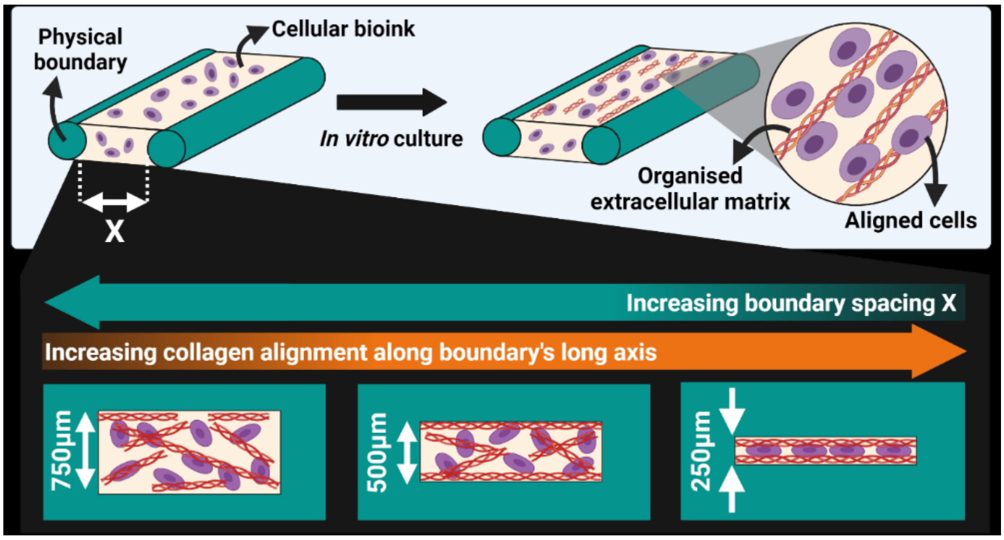


***Figure 1**: Diagrammatic representation of how external boundaries can direct neotissue growth of confined bioinks. The greater the boundary aspect ratio the higher the cell and collagen alignment along the long axis of the boundary. Created with biorender.com.*

### References

[1] Khoshgoftar, M, Wilson, W, Ito, K, and van Donkelaar, C, 2013, "The Effect of Tissue-Engineered Cartilage Biomechanical and Biochemical Properties on its Post-Implantation Mechanical Behavior." Biomech Model Mechanobiol., 12(1):43–54. https://doi.org/10.1007/s10237-012-0380-0.

## Optimizing AI with Hardware Acceleration: From Edge Devices to the Cloud

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Automotive networks enable the integration of advanced smart services in modern vehicles, such as Advanced Driver Assistance Systems (ADAS). However, these networks often lack built-in security protocols, making them vulnerable to cyberattacks. To address this, Intrusion Detection Systems (IDS) are essential for ensuring security in modern vehicles. Meanwhile, in cloud environments, motion picture tools like background matting require efficient processing for high-quality image-to-image (I2I) transformations. Both of these challenges—automotive security and image transformation—are increasingly being tackled by neural networks. Conventional software-based solutions, especially GPU accelerated models, face significant energy constraints in both edge and cloud environments, as well as latency issues in edge deployments. This research explores hardware acceleration techniques to deploy neural networks on Field Programmable Gate Array (FPGA) accelerators known for their energy efficiency. By integrating custom quantized variants of neural networks (QNNs) on FPGAs, we aim to improve their energy efficiency and processing latency, addressing the limitations of CPU/GPU-based deployments which suffer from either high power consumption or limited throughput. For edge IDS deployment on automotive networks, we implemented a Quantized Multilayer Perceptron (QMLP) model with 4-bit weights and activations on a AMD ZCU104 FPGA realizing an energy-efficient/low-latency IDS for modern vehicles. For cloud I2I transformations deployment, we develop an 8-bit quantized pix2pix U-Net model and deploy it on a AMD Alveo U50 FPGA platform to perform alpha background matting for video sequences. The key results are from the above studies are presented below:

- The **QMLP-based IDS** achieved near line-rate detection, processing over 8,300 messages per second on high-speed Controller Area Network (CAN), with a **4.8× improvement in latency** over SOTA systems and 0.25 mJ per inference energy consumption.
- The **U-Net model for background matting** achieved visually identical results to the ground truth, with an Intersection over Union (IoU) score of > 0.95 and 1.14× higher throughput. The system consumed **11× lower energy per inference** than GPU-based models.

This work demonstrates the effectiveness of custom hardware accelerators like FPGAs in improving both performance and energy efficiency of neural network deployments for latency & energy sensitive applications. By leveraging FPGAs for both edge and cloud neural network deployments, the research offers a promising alternative to traditional CPU and GPU systems, contributing to advancements in both automotive safety systems and high-quality media processing pipelines.

### References

[1] S. Khandelwal, A. Walsh and S. Shreejith, "Quantised Neural Network Accelerators for Low-Power IDS in Automotive Networks," *2023 Design, Automation & Test in Europe Conference & Exhibition (DATE)*, Antwerp, Belgium, 2023, pp. 1-2, doi: 10.23919/DATE56975.2023.10137016.

[2] E. Murphy, S. Khandelwal, S. Shreejith, "Custom precision accelerators for energy-efficient image-to-image transformations in motion picture workflows," Proc. SPIE 12674, Applications of Digital Image Processing XLVI, 126740R (4 October 2023); https://doi.org/10.1117/12.2677688

# Geopolymer, A Next Generation of Construction Materials: Why or Why not?

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Portland cement (PC), first patented on 21st October 1824, remains a dominant building material despite two centuries of technological and societal advancements. However, the environmental cost of PC production is substantial, with approximately one ton of $CO_2$ emitted for each ton of cement produced, contributing 6-8% of global anthropogenic $CO_2$ emissions. To achieve carbon neutrality and advance the circular economy, the construction sector needs to adopt new materials and methods.

Geopolymers offer a promising alternative to PC. Derived from minerals and industrial or agricultural wastes, geopolymers are activated chemically (e.g., using sodium hydroxide or sodium silicate) rather than through energy-intensive thermal processes. Their versatility and lower energy demands make them a more sustainable option, with production being highly localized and customizable.

Several waste streams, both from Ireland and globally, have been evaluated for their potential in geopolymer development, focusing on materials with high silicon and aluminium content or strong alkalinity. Geopolymers made from drinking water treatment sludge exhibit superior mechanical strength (>60 MPa) and rapid setting times (<30 minutes), making them suitable for use in repair materials. Geopolymers developed from biomass ash (e.g., agricultural residues) show mechanical strength comparable to PC (>40 MPa) while reducing carbon emissions by 67-91%. Moreover, geopolymers can act as carbon sinks by incorporating organic materials or biochar, with olive biomass ash-based geopolymers capable of sequestering up to 118.76 kg $CO_2$ per ton of binder. In extreme environments, such as under wet-dry cycling or sulphate exposure, specially formulated geopolymers demonstrate enhanced durability and even mechanical strength improvements of 30-80%.

Despite these advantages, transitioning from PC to geopolymer-based systems poses challenges. The supply chains for supplementary cementitious materials (SCMs) are already strained, and geopolymer adoption could exacerbate these issues. To reduce reliance on fly ash (FA) and ground granulated blast-furnace slag (GGBS), broader research is needed to diversify SCM sources. Furthermore, the chemicals used to activate geopolymers, such as sodium hydroxide and sodium silicate, have significant carbon footprints, which could present additional challenges in less-developed regions with less advanced processes.

The biggest hurdle to widespread geopolymer adoption, however, lies in the construction sector's reluctance due to concerns about building code compliance, worker training, and material safety. To address these issues, it is essential to standardize experimental methodologies, expand research, and explore opportunities for commercial-scale implementation.

**Uncovering the Visual Contribution in Audio-Visual Speech Recognition**

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Audio-Visual Speech Recognition (AVSR) systems exploit visual information from the speaker's face, e.g. lip movements, to enhance speech recognition. This area has attracted much research attention in recent years. The rapid development of artificial intelligence and end-to-end modelling for Automatic Speech Recognition has led to significant progress in AVSR, resulting in improved performance compared to audio-only systems across various acoustic environments [1].

Despite these advancements, the development of AVSR seems to have reached a "bottleneck" stage. State-of-the-art (SOTA) models continue to demonstrate improved performance, i.e. lower word error rates (WERs) and greater robustness, compared to their audio-only counterparts in noise. However, much of the current research remains focused on metric-driven improvements, i.e. incremental reductions to WER, with less attention given to understanding how visual information enhances these systems or whether the visual component is being fully exploited in existing approaches.

This research takes a step back to assess SOTA systems from a different perspective by considering human speech perception. Through this, we hope to gain insights as to whether the visual component is being fully exploited in existing AVSR systems, helping to uncover better approaches. Inspired by human speech perception studies, we explore this with three questions: 1) Can metrics beyond WER better reflect visual contributions? 2) How does the presence and timing of visual information influence AVSR systems? 3) Do AVSR systems perform better for words with higher levels of visual informativeness, as determined by human speech perception?

Using three SOTA AVSR systems, we revisit effective SNR gains to evaluate visual gains [2]. We also present two experiments. The first occludes the mouth region at different stages of words to assess the impact of lip movements. A second experiment compares errors made by audio-only, video-only, and AVSR systems with those made in human audiovisual speech perception.

The key contributions of this research are: 1) We quantify the visual contribution of AVSR systems using effective SNR gains. 2) We reveal a discrepancy in how AVSR systems use temporal visual information compared to human reliance on early visual cues. 3) Our empirical investigation of the relation between AVSR errors and visual informativeness for words.

**References**

[1] Sterpu, G., Saam, C. and Harte, N., 2018, October. Attention-based audio-visual fusion for robust automatic speech recognition. In Proceedings of the 20th ACM International conference on Multimodal Interaction (pp. 111-115).

[2] Potamianos, G., Neti, C., Iyengar, G. and Helmuth, E., 2001. Large-vocabulary audio-visual speech recognition by machines and humans. In Seventh European Conference on Speech Communication and Technology.

**Unveiling the Psychological Traits of Multi-Marathoners: Insights from TIPI Personality Trait Analysis**

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**Objectives:** Multi-marathoners, athletes dedicated to completing 100 or more marathons, represent a unique subculture within endurance sports. This study explores their psychological traits using the Ten Item Personality Inventory (TIPI) test[1]. The study aims to identify the unique personality profiles of multi-marathoners and understand their implications for participation, performance, and well-being.

**Methods:** TIPI was conducted via an online cross-sectional survey distributed to the multi-marathon community, which received 592 responses, 56% men (n=331, average age = 53.87 years, SD = 9.91), 44% women (n=261, average age = 54.06, SD 10.56) from 22 countries.

**Results:** The findings reveal distinctive personality traits among multi-marathoners, Compared to the general population (represented by TIPI Norms [2]), multi-marathoners displayed higher levels of conscientiousness ($F (1,591) = 2.42$, $p < 0.001$ for gender), indicating strong self-discipline, organisation, and goal-oriented behaviour. They exhibited lower levels of emotional stability ($F (1,591) = 5.525$, $p < 0.001$ for age group) and openness ($F (1,591) = 2.54$, $p < 0.001$ for age group), suggesting challenges in stress management and adaptability. Following significant results from ANOVA ART tests, the Wilcoxon rank-sum post-hoc analysis revealed a significant gender difference in agreeableness, with women exhibiting higher levels of agreeableness compared to men ($W = 50809$, $p<0.00091$). However, no significant differences were found in conscientiousness or emotional stability between genders after applying the Bonferroni statistical correction.

**Conclusion:** This study offers insights into the psychological traits of multi-marathoners, highlighting their high conscientiousness and lower emotional stability. No significant differences were found in openness, and age-related differences in personality traits were not statistically significant after applying the Bonferroni statistical correction. These findings suggest that while multi-marathoners possess distinct personality traits, the relationship between these traits and their engagement in endurance sports is more complex than initially anticipated. These insights can guide the development of interventions to foster resilience and sustained participation, enhancing overall experience and success in multi-marathoning. Future research should focus on longitudinal studies to track changes in personality traits and explore effective psychological interventions for this unique athletic community.

## References

[1] Gosling, S.D., Rentfrow, P.J., and Swann, W.B., Jr., A very brief measure of the Big-Five personality domains. Journal of Research in Personality, 2003(37(6)): p. p. 504-528.

[2] Gosling, S.D., Rentfrow, P. J., & Potter, J., Norms for the Ten Item Personality Inventory, 2014.

# Developing hydrogels with tuneable time-dependent mechanical properties to evaluate cornea resident cells responses

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Cornea blindness can arise from several reasons, including damages induced by numerous types of accidents and diseases.[1,2] Cornea transplantation constitutes the gold standard to treat cornea related blindness, but unfortunately the demand for donors is much higher than the offer.[3] Artificial scaffolds are a promising alternative, but even though they can replicate closely the original tissue, important features are often overlooked. Time-dependent mechanical properties are a fundamental aspect of the extracellular matrix (ECM) and although their role is less understood than other material properties (i.e. stiffness, substrate morphology) it has been demonstrated that they also play an important part in regulating cell behaviour.[4] Thus, it is fundamental to better understand how time-dependent mechanical properties affect corneal cells and how by modulating these properties we can achieve better results in engineering scaffolds for corneal regeneration purposes. Therefore the aim of this project is to develop hydrogels with tuneable viscoelastic properties and to evaluate how these can affect cornea resident cells. To this end alginate with variable molecular weight (MW), which was modulated by autoclaving, was used as the base material. The different alginates were then mixed with Collagen type I and PEG Succinimidyl Glutarate to produce 3 types of hydrogels, which were then tested for mechanical properties and cytocompatibility. Gels showed very close values of elastic modulus, but large differences in time-dependent mechanical properties (i.e. stress-relaxation). Hydrogels proved to be non-toxic to cells, moreover corneal stromal cells seemed to be remodelling them over the course of 2 weeks leading to an increase in transparency.

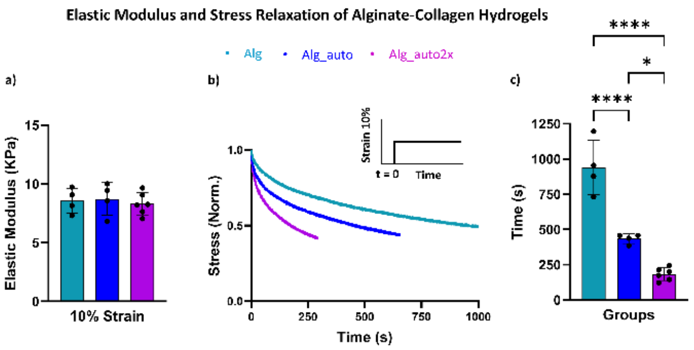


**Figure 5 .**(**a**) Gels show constant elastic modulus. **(b)** Representative stress relaxation profiles for hydrogels. (**c**) Stress Relaxation time is largely different among gels and decreases with each autoclaving cycle. Indicates statistically significant difference between groups ($p < 0.05$).

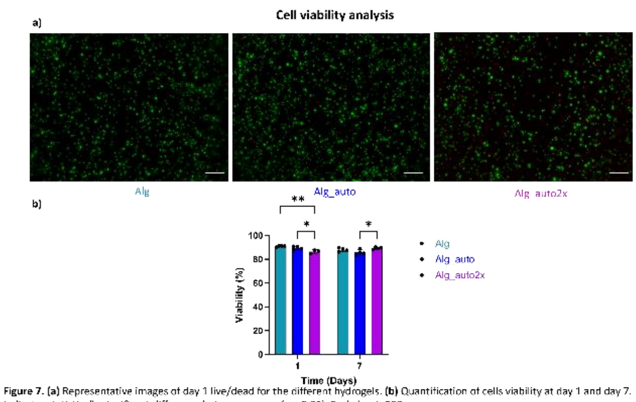


**Figure 7. (a)** Representative images of day 1 live/dead for the different hydrogels. **(b)** Quantification of cells viability at day 1 and day 7. Indicates statistically significant difference between groups ($p < 0.05$). Scale bar is 200 µm.

## References

[1] Li, C. *et al.* The global incidence and disability of eye injury: an analysis from the Global Burden of Disease Study 2019. *EClinicalMedicine* **62**, 102134 (2023). https://doi.org:10.1016/j.eclinm.2023.102134

[2] WHO, G. World Report on Vision. (2019).

[3] Gain, P. *et al.* Global Survey of Corneal Transplantation and Eye Banking. *JAMA Ophthalmol* **134**, 167-173 (2016). https://doi.org:10.1001/jamaophthalmol.2015.4776

[4] Lee, H. P., Gu, L., Mooney, D. J., Levenston, M. E. & Chaudhuri, O. Mechanical confinement regulates cartilage matrix formation by chondrocytes. *Nat Mater* **16**, 1243-1251 (2017). https://doi.org:10.1038/nmat4993

## Mechanically Activated Bone Cells by Fluid Shear Produce Extracellular Vesicles That Regulate Blood Vessel Formation in A Manner That Is Dependent on Their Cellular Origin

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The formation of new blood vessels, angiogenesis, plays a critical role in bone repair by allowing the diffusion of nutrients and oxygen. Moreover, vessels facilitate cell migration into the defect site [1] such as mesenchymal stem/stromal cells (MSCs) which can then undergo osteogenesis. Recent advancements from our lab have highlighted the significance of bone derived extracellular vesicles (EVs), which are nanoparticles that influence cell-cell communication. Particularly, osteocyte-derived EVs influence angiogenesis [2] and we have shown the impact of mechanical stimulation in priming the regenerative properties of these EVs [3]. However, whether cells earlier in the osteogenic lineage possess similar angiogenic properties remains poorly understood. Therefore, this study aimed to determine the role of EVs derived from cells at different stages of the osteogenic lineage (MSC, osteoblast, osteocyte) in regulating angiogenesis, how this is influenced by a dynamic mechanical environment, and whether these bone derived EVs can produce a mature stable vasculature. **METHODS:** Fluid shear was applied to human MSCs, human osteoblasts (OBs) or MLO-Y4 osteocyte-like (OCY) cells at 1Pa and 1Hz for 2h. Following 24h in culture, the conditioned media (CM) was collected and EVs were collected by ultracentrifugation. Following 18h on Geltrex, GFP-tagged human umbilical vein endothelial cells (HUVECs) were imaged to assess tube formation or fixed for immunofluorescent imaging. EVs and EV depleted media controls were added to the media, as well as 10 ng/ml VEGF as a positive control. The expression of CD31+ was assessed and mean fluorescent intensity was calculated using ImageJ. Proliferation was assessed through BrDU incorporation and migration was evaluated by the Transwell assay. **RESULTS:** The treatment of HUVECs with EVs collected from static cells (S-EVs) derived from the earlier stage in the osteogenic lineage (**MSCs**) induced a lower number of junctions compared to the negative control, moreover the same effect can be seen in the static depleted media group, as well as a slight trend of an increased number of junctions when these cells are mechanically stimulated (Figure 1A, B). Focusing on the next step in the lineage, EVs collected from mechanically activated cells (MA-EVs) derived from **OBs** induce higher number of junctions compared to the negative control (Figure 1A, C). Treatment with **OCY** derived MA-EVs lead to a significant increase in tube formation with thicker vessels present, comparable to the +VEGF control. **OCY** derived MA-EVs were chosen for further assessment, as they showed the highest efficacy in tube formation. OCY derived MA-EVs lead to an increase in HUVEC migration (Figure 2C) and trends of increased proliferation (Figure 2D). Remarkably, treatment with MA-EVs leads to a substantial increase in CD31+ expression (Figure 2A, B).

Herein, we demonstrate the importance of the stage of osteogenic lineage on the angiogenic potency of EVs. MSC derived S-EVs lead to a decrease in angiogenesis that is rescued with mechanical stimulation. Interestingly, both OB and OCY MA-EVs lead to a positive increase in angiogenesis and treatment with OCY derived EVs lead to the increased expression of CD31, migration and trend of increased proliferation, which could indicate more mature vessel formation. Therefore, this study highlights the importance of mechanical stimulation at different stages of osteogenic differentiation, whilst identifying EVs as a possible angiogenic therapy. **REFERENCES**:[1] Kusumbe, A. et al. (2014). [2] Shen, N. et al. (2023). [3] Eichholz, K. et al. (2020)

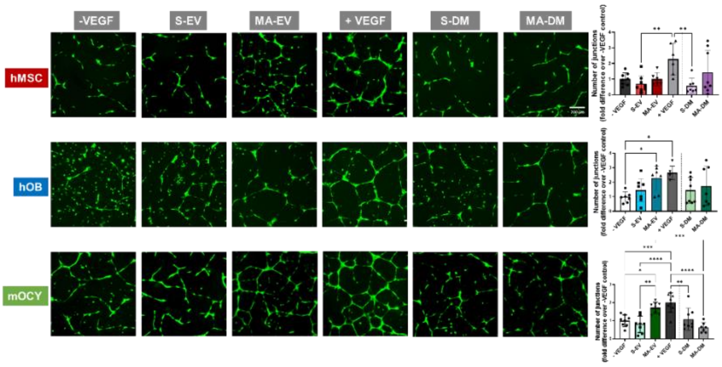


**Figure 1**. *In vitro* endothelial cell tube formation assay of hMSC, hOB and mOCY derived static and mechanically activated EVs and associated depleted medias. **(A)** Fluorescent images of tube formation at 18hrs. **(B,C,D)** Number of junctions normalized to negative control. Scale bar= 200 µm. Data presented as Mean ± SD, n>7, N=2. * p<0.05

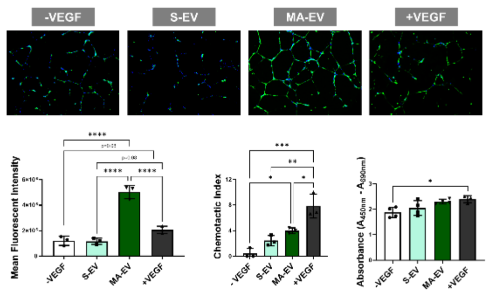


**Figure 2.** Advanced characterization of osteocyte- derived EVs. **(A)** CD31+ and DAPI immunofluorescent staining **(B)** Mean intensity quantification of CD31+ staining **(C)** Chemotactic index of static and mechanically activated EVs **(D)** BrdU incorporation absorbance. Data presented as Mean ± SD, n=4. * p<0.05

**Determining the effects of solar farm implementation on local microclimate and biodiversity.**

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Energy demands are ever increasing while governments around the world place their reliance in renewable energy sources to limit the environmental problems that arise from fossil fuels. Ireland is no different and has set targets to increase uptake in renewable sources. As part of Irelands Climate action plan 2023, as part of this plan a target of 8 GWs of solar PV is to be connected to the grid by 2030. As of June 2023, the ISEA reported that Irelands current installed PV capacity stands at 680MW [1]. From 2018-2020 the average size of solar farms in Ireland was between 20-40 hectares, while between 2021-2023 projects of over 100 hectares have entered the planning stages [2]. It is clear the target of 8 GW will require extensive land use all over Ireland, and it is important not to trade any benefits gained in renewable energy generation with the cost of destroying or disrupting local biodiversity. This project aims to understand the impact of solar farm installations on local microclimates and to develop strategies to mitigate biodiversity loss at solar farm sites due to these microclimates. Microclimate indicators such as relative humidity, wind speed, solar irradiance, soil moisture and air temperature will be measured at various positions throughout each solar farm, such as under solar modules, between module rows and at field boundaries. Data gathered from these sensors will be compared to an adjacent field under the same management regime as the solar farm was prior to the installation of the PV array, this will act as the control to evaluate the impact on local microclimates induced by the installation of PV arrays. Through this research, the aim is to gain a better understanding of the potential impacts with the widespread deployment of PV arrays as Ireland progresses towards its 8GW target.

## References

[1] - (2023). *Scale of Solar.* ISEA. Retrieved from https://www.irishsolarenergy.org/_files/ugd/dcb342_ff637a6960104140a73e6dd2b850ad88.pdf

[2] - Timoney, F. (2023). *Best Practice Guidance Report for Large Scale Solar Energy Development.* ISEA. Retrieved from https://www.irishsolarenergy.org/_files/ugd/dcb342_6e14be41b33049b08d6cdff1478b3d32.pdf

**Feature Selection of Normal Behaviour Models of Wind Turbine Generator Bearings with SCADA Data**

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The Supervisory Control and Data Acquisition (SCADA) systems installed in wind turbines have proven effective in enabling model-based, data-driven methods for fault detection in many subsystems, particularly the rear bearing of wind turbine gearboxes [1]. However, SCADA systems typically monitor hundreds of features, presenting challenges for deep learning models due to the curse of dimensionality and extended training times. A subset of the recorded features can be adequate [2] to provide reliable prediction accuracy for the sensor that best characterizes the targeted subsystem, namely the target feature. The selection of such features is often approached without a systematic method. To automate this process without computationally heavy wrapper methods, various filter feature selection techniques have been applied [3][4][5], but there is no consensus on which technique offers the best performance and reliability. A series of experiments was conducted to assess linear correlation, mutual information regression, the weights of a decision tree, and Shapley values [6] of a simple neural network as feature selectors. These selected features were then used as the basis to train a long short-term memory network, a convolutional neural network, and a feed-forward neural network across 10 datasets from 5 wind turbines to evaluate their performance in different scenarios. The results indicate that while the selected features vary significantly across different feature selection methods, the performance of the predictive model remains relatively consistent when the top 10 features from each method are used. This lack of a clear "best" feature selection method suggests that, in practice, multiple methods may lead to similarly effective outcomes in terms of model performance, despite the diversity of features chosen. The results highlight the need for practitioners to experiment with multiple feature selectors, as the end goal is not solely prediction performance but anomaly detection. Depending solely on one method may introduce bias or fail to capture key fault indicators, which may only appear in unselected features.

## References

[1] Helbing, Georg & Ritter, Matthias. (2018). Deep Learning for fault detection in wind turbines. Renewable and Sustainable Energy Reviews. 98. 189-198. 10.1015/j.rser.2018.09.012.

[2] Marti-Puig, Pere & Blanco-M, Alejandro & Cárdenas, Juan & Cusido, Jordi & Solé-Casals, Jordi. (2019). Feature Selection Algorithms for Wind Turbine Failure Prediction. Energies. 12. 453. 10.3390/en12030453.

[3] Tang, Zhanjun & Shi, Xiaobing & Zou, Huayu & Zhu, Yuting & Yang, Yushi & Zhang, Yajia & He, Jianfeng. (2023). Fault Diagnosis of Wind Turbine Generators Based on Stacking Integration Algorithm and Adaptive Threshold. Sensors. 23. 6198. 10.3390/s23136198.

[4] Qian, Peng & Tian, Xiange & Kanfoud, Jamil & Lee, Joash & Gan, Tat Hean. (2019). A Novel Condition Monitoring Method of Wind Turbines Based on Long Short-Term Memory Neural Network. Energies. 12. 3411. 10.3390/en12183411.

[5] Shi, Yilong & Liu, Yrong & Gao, Xiang. (2021). Study of Wind Turbine Fault Diagnosis and Early Warning Based on SCADA Data. IEEE Access. PP. 1-1. 10.1109/ACCESS.2021.3110909.

[6] Sundararajan, Mukund & Najmi, Amir. (2019). The many Shapley values for model explanation. 10.48550/arXiv.1908.08474.

**Optimal Monitor Placement in Quantum Network Tomography**

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Monitoring the performance of internal network elements is crucial for network management and optimizing network operations. Quantum Network Tomography (QNT) focuses on the characterization of quantum channels through end-to-end measurements between selected subsets of network nodes. QNT has been previously introduced in [1]–[3] for end- to-end characterization of network links. It provided efficient end-to-end estimation strategies for the characterization of bit flip [1], [2] and depolarizing channels [3] through multipartite entanglement distribution in stars of arbitrary size. These initial tomography strategies assumed that all star leaves were monitors, and that the star hub was a regular node. Previous results indicate that global measurements can improve the efficiency of estimators, and motivate the study of optimal monitor placement.

In this work, we examine optimal strategies for monitor placement in QNT. Our study specifically targets a four-node quantum star network in which links are modelled as depolarizing channels. We investigate QNT methods that utilize a single monitor in the four node star network, and evaluate estimation performance for all possible monitor placements in the star network. We perform a theoretical analysis of the estimators by calculating the Quantum Fisher information matrix (QFIM) and the Quantum Cramer Rao Bound (QCRB). The QCRB provides a lower bound on the variance of any estimator, thereby offering a benchmark for their efficiency. We identify the monitor placement at the hub as a baseline to analyse the performance of end-to-end estimation given that the monitor has direct access to every link of the network. Through further investigation, we find that the best performance is achieved by placing the monitor in the leaf with the least noisy link for the 4-node star network.

**References**

[1] MG De Andrade, Jaime Diaz, Jake Navas, Saikat Guha, Ines`Montano, Brian Smith, Michael Raymer, and Don Towsley. Quantum network tomography with multi-party state distribution. In 2022 IEEE International Conference on Quantum Computing and Engineering (QCE), pages 400–409. IEEE, 2022.

[2] Matheus Guedes De Andrade, Jake Navas, Ines Montano, and Don Towsley. On the characterization of quantum flip stars with quantum network tomography. In 2023 IEEE International Conference on Quantum Computing and Engineering (QCE), volume 1, pages 1260–1270. IEEE, 2023.

[3] Matheus Guedes De Andrade, Jake Navas, Saikat Guha, Ines Montano, Michael Raymer, Brian Smith, and Don Towsley. Quantum network tomography. IEEE Network, pages 1–1, 2024.

## A study on extreme behavior in Car Following Models and sensitivity analysis

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Self-driving vehicles often use Car Following Models (CFM) to control the movement of vehicles playing a foundational role in Intelligent Transportation Systems (ITS). Different CFMs have been proposed and compared, focusing on fuel efficiency, comfort, stability and safety. Extreme behavior which can lead to uncomfortable jerks and even accidents has not been used to compare between models. By considering the practical limits of vehicle dynamics and passenger comfort, we analyze the extreme behavior of three nonlinear car-following models: the Nonlinear Newell Model (NNM), the Optimal Velocity Model (OVM), and the Intelligent Driver Model (IDM). We then compare their performance under naturalistic driving conditions while following a leader with velocity profile of WLTC class 2. We observe that OVM trajectories show a significant proportion of acceleration and jerk values outside the comfortable range while following a naturalistic driving vehicle. The comparison is extended through sensitivity analysis using Response Surface Method. NNM is the least sensitive model while OVM is the most. The study of extreme behavior can be used to compare different CFMs effectively and develop safe and reliable ITS.

### References

Newell, Gordon Frank. "Nonlinear effects in the dynamics of car following." Operations research 9.2 (1961): 209-229.

Treiber, Martin, and Arne Kesting. "Traffic flow dynamics." Traffic Flow Dynamics: Data, Models and Simulation, Springer-Verlag Berlin Heidelberg 227 (2013): 228.

Treiber, Martin, Ansgar Hennecke, and Dirk Helbing. "Congested traffic states in empirical observations and microscopic simulations." Physical review E 62.2 (2000): 1805.

## From Synthesis to Fabrication: The Advancement of 2D Metal Matrix Composites (2DMMCs) in Additive Manufacturing

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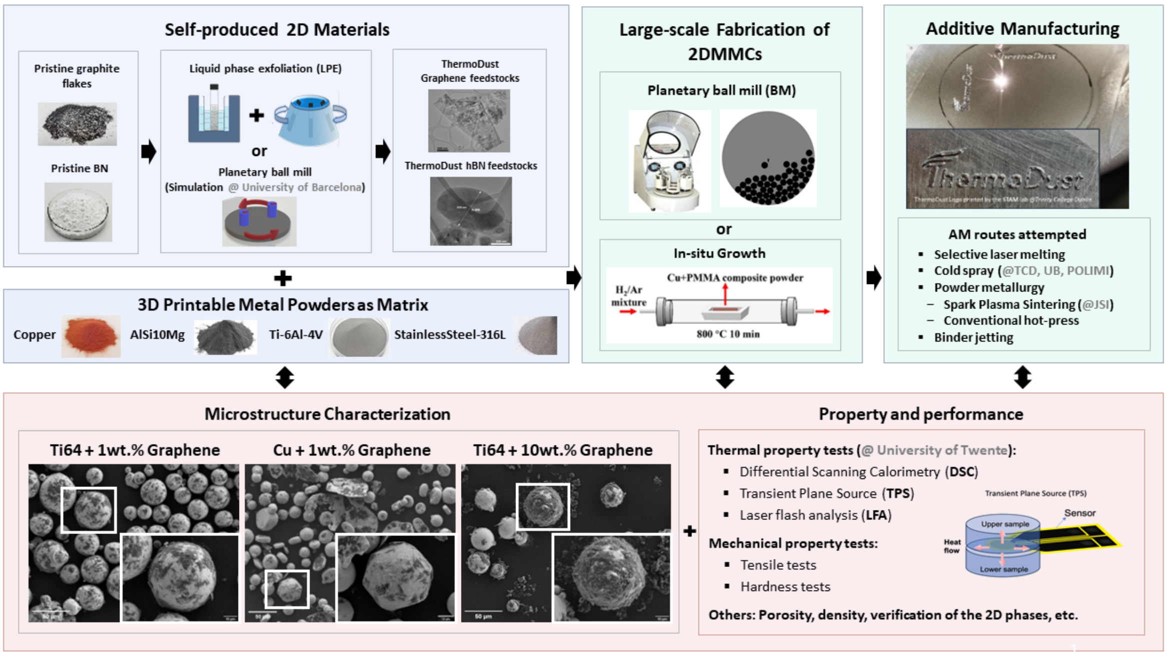
This study explores the integration of two-dimensional (2D) materials into metal matrix composites (2DMMCs) to enhance the thermal and mechanical properties of conventional metal matrices using additive manufacturing (AM) technologies. Initially, the research concentrated on creating 2DMMC powders reinforced with few-layer graphene (FLG) and hexagonal boron nitride (hBN) in various metal matrices (powders from the 3D printed standard with the size range in 15-53um), such as copper, AlSi10Mg, Ti-6Al-4V (Ti64) and stainless-steel 316L (SS316L). The overall objective is to establish a 2D phase network in the AM parts [1]. The printability and performance enhancement of the bulk composites has been investigated through the use of techniques including cold spray, selective laser melting (SLM), and powder metallurgy (traditional hot-pressing and spark plasma sintering).

The outcomes verified that there were 2D phase remains following every fabrication route. Specifically, a 32.2% rise in microhardness was observed upon adding 1 wt.% of mechanically exfoliated graphene to Ti64, suggesting a positive trend in mechanical property enhancement. Consequently, the present study highlights the challenges concerning the synthesis and processing of 2DMMCs, such as the dispersion of 2D materials and the interaction between the metal matrices and the reinforcements. The results will provide a basis for future research targets on exploiting the unique properties of 2DMMCs for applications in a range of industrial sectors.




### References

[1] Zhang, X., Xu, Y., Wang, M. et al. A powder-metallurgy-based strategy toward three-dimensional graphene-like network for reinforcing copper matrix composites. Nat Commun 11, 2775 (2020).

**Sustainable metal additive manufacturing using polymer-metal composites**

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Metal Additive using Powder Sheets (MAPS) is a recently proposed solution to various challenges in powder based additive manufacturing. While multi material printing can drive innovation and produce more efficient parts [1], the technologies that enable this are still primitive, costly and limited to a small selection of machines. In addition, separating and recycling mixed powders present economic challenges [2-4]. The authors aim to address this by exploring an innovation where the powder is bound by a polymer to form a composite [5], which can be easily manipulated and prevents powder mixing. Current research aims to form better understanding in the interaction between the polymer binder and the metal powder, and how material properties may change due to polymer influences. Various microscopy techniques such as SEM, EBSD and EDX are deployed and when coupled with chemical analysis such as LECO, help form a clear understanding [6]. It is found that the carbon from the polymer plays a key role in enhancing mechanical properties and promoting keyholing. Recent work aims to manipulate this finding to produce carbon gradient materials, unlocking new applications in areas such as biomedical mechanically gradient stents.

**References**

[1] Li, Xiaoshuang , and Arthur Seibel. Case Study: The Development of a Multi-Material Heat Sink by Additive Manufacturing Using Aerosint Technology. Vol. 9, Metal AM, 5 Apr. 2023.

[2] Wen, Yaojie, et al. “Laser Powder Bed Fusion of Compositionally Graded CoCrMo-Inconel 718.” Additive Manufacturing, vol. 40, 1 Apr. 2021, pp. 101926–101926.

[3] Wei, Chao, et al. “Embedding Anti-Counterfeiting Features in Metallic Components via Multiple Material Additive Manufacturing.” Additive Manufacturing, vol. 24, Dec. 2018, pp.

[4] Eckes, Kevin. “How Multi-Powder Deposition Will Transform Industrial 3D Printing.” Schaeffler Aerosint, 25 Jan. 2018, aerosint.com/powder-deposition-multimaterial-printing/. Accessed 30 July 2024.

[5] Lupoi, Rocco, et al. “Metal Additive Manufacturing via a Novel Composite Material Using Powder and Polymers Formed in Sheets.” CIRP Annals, vol. 71, no. 1, 2022, pp. 181–184.

[6] Arnoldas Sasnauskas, et al. “Metal Additive Manufacturing Using Powder Sheets (MAPS) of HEA CoNiCrFeMn: The Effect of the Polymer Content on Microstructure and Mechanical Properties.” CIRP Annals, vol 74, no.1, 2024, pp 173-176.

StEP: Stochastic EnergyPLAN for Enhancing Energy System Planning Under Uncertainties

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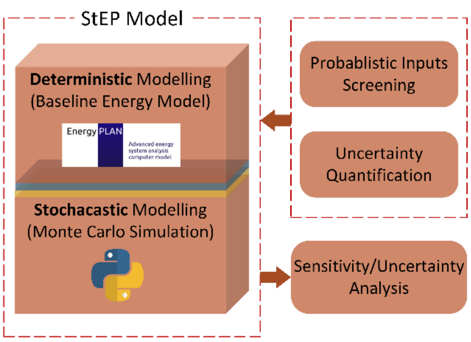
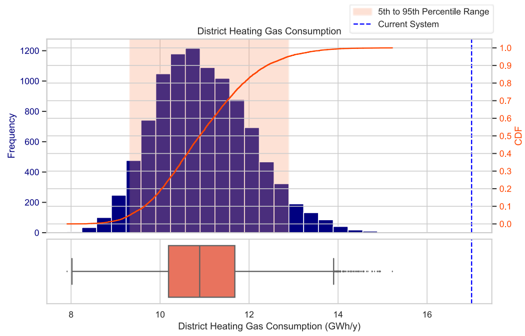
In response to the urgent need for energy systems that can effectively manage variability and uncertainty, this research introduces Stochastic EnergyPLAN (StEP), a novel framework that integrates Monte Carlo simulations with the EnergyPLAN software to transcend the limitations of its deterministic modelling approach. Addressing the inherent uncertainties in renewable energy resources, climatic conditions, equipment efficiencies, consumption patterns, and etc, StEP enhances energy system planning by providing the data required for analysing systems uncertainty and sensitivity across all design variables in EnergyPLAN. By automating scenario generation with random sampling and employing parallel computing, StEP explores a broad spectrum of possibilities based on probability density functions within defined ranges. This method provides deeper insights into factors influencing the performance of energy systems, aiding in the development of robust, cost-effective, and adaptable strategies. A case study on Trinity College Dublin's district heating system demonstrates StEP's dual application: first, a stochastic optimisation of a hypothetical enhancement scenario involving Combined Heat and Power (CHP) units and Heat Pump aimed at minimising gas consumption, and second, confirming the design robustness through another Monte Carlo simulation for Uncertainty and Sensitivity Analysis (UA and SA). Based on the results, the suggested optimal design can reduce gas consumption and CO2 emissions in the TCD campus district heating system by 35.5% on average, and at least 27% in 90% of probable situations. The proposed tool can offer vital insights for policymakers and stakeholders, facilitating the formulation of strategies that are not only economically viable but also resilient to future uncertainties.




*StEP Model's framework schematic*




*The frequency distribution of outcomes across 10,000 Monte Carlo simulations of the proposed optimal design, and potential reductions in gas consumption compared to the current system performance (vertical blue line).*

## References

[1] Aghamolaei, Reihaneh, and Marzieh Fallahpour. 2023. "Strategies towards Reducing Carbon Emission in University Campuses: A Comprehensive Review of Both Global and Local Scales." *Journal of Building Engineering* 76 (October): 107183, https://doi.org/10.1016/j.jobe.2023.107183.

[2] Ahn, Hyeunguk, Donghyun Rim, Gregory S. Pavlak, and James D. Freihaut. 2019. "Uncertainty Analysis of Energy and Economic Performances of Hybrid Solar Photovoltaic and Combined Cooling, Heating, and Power (CCHP + PV) Systems Using a Monte-Carlo Method." *Applied Energy* 255 (December): 113753. https://doi.org/10.1016/J.APENERGY.2019.113753.

# A Causal Mechanism Enhanced Deep Learning for Energy Management of Reconfigurable Power Grids (Microgrids)

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Effective energy management in microgrids (MGs), which are self-sufficient power systems incorporating renewable energy sources (RESs), is essential for ensuring low-carbon operations, cost reduction, and system security [1]. Traditional physical models for energy management struggle to adapt to the dynamic and reconfigurable nature of modern microgrids. This research proposes a model-free deep learning (DL) approach to manage energy flow and optimize the performance of reconfigurable microgrids.

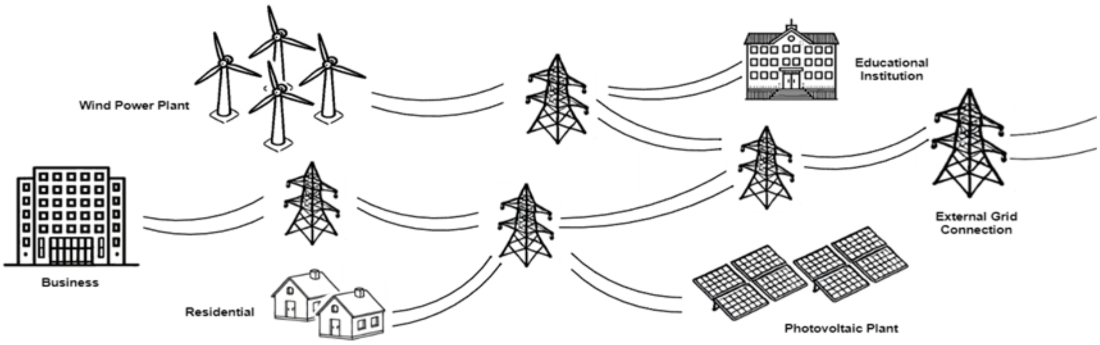


***Figure 1.*** *A simple microgrid model*

The proposed method is based on Graph Convolutional Networks (GCNs) [2], which efficiently represent the microgrid's graph-structured data. Our model integrates a causal mechanism that improves prediction accuracy and enhances the model's explainability. The causal module is deployed parallel to a series of residual connected GCN layers and helps identify key nodes influencing the energy flow, thus improving decision-making in dynamic grid environments. The challenge in current research is the lack of adaptive, scalable, and explainable energy management solutions for microgrids [3]. Our research addresses this challenge by offering a method that adapts to various microgrid topologies and scales, enabling low-carbon operations even under fluctuating renewable energy conditions. Key findings demonstrate a 40x increase in computational efficiency, with the model being capable of training on small-scale network datasets and subsequently applying the learned knowledge to larger-scale networks (from 14 to 79 buses) without a significant increase in computation time. This research contributes to the field by providing a flexible, scalable, and explainable solution for real-time energy management in reconfigurable power grids, ensuring both operational efficiency and sustainability.

## References

[1] García Vera, Y. E., Dufo-López, R., & Bernal-Agustín, J. L., 2019. Energy Management in Microgrids with Renewable Energy Sources: A Literature Review, *Applied Sciences*, https://doi.org/10.3390/app9183854.

[2] Kipf, T. N., & Welling, M. (2017). Semi-Supervised Classification with Graph Convolutional Networks. International Conference on Learning Representations (ICLR), 2017, https://doi.org/10.48550/arXiv.1609.02907.

[3] Joshi, A., Capezza, S., Alhaji, A., & Chow, M.-Y., 2023. Survey on AI and Machine Learning Techniques for Microgrid Energy Management Systems, *IEEE/CAA Journal of Automatica Sinica*, 10, pp. 1513-1529, https://doi.org/10.1109/JAS.2023.123657.

**High-throughput printing of inkless materials from laser-produced dry aerosols**

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Additive and solvent-free direct printing is crucial for various applications, including smart electronics, solar cells, healthcare, and electrochemical energy storage. While several eco-friendly methods for directly patterning inorganic functional materials have emerged, they typically operate on a small scale and involve lengthy processing times, limiting their practical transition from the lab to commercial use. Here we report a rapid, scalable, and environmentally friendly aerosol-based printing method that enables the fabrication of liquid-free materials with linear or planar structures at microscale resolution. In situ and on-demand generation of dry aerosol via pulse laser ablation coupled with real-time aerodynamical focusing by a co-flowing sheath gas allows the deposition of a wide variety of materials on various substrates simply at room temperature and atmospheric pressure. Using silver as a representative, we systematically characterized the laser-generated aerosol deposits in terms of microstructural morphologies, sintering activity, mass yield, densities and electrical performance to show the relationship between process variability and underlying mechanisms. The capacity of high-throughput printing of silver deposits with thickness of a few dozen or even a hundred microns in a single printed path was demonstrated, which is inaccessible via conventional ink-based approaches. This rapid, efficient direct-inkless-printing process opens new exciting opportunities for future applications of easy-to-integrate components of printed electronic devices.

**Utilising compound parabolic concentrators for daylighting for occupants' health**

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The Sun, through Earth's regular axial rotation, causes regular changes in brightness across a 24-hour cycle. This caused living beings, including humans, to adapt and have a regular cycle, known as the circadian rhythm or internal clock, influenced mainly by light exposure to regulate bodily functions [1]. Daylighting is the concept of using natural light to illuminate the internal space of a building for the purpose of visual and biological needs [1]. Daylighting can be achieved easily through windows. However, as building sizes increase, the reduction in daylight penetration causes insufficient brightness deep in the room for both visual purposes and circadian health. This is even more important during winter or overcast sky conditions due to shorter daytime and solar intensity.

This research proposes using compound parabolic concentrators (CPCs) to increase the collection of solar irradiation for daylighting purposes. CPCs use parabolic surfaces to reflect and concentrate light into a smaller area, thus increasing the light concentration [2]. CPCs are also useful for collecting even diffuse light, which is abundant during overcast days. As such, CPCs have been widely explored for their purposes for solar concentration for solar panels for energy generation [2]. However, the idea of using CPCs for daylighting was not largely explored. Instead of using solar panels at the CPC aperture, a light guide can be installed to channel the light efficiently to achieve sufficient illumination deep into the building.

This research looks at simulations of CPC efficiencies to optimise the design for a CPC daylighting system. With the current simulations done, a dielectric CPC can concentrate daylight into a small aperture as much as 2.3 times. A dielectric channel can then be used to transport the light through total internal reflection, resulting in only about 25% of the light lost. In future work, small-scale CPCs will be produced and tested to look at the real-world data and compare it with the simulation data. By showing the viability of using CPCs for daylighting purposes, this could provide sufficient daylight to reduce the dependency on artificial lighting, achieving sustainable buildings while enhancing occupants' health.

## References

[1] Brown, T. M., Brainard, G. C., Cajochen C., *et al.*, 2022. Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults, PLoS Biology, 20(3), e3001571, https://doi.org/10.1371/journal.pbio.3001571

[2] Duffie J. A., Beckman W. A., 2013. Concentrating Collectors. In book: Solar Engineering of Thermal Processes, 4th edition. ISBN 9781118671603. https://doi.org/10.1002/9781118671603.ch7

## Wearable Brain Health Monitoring with Ear-EEG

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In Ireland, approximately 64,000 people live with dementia, projected to rise to 150,000 by 2050 [1]. While tools, such as MRI and scalp-EEG, are expensive and infeasible for continuous monitoring of brain health, ear-EEG presents an interesting opportunity to enable more regular and accessible brain health monitoring through incorporation into wearable devices [2]. This research aims to address the following research questions: (1) To what degree can we accurately reconstruct scalp-EEG on a blind basis by applying machine learning models on ear-EEG data? (2) How accurately can neural biomarkers associated with neurodegenerative diseases, such as AD, be predicated from ear-EEG data? (3) Can ear-EEG be leveraged to estimate a brain-age gap metric when compared to full scalp-EEG and MRI? This work aims to advance the early detection of neurological diseases, allowing for timely interventions, and to provide individuals with a tool to monitor the impact of their lifestyle choices on brain health. The intended impact of this dual approach is to promote proactive management of neurological well-being.

### References

[1] E Begley, M.G., G Kelly, F Keogh, S Timmons, Model of Care for Dementia in Ireland. 2023.

[2] Looney, D., et al., The in-the-ear recording concept: user-centered and wearable brain monitoring. IEEE Pulse, 2012. **3**(6): p. 32-42.

## Compressed Sensing-based Estimation with Receiver Windowing for Delay-Doppler Channels

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Orthogonal Time-Frequency Space (OTFS) has emerged as a promising modulation scheme, offering robust performance in high-mobility environments compared to Orthogonal Frequency Division Multiplexing (OFDM), which is widely used in 4G/5G systems. However, accurate estimation of time-frequency doubly selective channels remains a major challenge, primarily due to large number of unknown parameters in the channel estimation(CE) problems. In recent OTFS literatures, compressed sensing(CS)-based methods, such as Orthogonal matching pursuit(OMP) and Simultaneously OMP(SOMP) are proposed to leverage the inherent sparsity of the delay-Doppler(DD) domain to reduce estimation overhead. Despite their efficiency, the presence of fractional Doppler shifts can degrade performance due to the damage of DD domain sparsity. Our research addresses this limitation by introducing a global window at the receiver and incorporating it into the dictionary design, thus reducing the leakage in the DD domain. Furthermore, we propose a threshold-based OMP algorithm that further improves estimation accuracy in our simulation results, with careful threshold selection. Our work highlights the potential of CS-based multi-dimensional frameworks in integrating sensing and communication, contributing to the development of more efficient and adaptive future wireless communication systems.

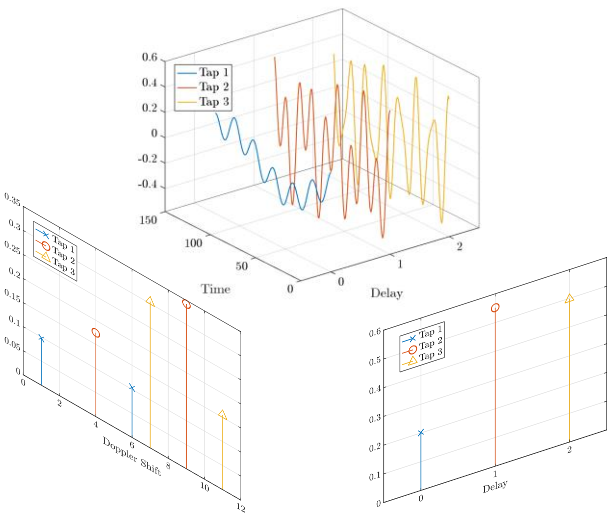


***Figure 1*** *Time-frequency selective channel and its sparse representations*

### References

[1] Chen, J., et al. (2023). "Channel Estimation for Reconfigurable Intelligent Surface Aided Multi-User mmWave MIMO Systems." IEEE Transactions on Wireless Communications **22**(10): 6853-6869.

[2] Srivastava, S., et al. (2022). "Delay-Doppler and Angular Domain 4D-Sparse CSI Estimation in OTFS Aided MIMO Systems." IEEE Transactions on Vehicular Technology **71**(12): 13447-13452.

[3] Keskin, M. F., et al. (2024). "Integrated Sensing and Communications with MIMO-OTFS: ISI/ICI Exploitation and Delay-Doppler Multiplexing." IEEE Transactions on Wireless Communications: 1-1.

Distributionally Robust Deep Reinforcement Learning for Survival of Critical Loads

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## INTRODUCTION

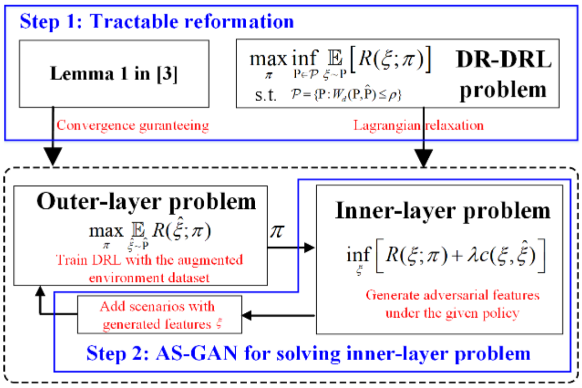
Deep reinforcement learning (DRL)-based approaches have shown promising performance in resilient defense to ensure the survival of critical loads (CLs) during sequential extreme events (SEEs). Scenario generation (SG) methods are widely used to augment environment data for DRL training. However, most existing works separate the scenario generation from DRL training process, which risks policy robustness against uncertainties during the SEE [1]. This study aims to integrate the interaction between SG and DRL training process and develop robust defense policy against the dynamic event evolution process.

## METHODS

The sequential resilient defense decision-making problem is formulated as a distributionally robust DRL (DR-DRL) learning problem to optimize CL survival and microgrid operation under the worst-case scenario distribution. Then, the learning problem is reformulated into a bilevel optimization problem, in which the out-layer is to DRL training and the inner-layer is to adversarially generate the worst-case scenarios to augment the dataset under the current policy via the adversarial scenario generative adversarial network (AS-GAN). The implementation is presented in Figure 1.

*Figure 1. implementation of the DR-DRL problem*

## RESULTS




The results in case studies on IEEE 33 and 123 bus systems demonstrated that: 1) In-sample testing performance in extreme cases improves by an average of 265.91%. 2) Out-of-sample testing performance improves by an average of 27.24%. 3) Achieves 100% critical load survival in both in-sample and out-of-sample tests. 4) Generates meaningful return-benefited training scenarios.

## DISCUSSION

The integration of SG and DRL training benefits for training resilient defense policy with improved adaptability to deal with the dynamic SEEs. Moreover, the proposed approach constructs training performance-informed model-free structure for the resilient defense.

## References

[1] Justesen, Niels, et al. "Illuminating generalization in deep reinforcement learning through procedural level generation." arXiv preprint arXiv:1806.10729 (2018).

[2] Zhao, Jin, et al. "Self-attention generative adversarial network enhanced learning method for resilient defense of networked microgrids against sequential events." IEEE Transactions on Power Systems 38.5 (2022): 4369-4380.

[3] Sinha, Aman, et al. "Certifying some distributional robustness with principled adversarial training." arXiv preprint arXiv:1710.10571 (2017).

**Seismic fragility curves for onshore wind turbines subjected to earthquake-induced landslides**

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Onshore wind turbines are key components of green and sustainable energy infrastructure in many countries, which are built to exploit wind energy and turn it into electricity. To maximize input energy, onshore wind turbines are typically placed in open areas or on the crest of slopes in mountainous regions. Their location poses the need to analyze the geological hazards that affect the risk of these type of structures, such as earthquakes and landslides. Previous studies focused on the vulnerability of onshore wind turbines against wind and seismic ground motion only. Therefore, potential damaging effects of secondary earthquake events (such as landslides, soil fracture, and liquefaction) on wind turbines need to be investigated.

This study presents a methodology for the development of fragility curves of wind turbines located on soil slopes subjected to earthquake-induced landslide hazard, accounting for damage due to slope instability on both underground electric power pipelines and above-ground structure. Different damage states (DSs) are quantitatively defined through proper thresholds of engineering demand parameters that capture the structural response of the wind turbine at both local and global spatial scales. To that aim, a detailed finite element model of a benchmark wind turbine developed by the National Renewable Energy Laboratory was developed in OpenSees software. After that a suite of ground motion records after strong earthquakes is selected, permanent slope displacement is predicted and nonlinear dynamic response analysis of the wind turbine is carried out to calculate seismic fragility of both the pipeline and above-ground structure. Analysis results show a strong influence of slope geometry and soil properties on seismic fragility, demonstrating the impact that landslide hazard can have on seismic risk of onshore wind turbines in addition to seismic ground shaking.

### References

[1] Jonkman, J., Butterfield, S., Musial, W., Scott, G., 2009. Definition of a 5-MW reference wind turbine for offshore system development. Tech. Rep.. National Renewable Energy Laboratory.

[2] Fotopoulou, S.D., & Pitilakis, K.D., 2015. Predictive relationships for seismically induced slope displacements using numerical analysis results, Bulletin of Earthquake Engineering, 13, 3207–3238, https://doi.org/10.1007/s10518-015-9768-4.