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RESEARCH & INNOVATION DAY 2025

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INNOVATION FOR HEALTH

SUSTAINABLE FUTURES

Abstracts

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CURIOSITY & DISCOVERY

DECISIVE DATA

Oral Presentations

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Evaluation of Large Language Models for the reassembly of proteins from peptides

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INTRODUCTION

Proteomics and metaproteomics play a crucial role in biomedical, environmental and biotechnological research in the post-genomic era. While genomics and transcriptomics provide information on microbial potential, proteomics is closer to phenotypes and as such reflects well ecosystem functions. Proteomics typically involves peptide digestion followed by tandem mass spectrometry (MS) with protein identification relying on the efficient mapping of MS peaks. This typically requires access to relevant databases, which are not readily available for example in the case of soil. To overcome this limitation, de novo peptide sequencing can be deployed, which mines directly peptide sequence information from MS spectra. Such strategy however does not address de novo protein reassembly.

MATERIALS AND METHODS

Here, we propose to use Large Language Models (LLMs) to predict protein sequences from fragmented peptides. As a first step, we evaluated the ability of LLMs to assign unknown peptides to their proteins. To this end, we fine-tuned BERT, RoBERTa, ALBERT and ProteinBERT on peptide sequences and assessed the impact of artificially masked data on model performance.

RESULTS AND DISCUSSION

RoBERTa outperformed other models reaching 83% accuracy when trained on augmented data, while ProteinBERT, which was initially designed to predict proteins properties only display 63% accuracy when trained on the same dataset. Overall we demonstrate that LLMs are a promising avenue for de novo protein reassembly, when deployed with appropriate data augmentation strategies.

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Abstract

Haematological deterioration of *Hematodinium*-infected decapod crustaceans

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INTRODUCTION

Parasitic dinoflagellates, namely *Hematodinium* spp., infect a growing number of decapod crustacean species worldwide. Known as bitter/pink/milky crab disease or post-moult syndrome, these infections can be fatal, with no known treatments or disease management strategies currently available. Longstanding concerns persist in commercial fisheries in Europe and North America, such as for the Norway lobster (*Nephrops norvegicus*), and this parasite is an emerging concern in aquaculture and polyculture systems in Asia.

MATERIALS AND METHODS

To enhance our understanding of *Hematodinium*-crustacean pathosystems, particularly haemolymph condition during parasitaemia, we conducted a meta-analysis of the existing literature. Our goal was to determine whether cellular or biochemical markers in the haemolymph could aid in detecting or diagnosing *Hematodinium* spp. infection in decapods. From 15 original studies that met strict inclusion criteria, we extracted 184 effect sizes across 18 haematological markers, including haemocyte counts and enzymatic activities. Generalised linear mixed models were utilised to assess patterns across parameters. Additional models were constructed to consider the influence of various environmental/host variables (e.g., sex, water temperature, salinity) in response to *Hematodinium* spp.

RESULTS AND DISCUSSION

Our results show significant haematological deterioration associated with *Hematodinium* infection, including depleted haemocyte numbers (e.g., hyaline cells) and reductions in protein levels (e.g., haemocyanin). Crustaceans were more likely to experience severe *Hematodinium* burdens under environmental conditions of high salinity (>30 psu) and elevated temperatures (≥20°C). Wild-caught hosts exhibited more intense infections compared to laboratory infected individuals.

This study adds quantitative rigour to widely held assumptions about Hematodinium-driven pathology and highlights consistent physiological markers that may inform future diagnostic or monitoring approaches.

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Abstract

Video-DPRP: A Differential Private approach for Visual Privacy-preserving Video Human Activity Recognition

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ABSTRACT

Considerable effort has been made in privacy-preserving video human activity recognition (HAR). Two primary approaches to ensure privacy preservation in Video HAR are differential privacy (DP) and visual privacy. Techniques enforcing DP during training provide strong theoretical privacy guarantees but offer limited capabilities for visual privacy assessment. Conversely methods, such as low-resolution transformations, data obfuscation and adversarial networks, emphasize visual privacy but lack clear theoretical privacy assurances. In this work, we focus on two main objectives: (1) leveraging DP proper- ties to develop a model-free approach for visual privacy in videos and (2) evaluating our proposed technique using both differential privacy and visual privacy assessments on HAR tasks. To achieve goal (1), we introduce Video- DPRP: a Video-sample wise Differentially Private Random Projection framework for privacy-preserved video reconstruction for HAR. By using random projections, noise matrices and right singular vectors derived from the singular value decomposition of videos, Video-DPRP reconstructs DP videos using privacy parameters (ε, δ) while enabling visual privacy assessment. For goal (2), using UCF101 and HMDB51 datasets, we compare Video-DPRP's performance on activity recognition with traditional DP methods, and state-of-the-art (SOTA) visual privacy-preserving techniques. Additionally, we assess its effectiveness in pre-serving privacy-related attributes such as facial features, gender, and skin colour, using the PA-HMDB and VISPR datasets. Video-DPRP combines privacy-preservation from both a DP and visual privacy perspective unlike SOTA methods that typically address only one of these aspects.

INTRODUCTION

Human activity recognition (HAR) systems inherently process video data that often includes sensitive personal information such as facial identity, skin colour, or even intimate behaviours raising serious ethical and legal concerns. While existing solutions address privacy either at the model training stage using differential privacy (DP) or at the data level using visual anonymization techniques, they often do so in isolation. Model-based DP methods offer strong theoretical privacy guarantees but do not allow for post-hoc visual privacy assessments. Conversely, visual obfuscation methods lack formal privacy guarantees and are susceptible to adversarial attacks or reconstruction. There exists a critical need for HAR systems that can preserve visual privacy in a theoretically grounded and quantifiable manner, while maintaining performance on downstream recognition tasks.

RESULTS AND DISCUSSION

Experimental results demonstrate that, across varying values of differential privacy (DP) parameters, it is possible to reconstruct visually privacy-preserved videos that are robust to adversarial attacks, without compromising their utility for human activity recognition (HAR).

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Abstract

Harnessing Reinforcement Learning for Sustainable Peer-to-Peer Energy Trading in Dairy Farms

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INTRODUCTION

Renewable energy adoption in dairy farms enhances efficiency and reduces grid dependency, but rural communities, specifically Irish dairy farms, face challenges due to varying energy needs. The Multi-Agent Peer-to-Peer Dairy Farm Energy Simulator (MAPDES) addresses this by combining Peer-to-Peer (P2P) energy trading with advanced Multi-Agent Reinforcement Learning (MARL) techniques like Proximal Policy Optimization (PPO) and Deep Q-Networks (DQN). By optimizing auction-based trading, price advisory, and energy management, this approach reduces costs, lowers peak hour demand, and supports sustainable energy management in rural dairy farming communities.

METHODOLOGY

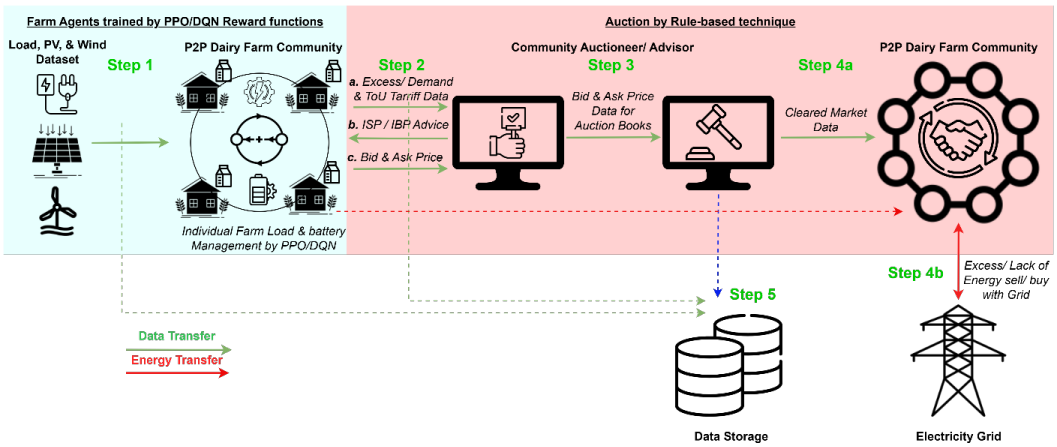

Figure 1 MAPDES Methodology

RESULTS AND DISCUSSIONS

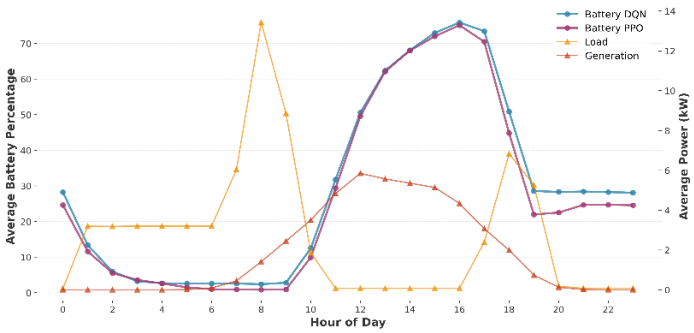

Figure 2 Typical daily patterns of Irish dairy farms' battery SOC (PPO & DQN), load, and generation

Results of energy management in Figure 2, compared to a baseline rule-based model published earlier, show that current DQN model reduces electricity costs by 14.2% in Irish dairy farms, while increasing revenue by 7.24%. PPO achieves the lowest peak hour demand, reducing it by 55.5%, with DQN reducing it by 50.0%. These results highlight the synergy of MARL algorithms and P2P trading in achieving cost savings, peak hour demand reduction, and sustainable energy management in rural communities.

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Abstract

AN AGENTIC AI ARCHITECTURE TO ENHANCE MICRORNA RESEARCH DATA INTERACTION

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1. School of Mathematical & Statistical Sciences, 2. School of Biological and Chemical Sciences, 3. School of Medicine, * These authors contributed equally to the project

INTRODUCTION

The study of microRNAs (miRNAs) and their targets increasingly requires significant data science skills - navigating databases requires SQL skills, literature review is extensive, and visualization demands separate tools. These hurdles delay scientific progress. Generative AI (GenAI) agents can simplify these tasks. We developed the MiRKatDB Assistant, a conversational AI agent using Google Gemini and LangGraph, to streamline miRNA data retrieval, synthesis, and visualization for researchers.

MATERIALS AND METHODS

An agentic AI architecture was developed using Python, the Gemini API (gemini-2.0-flash), and LangGraph. Key agents include: 1) a Master Router interpreting queries and directing workflow; 2) an SQL Agent translating natural language to SQL queries for a curated miRNA database (miRKatDB) via function-calling tools; 3) a Literature Research Agent performing grounded Google Searches to synthesize cited answers; 4) A Plotting Agent generating Python visualizations using code execution tools. Agent state (GraphState) preserves context between nodes.

RESULTS AND DISCUSSION

The MiRKatDB Assistant successfully demonstrated multi-step conversational interaction. It accurately routed queries, executed database lookups based on natural language, generated synthesized literature summaries with citations, and created plots from retrieved data. This multi-agent system effectively integrates data querying, literature review, and visualization into a single interface.

While proving the concept's viability, limitations like SQL query robustness and literature source validation need addressing. Future directions include refined node capabilities using Retrieval-Augmented Generation (RAG), formal evaluation, and deployment as an interactive tool. This agent-based approach significantly reduces data management friction, potentially accelerating miRNA research.

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Abstract

Evaluating Clinical BERT for Multiclass Pathology Report Classification with Interpretability

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Pathology reports are essential documents physicians use to establish a diagnosis and formulate a treatment plan for a specific health condition or disease. The significance of these reports is particularly pronounced in the context of cancer. The accurate classification of these reports is essential for optimising clinical decision-making, ensuring timely interventions, and maintaining high-quality patient care. We fine-tuned Bio+Clinical BERT-based multiclass classification approach that accurately distinguishes across 32 cancer tissues, offering a more clinically relevant solution compared to binary classification methods. In addition, we developed a framework that integrates LIME to examine the interpretability of the BERT-based model's decisions and identified the domain-specific features that influence the classification results. We have demonstrated that high-performance transformer models can maintain transparency in clinical settings. Our interpretable framework enables pathologists to assess model outputs against established diagnostic criteria, facilitating the responsible integration of clinical language processing systems into clinical workflows.

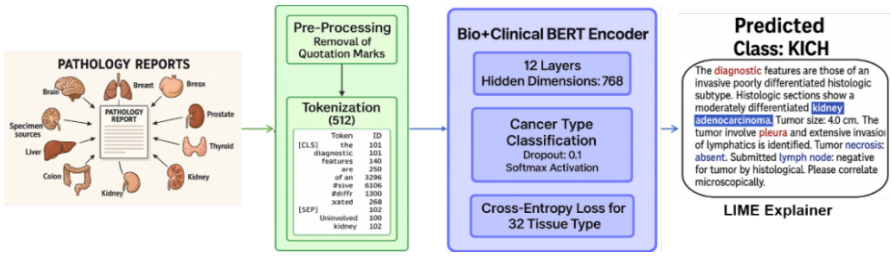

Figure 1. *Overview of the Proposed Approach*

INTRODUCTION

Pathology reports play an important role in cancer diagnosis and treatment planning. However, accurate classification remains a challenge due to the complexity of medical language and the lack of interpretability in deep learning models. We address this by fine-tuning a Bio+Clinical BERT-based model for multiclass classification of pathology reports across 32 cancer types, with integrated explainability using LIME.

MATERIALS AND METHODS

- **Dataset**: 9,523 pathology reports from The Cancer Genome Atlas (TCGA).
- **Preprocessing**: Tokenisation with a maximum sequence length of 512 tokens.
- **Model**: Bio+Clinical BERT fine-tuned for 32-class cancer types.
- **Explainability**: Integrated LIME to assess word-level impact on model predictions.

RESULTS AND DISCUSSION

The fine-tuned Bio+Clinical BERT model achieved an average AU-ROC of 0.997 in distinguishing 32 tissue types while maintaining consistent performance across five cross-validation folds, with a balanced accuracy of 0.966. Precision, recall, and F1 scores were also calculated for each tissue type. Our framework provides accurate classification with high interpretability, aiding clinical decision-making. LIME integration ensures transparency, allowing pathologists to validate model outputs against established diagnostic criteria.

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Abstract

Predicting social participation using brain MRI, environmental and genetic measures in the UKB using Extreme Gradient Boosting (XGBoost)

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* Authors jointly directed this work

INTRODUCTION

Experience of psychosis is often associated with poor social outcomes, even with successful antipsychotic treatment. Understanding which factors influence an individual's social behaviour is an important step in understanding this problem. Here, we aim to identify to what degree social participation (SP) can be predicted in healthy individuals and by which specific brain MRI, environmental, and genetic factors.

MATERIALS AND METHODS

SP (range:0–10) was defined based on a metric comprised of frequency of friend/family visits (UKB:p1031) and leisure/social activities (UKB:p6160). Individuals were classed as having low SP (n=8,288) or high SP (n=5,681) using cutoffs related to the top and bottom quartile of the SP distribution. Measures of brain MRI volume (n=451), environmental exposures (n=32) and genetic polygenic risk scores (n=36) with <10% missingness, as well as age, sex and educational attainment (EA) were used to predict SP in healthy individuals in the UK Biobank. Data were split into 75:25 training:test cohorts.

RESULTS AND DISCUSSION

Balanced prediction accuracy for classifying high/low SP in the test set was 61.4%. ROC analysis indicated a total AUC of 69.4%. Precision and recall were 66.7% and 84.5% respectively. Age was the most significant predictor by variable importance, followed by friendships satisfaction, length of time at current address, sex and household income. Among the top 20 predictors, 8 (40%) were environmental, 8 (40%) were brain measures, and 1 (5%) was genetic. This work suggests that SP is a predictable measure and that brain MRI features and environmental exposures are more important than genetic factors. Although literature details the link between brain MRI features behaviour, the role and causality of environmental factors appears less clear. Further work including robust feature selection of factors and validation in affected individuals is required to fully understand the environmental and biological factors that influence social behaviour in psychosis.

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Abstract

Species distribution modelling of deep-sea antipatharians reveals environmental heterogeneity across the Irish margin

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INTRODUCTION

Antipatharians are corals that support biodiversity by providing other species with shelter, food, and nursery areas, and form habitats vulnerable to human impacts. Most species inhabit deep-sea ecosystems characterised by distinct topographies. In canyons, defined by steep slopes and strong currents, antipatharians are mostly sparse, while they likely form aggregations in habitats with more moderate conditions. Deep-sea habitats are difficult to survey due to inaccessibility; to overcome data scarcity, conservation relies on informative, cost-effective tools such as species distribution models (SDMs), which predict species distributions using environmental and occurrence data. However, SDMs reflect the real distribution of a species only when its ecology and habitat are well understood. This study models the distribution of six antipatharian morphotypes across the Irish margin, and compares predictions with real observations (ground-truthing) to test model reliability for conservation management.

METHODS

Video data were collected across canyon and not-canyon locations of the Irish margin. Antipatharians were annotated, and their likelihood of presence was modelled using MaxEnt. Three models were built using (1) canyon-only data, (2) not-canyon-only data, and (3) 80% of the full dataset. Each model was evaluated through several metrics, and ground-truthed with (1) not-canyon data, (2) canyon data, and (3) the remaining 20% of the dataset, respectively.

RESULTS AND DISCUSSION

While two models consistently performed poorly, others performed better when the training data reflected the actual environmental niche of the morphotypes. Ground-truthing revealed that models did not transfer well between canyon and not-canyon sites. Poor results were also observed when models were trained using data collected in both locations. Further spatial analysis identified five poorly surveyed environmental envelopes in the Irish margin, indicating that treating the margin as a single region affects the reliability of SDM predictions. Further studies should focus on a better understanding of each envelope to improve conservation efforts.

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Abstract

Dynamic Time-Frequency Decompositions as Unique Fingerprints for Time-Series Feature Extraction

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INTRODUCTION

This presentation will highlight research done on the use of wavelet transforms serving as unique fingerprints for time series data. Opening with an overview of the challenges in time-frequency decompositions derived from the uncertainty principle [2] and laying out the motivations for a dynamic mesh resolution in the transform space.

The motivation for a dynamic decomposition leads into an exploration of audio data as time series, wavelet transform computation [1], and an overview of wavelet coherence analysis [3], including examples from other domains. The wavelet transform coefficients will be used to show the spectrograms of both recorded Irish music and synthetically generated tunes.

The talk will include a live demonstration of the capabilities of the wavelet coherence model by recording a tune and matching the wavelet transform up against a database of sheet music to, without deep learning or the internet, correctly identify the tune.

References

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[3] Chavez, M., Cazelles, B. Detecting dynamic spatial correlation patterns with generalized wavelet coherence and non-stationary surrogate data. Sci Rep 9, 7389 (2019).

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Posters

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Abstract

A Semantic Approach for Linked Model, Data, and Dataspace Cards

Donald, A.[1], Galanopoulos, A.[2], Curry, E.[1], Munoz, E.[2], Ullah, I.[1], Waskow, M.A.[1], Kalra, M.[2], Saxena, S.[2], Iqbal, T.[1]

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INTRODUCTION: In artificial intelligence, the significance of thorough documentation of models and datasets for publication is underestimated. However, due to the rising trend in the explainability and fairness of AI models, frameworks like Model, Service and Data Cards have emerged to facilitate understanding and reusing those models and datasets. The Dataspace concept then unifies these into Dataspace Cards, a single framework that organizes essential information to guide model and data selection.

METHODS: This work introduces a Semantic Web method to turn Model/Data Cards into machine-readable knowledge graphs within a Dataspace. A significant contribution is the development of a vocabulary that unifies Data, Model and Dataspace Card (LMDC) ontologies (Figure 1), enhancing consistent documentation and understanding of the Dataspace design. The paper validates the schema across multiple use cases.

RESULTS AND DISCUSSION: The proposed unified, ontology-driven approach results in more consistent metadata linking and more fine-grained bias detection in BERT-based-uncased (one use-case) than standalone documentation tools relying solely on Model or Data Cards. Furthermore, compared to existing frameworks, the richer interlinking capabilities of our proposed Dataspace Cards facilitates easier traceability of performance outcomes, ultimately fostering higher trustworthiness and reusability of AI resources.

Impact: In health domain, clinicians can quickly identify and trust sentiment and emotion insights that are tailored to specific patient cohorts and data types, improving the accuracy of real-time patient feedback and care adjustments. The policymakers gain a transparent, auditable view of patient sentiment across all feedback channels, enabling evidence-based decisions and targeted resource allocation.

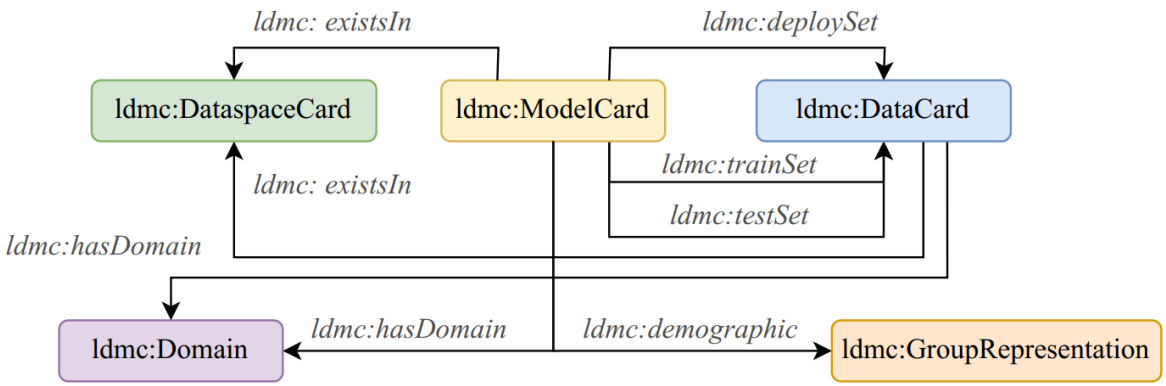

Figure 1. LMDC Ontology where Dataspace, Model and Data Cards are semantically connected with domain and demographic information.

Acknowledgment: This research was conducted with the financial support of Science Foundation Ireland under Grant Agreement Nos SFI/12/RC/2289\P2 and 20/SP/8955 at the Insight SFI Research Centre and Department of Computer Science at the University of Galway.

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Abstract

Trustworthy Requirements for Foundation Models - A Comprehensive Survey and Roadmap

Ping Song

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INTRODUCTION

Foundation models are being broadly adopted for downstream tasks and then deployed in real-world systems due to their diverse and generalisation capabilities. This versatility allows them to excel across various domains, providing a strong basis for building specialised models and solutions, thus, accelerating the process of artificial intelligence (AI) transition from research to real-world deployment. However, these foundation models and implemented AI systems driven by these models present many challenges, particularly in the area of trustworthiness. They might be vulnerable to adversarial attacks, output incorrect answers or decisions, biased against certain groups, prone to privacy leakage etc. This can cause severe outcomes, especially with the application of AI in high stake areas such as finance and healthcare. Thus, developing trustworthiness of foundation models-based AI systems has become important and necessary. Trustworthy AI systems ensure reliability, safety, and fairness, making them crucial for successful real-world implementation and user acceptance. The core questions under this survey topic are: How to define trustworthiness in foundation models? What trustworthy aspects should we take into consideration regarding foundation models? What approaches can enhance their trustworthiness? What are challenges and what future directions? In this survey, we present a comprehensive analysis of what constitute trustworthy foundation model. We summarized, analysed and discussed highly relevant trustworthy aspects for foundation models. To structure our analysis, we also formalised lifecycle of foundation model-based AI systems. This allowed us to specify the requirements and approaches for each stage of the lifecycle. Lastly, we outlined challenges and future directions towards trustworthy foundation models. The main contributions of this paper are four-fold: (1) Formalization of the lifecycle for foundation models and definition of each phase. (2) Summary of key trustworthy aspects of foundation models and define them. (3) Examination of approaches for each aspects across the lifecycle. (4) Identification of challenges, gaps, and future directions.

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Abstract

SMARTER ENVIRONMENTAL GOVERNANCE: A HYBRID RAG FRAMEWORK FOR MULTILINGUAL PEATLAND POLICY DISCOVERY

Muhammad Yasar Khan, Niall Ó Brolcháin, Al Waskow, Waqas Shoukat, Yifan Wang, Fergus O'Donoghue

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INTRODUCTION

Peatlands play a pivotal role in global climate regulation through carbon sequestration and biodiversity support, positioning them as critical ecosystems within environmental policy discourse. Despite their ecological significance, policy documents pertaining to peatland management are often fragmented across linguistic, geographic, and jurisdictional boundaries, thereby hindering integrative analysis and evidence-based decision-making.

MATERIALS AND METHODS

In this study, we propose a hybrid Retrieval-Augmented Generation (RAG) framework tailored for multilingual peatland policy discovery. Our approach integrates dense semantic retrieval with BM25 lexical matching, achieving a balanced trade-off between contextual understanding and recall. To enable fine-grained, jurisdiction-specific analysis, the framework supports metadata-driven filtering across dimensions such as country, governance level, and document language.

RESULTS AND DISCUSSION

The system is evaluated using the RAGAS benchmark, which quantitatively assesses generation performance along axes of grounding, factual consistency, and contextual relevance. Empirical results demonstrate that our hybrid search architecture, combined with structured metadata constraints, substantially enhances answer accuracy, traceability, and multilingual robustness in heterogeneous policy corpora.

This work contributes a reproducible methodology for policy discovery in fragmented regulatory environments and represents a significant step toward data-informed environmental governance. The proposed framework is domain-agnostic and can be extended to other areas of sustainability policy, offering a practical tool for researchers, policymakers, and transnational organizations engaged in environmental monitoring, compliance, and strategy formulation.

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Abstract

Cross-lingual Transfer and Multilingual Learning for Detecting Harmful Behaviour in African Under-Resourced Language Dialogue

Tunde Ajayi

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INTRODUCTION

Most harmful dialogue detection models are developed for high-resourced languages. Consequently, users who speak under-resourced languages cannot fully benefit from these models in terms of usage, development, detection and mitigation of harmful dialogue utterances. Our work aims at detecting harmful utterances in under-resourced African languages. We leverage transfer learning using pretrained models trained with multilingual embeddings to develop a cross-lingual model capable of detecting harmful content across various African languages. We first fine-tune a harmful dialogue detection model on a selected African dialogue dataset. Additionally, we fine-tune a model on a combined dataset in some African languages to develop a multilingual harmful dialogue detection model. We then evaluate the cross-lingual model's ability to generalise to an unseen African language by performing harmful dialogue detection in an under-resourced language not present during pretraining or fine-tuning. We evaluate our models on the test datasets. We show that our best performing models achieve impressive results in terms of F1 score. Finally, we discuss the results and limitations of our work.

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Abstract

WHEN RETRIEVAL OUTPERFORMS GENERATION: DENSE EVIDENCE RETRIEVAL FOR SCALABLE FAKE NEWS DETECTION

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INTRODUCTION

The exponential growth of misinformation across digital platforms presents an urgent challenge to information integrity and societal decision-making. Decisive, data-driven approaches to fact verification are essential for combating fake news at scale. While recent approaches leverage Large Language Models (LLMs) to generate explanatory rationales, these methods face significant computational barriers and hallucination risks. We present DeReC (Dense Retrieval Classification), a lightweight framework that transforms how data can be leveraged to make decisive determinations about content veracity, demonstrating how evidence-based decision systems can benefit society through more accurate and accessible fact verification.

MATERIALS AND METHODS

Our framework consists of three key components: (1) evidence extraction using dense embeddings, (2) evidence retrieval through FAISS-based similarity search, and (3) veracity prediction using a specialized classifier. We evaluated DeReC on two extensive benchmarks: LIAR-RAW and RAWFC. For embedding generation, we employed two models: Qwen2-1.5B (1.5B parameters) and Nomic-embed (137M parameters). Document retrieval utilized FAISS with cosine similarity search, while classification leveraged DeBERTa-v3-large.

RESULTS AND DISCUSSION

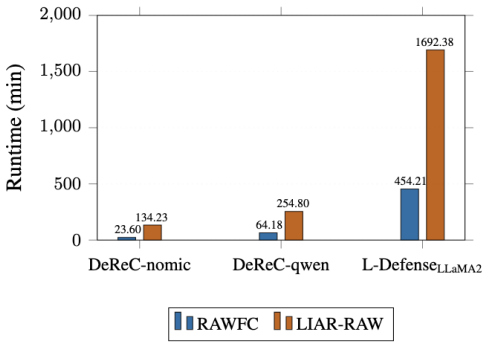

Figure 1: Complete pipeline runtime comparison (in minutes) on RAWFC and LIAR-RAW datasets.

DeReC delivers decisive data-driven insights with state-of-the-art accuracy while dramatically reducing computational requirements. By prioritizing evidence retrieval over generation, DeReC creates a decisive data pipeline that benefits society through democratizing access to reliable fact verification technology, challenging the assumption that resource-intensive LLM approaches are necessary for effective information integrity.

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Abstract

Towards Robust Autonomous Driving: Out-of-Distribution Object Detection in Bird's Eye View Space

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2. Valeo, Tuam, Ireland

INTRODUCTION: Robust perception is important for safe autonomous driving, particularly when encountering unknown or Out-of-Distribution (OOD) objects. Existing object detection approaches often fail to recognize objects outside their training data. This work enhances OOD object detection in the Bird's Eye View (BeV) space by introducing two strategies: (1) patch-based occlusions; (2) a new NuScenesOOD dataset. We modify the Lift-Splat-Shoot (LSS)1 framework to enable it to segment both known and unknown objects. Our NuScenesOOD dataset augments vehicles with visually distinct patterns, creating OOD object appearances.

METHODOLOGY: To enable the detection of OOD objects in dynamic driving environments, we modify the perception pipeline of LSS. We apply patches to selected vehicles in the projected BeV space, that allows the model to learn and localize objects even when they are not directly visible. We also change the model's output so it can predict both known and unknown objects. During training, we keep track of the same vehicles using instance tokens across frames to keep patch consistency. In addition, we introduce NuScenesOOD, a custom dataset where vehicles are augmented with unusual patterns to create OOD objects and test model robustness.

RESULTS AND DISCUSSION: We tested our approach on both NuScenes dataset and our new NuScenesOOD dataset. The results show that adding patches helps the model learn to handle occluded or unknown objects, making a significant drop in accuracy where patches were applied, i.e., 65.7%. This shows the model treats patched areas as uncertain or unknown. On NuScenesOOD, the model was able to detect augmented vehicles with unusual patterns. That shows it has learned to identify unknown objects and also increased the performance on known objects by 11.35%. This shows our approach enhances OOD detection without affecting regular known object detection.

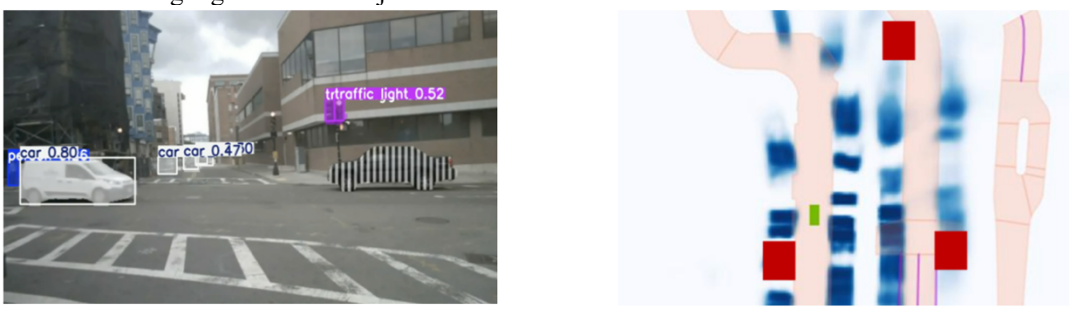

Figure 1: Left: A vehicle augmented with a zebra-striped texture simulates an unknown object and is missed by a state-of-the-art detector. Right: Red rectangular patches in the Bird's Eye View (BEV) space fully occlude vehicles (e.g., cars or trucks) to test the model's ability to detect unknown or unlabelled objects. Occluded vehicles appear as solid red blocks in the top-down BEV layout.

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Abstract

Can Synthetic Data Improve Symbolic Regression Extrapolation Performance?

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ABSTRACT

Many machine learning models perform well when making predictions within the training data range, but often struggle when required to extrapolate beyond it. Symbolic regression (SR) using genetic programming (GP) can generate flexible models but is prone to unreliable behaviour in extrapolation. This paper investigates whether adding synthetic data can help improve performance in such cases. We apply Kernel Density Estimation (KDE) to identify regions in the input space where the training data is sparse. Synthetic data is then generated in those regions using a knowledge distillation (KD) approach: a teacher model generates predictions on new input points, which are then used to train a student model. We evaluate this method across six benchmark datasets, using neural networks (NN), random forests (RF), and GP both as teacher models (to generate synthetic data) and as student models (trained on the augmented data). Results show that GP models benefit most when trained with synthetic data from NN and RF. The most significant improvements are observed in extrapolation regions, while changes in interpolation areas show only slight changes. We also observe heterogeneous errors (HE), where model performance varies across different regions of the input space. Overall, this approach offers a practical way to improve extrapolation in symbolic regression.

INTRODUCTION

Machine learning models are typically evaluated based on their ability to interpolate, i.e., to predict outcomes within the range of their training data. However, many practical applications require extrapolation, where models are expected to make predictions in regions of the input space not covered during training [1]. In these cases, performance often gets worse, especially when models do not have access to domain-specific knowledge or constraints [2, 3].

A major challenge in extrapolation is managing prediction error. Models tend to produce larger and more unpredictable errors in areas where they have not been trained [3, 4]. These unpredictable behaviours are often linked to heterogeneous errors (HE) [3, 5], systematic variations in error magnitude across the input space [4, 6]. HE becomes more pronounced during extrapolation, where the training data provides insufficient coverage of the full problem domain. To address this, our study investigates whether synthetic data augmentation can help reduce extrapolation error and HE. Rather than expanding the training dataset directly, we aim to expand the model's knowledge landscape, its exposure to diverse inputs by generating artificial samples in regions with sparse training data. These extrapolation prone regions are identified using Kernel Density Estimation (KDE), a density-based method that estimates how training data is distributed in the input space. Areas with low density are treated as extrapolation zones, where errors are more likely to increase.

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Abstract

CMVC+: A Multi-View Clustering Framework for Open Knowledge Base Canonicalization via Contrastive Learning

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INTRODUCTION

Open information extraction (OIE) methods extract plenty of OIE triples <noun phrase, relation phrase, noun phrase> from unstructured text, which compose large open knowledge bases (OKBs). Noun phrases and relation phrases in such OKBs are not canonicalized, which leads to scattered and redundant facts. It is found that two views of knowledge (i.e., a fact view based on the fact triple and a context view based on the fact triple's source context) provide complementary information that is vital to the task of OKB canonicalization, which clusters synonymous noun phrases and relation phrases into the same group and assigns them unique identifiers. In order to leverage these two views of knowledge jointly, we propose CMVC+, a novel unsupervised framework for canonicalizing OKBs without the need for manually annotated labels. Specifically, we propose a multi-view CHF K-Means clustering algorithm to mutually reinforce the clustering of view-specific embeddings learned from each view by considering the clustering quality in a fine-grained manner. Furthermore, we propose a novel contrastive learning module to refine the learned view-specific embeddings and further enhance the canonicalization performance. We demonstrate the superiority of our framework through extensive experiments on multiple real-world OKB data sets against state-of-the art methods.

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Abstract

Using polarized intrinsic emission (PIE) to measure the kinetics of protein-liposome interactions on a second timescale: Exploring the Role of Ionic Strength

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INTRODUCTION

Liposomes are widely used as drug delivery systems due to their ability to encapsulate therapeutic agents and interact with biological environments. Upon intravenous administration, liposomes are immediately exposed to plasma proteins, leading to the formation of a dynamic "protein corona" that governs their biological fate, stability, and clearance. One of key factors affecting protein-liposome interactions is ionic strength, which influences protein binding, aggregation, and membrane penetration. However, lacking the time-resolved perspective crucial to understanding early-stage events. Here we developed a novel analytical method based on polarized fluorescence spectroscopy, combined with a rapid mixing accessory, to monitor the real-time kinetics of human serum albumin (HSA) interactions with DMPC liposomes by measuring the intrinsic emission of HSA at second-time scales under varying ionic strengths.

MATERIALS AND METHODS

HSA and DMPC liposomes in ABC (ammonium bicarbonate) buffer solutions(pH~8.0), with ionic strengths (25, 50, 100, and 150 mM) were prepared. Real-time measurements were performed using a Horiba Aqualog fluorometer with wire grid polarizers. PIE spectra (VV and VH polarizations) were recorded at 1-second intervals with fixed 280 nm excitation and a 200–800 nm emission range. Dynamic Light Scattering (DLS) provided reference particle size, polydispersity, and diffusion data.

RESULTS AND DISCUSSION

This was the first use of PIE for real time monitoring of HSA-liposome interactions and the effect of ionic strength on the interaction process. Using the ratio of the Emission to Rayleigh scatter from PIE spectra which can be correlated with particle size provides a faster, and more accurate picture than DLS (which takes 10x time longer) of the changes occurring during the initial interaction stage.

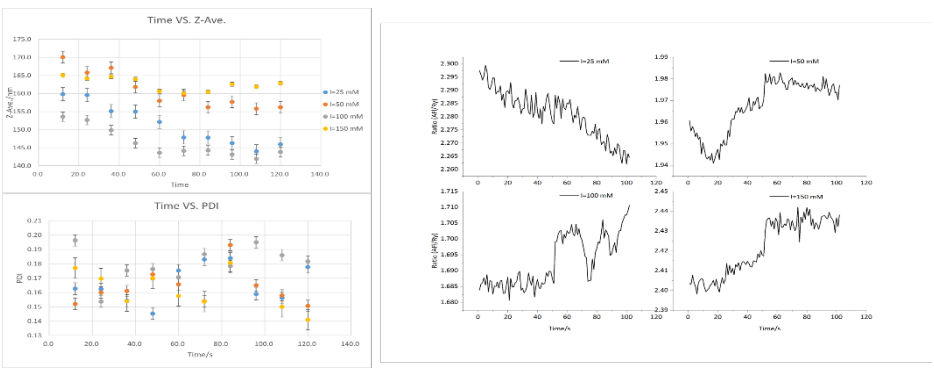

Figure1: Effect of HSA interacting with liposomes over first 100 s at varying ionic strengths as monitored by DLS (L) and PIE via the Emission/Rayleigh ratio (R).

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Abstract

Novel approach to image formation in OCT. Label free superresolution and nanosensitive imaging.

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INTRODUCTION

Optical coherence tomography (OCT) has revolutionized biomedical imaging and diagnostics. The 3D visualization of the microstructural compositions of biological objects becomes possible. Unfortunately the resolution and sensitivity of conventional OCT are limited to micron scale and not suitable for early onset of a disease when the morphological changes manifest themselves on a cellular level (submicron scale).

MATERIALS AND METHODS

Analysis of the spatial frequency content of OCT signal based on general scattering theory demonstrated that the OCT signal, even at limited spectral bandwidth, contains information about high spatial frequencies of the object which relate to small, sub-wavelength size structures. The method for 3D quantitative visualization of these high spatial frequencies of the object, nano-sensitive OCT (nsOCT), was proposed and applied to different biomedical objects. Beside that, the novel approach to image formation, synthetic OCT (synOCT), has been proposed to improve the resolution and depth range.

RESULTS AND DISCUSSION

The proposed approach has been validated using numerical simulations. Abilities of the proposed approach to overcome the fundamental limitations in depth range and resolution have been demonstrated. Experiments using samples with well-known submicron internal structures confirmed our theoretical predictions. This novel approach was applied to different biomedical objects, including humans *in vivo.* Some results, including cornea study, stem cells study, detection of cancer in biological tissues at early stage, visualization of small structural changes in human skin in vivo, will be demonstrated in this presentation.

In spite of many promising results, this approach is still under development. Potential possibilities of the approach, for example, breaking the fundamental limitations in depth range and resolution in all 3D directions should be further investigated and validated experimentally. Areas of application will be extended. Now we are doing experiments in clinic to investigate possibility to detect cancer in humans in vivo, at early stage.

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Abstract

Explainable Lightweight Neural Architectures

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INTRODUCTION

The increasing demand for deploying neural networks in resource-constrained environments has led to growing interest in models that are both lightweight and explainable. Lightweight neural networks (LNNs) aim to reduce model size and computation without sacrificing accuracy. However, transparency is equally critical in high-stakes applications such as healthcare, finance, and autonomous systems. This literature-based study investigates the trends, challenges, and future directions in Explainable Lightweight Neural Networks.

MATERIALS AND METHODS

We conducted a publication trend analysis to observe research activity from 2019 to 2024 across five key lightweight techniques: pruning, quantization, knowledge distillation, low-rank factorization, and weight sharing. The frequency of papers for each method was recorded and visualized to identify emerging research directions. In addition, we reviewed studies applying explainable AI (XAI) techniques to LNNs across various teacher-student architectures, noting which XAI methods are commonly used and how they perform after distillation.

RESULTS AND DISCUSSION

Our findings show an increase in studies focused on explainable LNNs, with knowledge distillation emerging as the most widely adopted lightweight approach. Literature examples demonstrate efforts to integrate XAI tools such as SHAP, and LIME in student models. We highlight both qualitative and quantitative XAI evaluation metrics, including user trust, explanation satisfaction, and fidelity. However, challenges remain in preserving explainability after compression, adapting XAI methods to different model types, and evaluating explanations consistently. The lack of standardized evaluation framework strategies indicates a need for future research in explainable lightweight model design.

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Abstract

Analysis of ML/AI model optimization for assessing the hydro-climatic impacts on water quality

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Climate change is one of the most critical global challenges causing the disruption of the complex hydro-climatic systems and is significantly affecting the quantity and quality of water resources. For the mitigation of the adverse effects of climate change impact on water resources, it should be measured accurately. According to the recent literature, there is a lack of approaches available that can be utilized to effectively detect or evaluate the degree of impact that various hydro-climatic factors have on water quality (WQ). Therefore, this study aims to introduce an optimized framework for assessing the impact of various hydro-climatic factors on surface WQ. As inputs, this study used eight hydro-climatic variables and eight WQ indicators and Irish Water Quality Index (IEWQI) scores as output. This research identifies the best ML/AI model to predict the interrelationship between different hydro-climatic variables and WQ indicators in the context of Ireland. The study utilized 34 ML/AI algorithms to identify the best model using evaluation metrics including the calculation of R^2 (correlation coefficient), root mean square error (RMSE), mean square error (MSE) and mean absolute error (MAE). In addition to identifying the outperforming model, the study also optimized the input using Gradient Boosting Decision Tree (GBDT) feature selection technique for selecting 8 crucial inputs amongst the set of 16 inputs to analyse their relationship with IEWQI scores.

Based on the performance of 34 ML/AI algorithms, the ensemble model (GBDT + Random Forest) outperformed other models in terms of performance metrics during both training (R^2= 0.95) and testing phases (R^2=0.95). Amongst the studied inputs in terms of hydro-climatic variables and WQ indicators, surface run-off, precipitation, total run-off, molybdate reactive phosphorus, pH, evapotranspiration, dissolved inorganic nitrogen, and biological oxygen demand were the top 8 features selected based on GBDT feature selection. Moreover, the ensemble model performance was further enhanced due to input optimization leading to training R^2= 0.96 and testing R^2= 0.99.

The result of the study reveals that the ensemble model could be effectively utilized for assessing the association between hydro-climatic variables and WQ and outperform the standalone ML/AI models. Hence, there is a potential for world-wide applications of the proposed modelling approach for predicting overall WQ incorporating various hydro-climatic variables.

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Abstract

Noise Onshore from Offshore Wind Turbines

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INTRODUCTION

There is a perception that offshore wind turbines are far enough from the coast that noise will not be an issue for consideration in the Environmental Impact Assessments for such projects. Preliminary modelling indicates that the offshore turbines will be audible under certain weather conditions at onshore locations. If the issue is ignored, unwarranted concerns are likely to arise, leading to social acceptance issues.

MATERIALS AND METHODS

The School of Engineering is collaborating with the School of Psychology, Mace Head Observatory, The Marine Institute and Met Eireann to create a large database of environmental conditions and sound propagation models to quantify the intensity and frequency of occurrence of audibility and annoyance conditions using historical and current measurements.

Measurements include wind speed and direction, temperature, relative humidity and boundary layer height up to two kilometres vertically. This is combined with Met Eireann weather data at ground level and Marine Institute wave and sea temperature data. The output is a long term, high resolution, sound speed profile for a coastal site with propagation modelling to indicate potential annoyance.

RESULTS AND DISCUSSION

International Research, using propagation models, to date is limited to 100m above sea level and short-term atmospheric condition measurements. The high-resolution data is being used to provide input to computationally intensive models to predict sound levels over long distances. Modelling flat water and temperature inversion conditions, which arise during anti-cyclonic weather patterns.

Preliminary sound speed profiles and the relationship of the turbines to boundary layer height will be presented along with some preliminary propagation models.

The results will provide data-driven approaches to inform the extent of onshore audibility. Providing scientific data for decision makers will assist in societal acceptance of Environmental Impact Assessment decisions.

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Abstract

Implications of Plant-Based Diet Trends for Anaemia Risk in Women: A Data-Driven Study

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INTRODUCTION

Adequate nutrition is essential for health and well-being (SDG 3). As dietary guidelines increasingly promote plant-based eating and reduced red meat intake for environmental and health reasons, concerns arise about micronutrient adequacy, particularly regarding iron, vitamin B12, and related cofactors. Anaemia, defined as haemoglobin levels <120 g/L in non-pregnant women aged 15–49, remains a widespread concern (SDG 2.2.3), impairing cognition, motor function, and reproductive outcomes. Although red meat is known to support haemoglobin levels, its reduced consumption poses potential nutritional risks. This study aims to predict the food items and nutrient profiles most effective for alleviating anaemia in non-pregnant women, using the National Health and Nutrition Examination Survey (NHANES) data and machine learning to identify critical nutrients associated with improved haemoglobin status.

MATERIALS AND METHODS

This analysis used nine NHANES cycles (2003–2020), focusing on 9,516 non-pregnant females aged 15–49, classified by anaemia status via haemoglobin measures and medical records. Participants with confounding conditions were excluded. Dietary intake was assessed through two 24-hour recalls, covering 63 nutrients. Machine learning and statistical methods were used to identify nutrient patterns and NHANES food codes associated with non-anaemic status.

RESULTS AND DISCUSSION

Anaemic individuals consumed significantly less iron, zinc, magnesium, copper, folate, and vitamins A, B1–B3, B6, and B12 ($p < 0.05$). Iron and copper intakes were notably below recommended levels. Extreme gradient boosting identified vitamin B2, B12, copper, zinc, and magnesium as strong predictors of non-anaemic status. These results support the study's aim by highlighting key micronutrients beyond iron that may guide food formulation and dietary recommendations. The model offers a potential tool for identifying nutrient-rich foods including plant-based alternatives to reduce anaemia risk in women of reproductive age.

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Abstract

Regional-Scale Changes in Greenhouse Gas Emissions during Peatland Rewetting

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The rehabilitation of extracted post-industrial peatland is the process of transitioning from a bare-peat to natural environment. In Ireland, this involves sufficiently raising the underlying Water Table Depth (WTD), such that greenhouse gas emissions are minimised and the growth of *Sphagnum* moss promoted. This process is widely known as "rewetting", and is a cornerstone of Ireland's efforts to comply with the EU's Nature Restoration law. The WET-PEAT project uses a combination of fieldwork, modelling, and remote sensing methods to assess the performance of rewetting efforts. Here, these efforts are evaluated at a regional scale using a dense network of piezometer data.

This dataset of WTD measurements was collected by Bord Na Móna between 2020 and 2024. It consists of hourly measurements at 70 sites, from over 500 piezometers, totalling over 10,000,000 ~~total~~ observations. These time series are analysed to determine the temporal variation in WTD at a regional scale following rewetting. Previous studies have identified relationships between WTD and emissions of CO_2 and CH_4. These relationships are used to assess changes in peatland greenhouse gas balance through following rewetting.

Between 2020 and 2024, the WTD at the sites presented here rose significantly, occurring most rapidly in Autumn 2022. Across the entire time series, > 50% of the peatlands act as net sources of greenhouse gases. However, following the WTD shallowing in 2022, this reversed, and the majority of sites were greenhouse gas sinks. These analyses shows that when WTD is maintained within an optimal range, peatlands may successfully act as GHG sinks during rehabilitation. However, the period following Autumn 2022 experienced significantly more precipitation than the preceding period, and ongoing monitoring is essential to determine whether WTD may be successfully maintained during dryer years, in order to fully assess the success of rehabilitation.

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Abstract

Leveraging Visual Scene Graph to Enhance Translation Quality in Multimodal Machine Translation

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INTRODUCTION

Despite significant advancements in Multimodal Machine Translation, understanding and effectively utilising visual scenes within multimodal models remains a complex challenge. Extracting comprehensive and relevant visual features requires extensive and detailed input data to ensure the model accurately captures objects, their attributes, and relationships within a scene. In this paper, we explore using visual scene graphs extracted from images to enhance the performance of translation models. We investigate this approach for integrating Visual Scene Graph information into translation models, focusing on representing this information in a semantic structure rather than relying on raw image data. The performance of our approach was evaluated on the Multi30K dataset for English into German, French, and Czech translations using BLEU, chrF2, TER and COMET metrics. Our results demonstrate that utilising visual scene graph information improves translation performance. Using information on semantic structure can improve the multimodal baseline model, leading to better contextual understanding and translation accuracy.

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Abstract

Semantic Modelling of DDoS Attacks: An Ontology-Driven Cybersecurity Framework

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This research proposes a domain-specific ontology for Distributed Denial of Service (DDoS) attacks, developed using Web Ontology Language (OWL) and Protégé, to overcome the limitations of conventional detection approaches that lack semantic awareness and structured knowledge representation. Unlike purely data-driven methods, the proposed ontology formalises key concepts, relationships, and behaviours associated with exploitation- and reflection-based DDoS attacks, enabling a richer contextual understanding of threat patterns. This structured semantic framework supports integration with threat intelligence platforms and facilitates automated reasoning, providing a foundation for more informed and interpretable machine learning (ML) models. By embedding ontological knowledge into the deep learning (DL) pipeline, the approach aims to enhance detection performance, improve model explainability with the usage of explainable AI (XAI), and support timely and adaptive responses to evolving DDoS threats.

INTRODUCTION

DDoS attacks pose a persistent threat to online services, causing severe disruptions and financial losses. Ontology enables semantic representation of DDoS attack patterns, behaviours, and relationships, which improves detection accuracy, contextual reasoning, and interoperability across cybersecurity systems. This research proposes a novel, ontology-driven framework developed in OWL using Protégé to address this challenge. The ontology models a detailed vocabulary of exploitation and reflection-based DDoS attacks and addresses the lack of semantic structure in traditional detection methods. This approach aims to improve detection accuracy, model explainability, and real-time response to evolving DDoS threats.

RESULTS AND DISCUSSION

Figure 2 presents the structure of the DDoS ontology, which classifies attacks into two primary types: Exploitation-based and Reflection-based, along with their subtypes. The ontology integrates static features (e.g., protocols, vulnerable services) and dynamic behaviours (e.g., traffic volume, spoofing) to provide a rich semantic representation of DDoS activity.

- Captures structural and behavioural differences through hierarchical class design.
- Enables reasoning via linked object and data properties to identify attack vectors.
- Supports explainable AI by enhancing interpretability of detection models.
- Designed for integration with real-world datasets and real-time systems.
- Facilitates future machine learning applications and semantic enrichment of threat intelligence.

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Abstract

Validation of Copernicus Marine Service Water Products in Irish Shelf and Celtic Sea

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Tremendously, there has been growing interest in research on remote sensing (RS) technology, highlighting its importance in retrieving ocean colour products (e.g., chlorophyll, suspended materials, etc.). Commonly the *in-situ* water quality (WQ) measurements provide more accurate estimates compared to other techniques, although this process has received much more criticisms recently in regarding its reliability in focusing a few constrains like expensive to maintain, time-consuming and has some geographical constraints. In contrast, the RS offers more comprehensive open access data that can cover large geographical areas; but the RS data also has some limitations, such as cloud cover, data availability, resolution, calibration and validation, etc. Despite these limitations, the RS technology offers a wide range of data at various resolutions and different scales.

Generally, RS data from Sentinel-2 MSI and Sentinel-3 OLCI are widely utilized for ocean colour product retrieval in the European Union (EU) region. The Copernicus offers these RS products in both atmospherically uncorrected (Level 1) and atmospherically corrected (Level 2) versions that cover a certain portion of the earth. However, for long-term assessments of ocean colour, if the area of interest covers a large area, a single daily image would need to be downloaded and mosaicked, this approach might be time consuming and more expensive in terms of technological attributes and facilitates. To address this issue, the Copernicus Marine Service (CMS) offers daily L3 (Level 3) data for different RS products, such as Sentinel-2 MSI (at 100 resolution), Sentinel-3 OLCI (at 300m resolution), and Multi-Sensor (SeaWiFS, MODIS, MERIS, VIIRS-SNPP & JPSS1, OLCI-S3A & S3B at 4km resolution), etc., which are mapped onto a uniform spatial grid, corrected for atmospheric effects, cover large areas and need less storage on a PC. Although this product has been declared as more standardized, calibrated and has undergone a quality control process, validation with *in-situ* hyperspectral measurement is still required to understand the dispersion between satellite and *in-situ* RS reflectance (R*rs*). This assessment would be helpful for researchers/organizations/institutions to quantify the accuracy of retrieved ocean colour products using CMS L3 products; as well as it enhance the application of the RS technology within the EU extent to achieve the sustainable water resources management Therefore, the aim of the research was to assess the accuracy of CMS water products on the Irish Shelf and the Celtic Sea.

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Abstract

Development of a CT Image Database for Machine Learning-Based Automated Feature Extraction in Abdominal Aortic Aneurysms (AAAs)

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INTRODUCTION

Abdominal aortic aneurysms (AAAs) are life-threatening conditions characterised by permanent dilation of the aorta[1,2]. Endovascular aneurysm repair (EVAR) offers a curative treatment, but post-EVAR monitoring via computed tomography (CT) is essential to detect complications like endoleaks or sac expansion[1–3]. CT-enabled volumetric analysis promises a more in-depth assessment of AAAs than traditional diameter measurements, potentially providing greater sensitivity in identifying post-EVAR sac changes[1–3]. However, wider acceptance requires further data and analysis to standardise this approach [1–3]. To improve AAA management with AI supported CT-scans, larger, more diverse datasets are needed to be analysed. These datasets should specifically focus on AAA measurements across various patient populations and post-EVAR stages to facilitate the development of robust and clinically applicable AI-driven solutions in the future[2–4].

MATERIALS AND METHODS

This project involves creating a comprehensive database of analysed CT images from AAA patients. Based on a literature review and consultation with vascular surgeons, we have identified key parameters/features necessary for monitoring, including age, gender, aneurysm location, neck diameter, neck angle, largest sac diameter, and segmentation of the region of interest (e.g., the entire abdominal aorta or aneurysm sac). A review was also conducted to identify suitable AI techniques and associated challenges. A publicly available CT scan database (MedPix[5]) was selected for initial analysis and algorithm development. Subsequently, following ethical approval, a more comprehensive CT scan dataset will be collected from AAA patients at University Hospital Galway to validate the feature extraction algorithms.

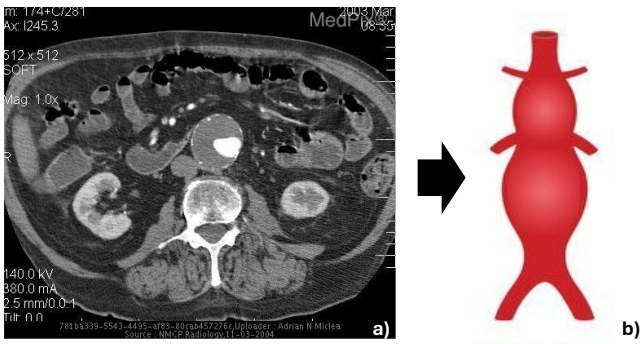

Fig. 1 Example analysis of CT scan and approximated model of a bilobed AAA. Dataset available in the open-source MedPix[5] database.

RESULTS AND DISCUSSION

This project focuses on the ongoing extraction of features from CT scans to build a robust database of AAA post-EVAR data. This data will subsequently support the training of a machine learning model for automated volume and diameter extraction in patient evaluations. The ultimate goal is to facilitate software development for automated AAA characterisation and measurement in post-EVAR CT scans.

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Abstract

RADIOACTIVITY IN SALMON (SALMO SALAR) AND OYSTERS (CRASSOSTREA GIGAS) FARMED IN THE IRISH SEA AND NORTH ATLANTIC WATERS

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INTRODUCTION

Radionuclide monitoring within the Irish marine environment has focused on assessing the impact, and potential public health implications of discharges of artificial radionuclide waste from the Sellafield nuclear fuel reprocessing site in Cumbria (UK) into the Irish Sea. These discharges commenced in the early 1950s, and peaked between the late 1970s and early 1980s, and have since reduced significantly. This has resulted in significant research on the geographical and temporal spread of these artificial radionuclides discharged from Sellafield. In comparison, little data exists on the presence of natural radionuclides within the Irish marine environment. Samples of Pacific Oysters (Crassostrea gigas) were acquired from seven commercial oyster farms along the Irish coastline, while samples of Irish, Norwegian and Scottish farmed Atlantic Salmon (Salmo salar) were acquired from Irish retailers and fishmongers. Concentrations of the natural radionuclides 40K, 210Pb, 226Ra, 228Ra and 238U, as well as the artificial 137Cs were determined using high-resolution gamma spectrometry. The naturally occurring 210Po was chemically separated from the sample and determined using high-resolution alpha-spectrometry. The artificial radionuclide 137Cs was detected at much lower activity concentrations than the other natural radionuclides in both the oysters and salmon, while 40K and 210Po had the highest activity concentrations in the oysters and 40K had the highest activity concentration in salmon. The radionuclide activity concentrations were used to determine the potential dose associated from the consumption of salmon and oysters. For a typical oyster consumer (0.54 kg/year), the annual effective dose was estimated to be 44 µSv, while for a typical salmon consumer (4.7 kg/year), the estimated annual effective dose was 12 µSv, with most of the dose in both cases due to 210Po. The estimated doses, however, are well below the annual dose limit for a member of the public (1000 µSv).

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Abstract

A polynomial framework for estimating/detecting the Chlorophyll-a accurately utilizing the remote sensing data

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2. Ryan Institute, University of Galway, Ireland
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Abstract

For the purposes of initiating effective measures during eutrophication and algal bloom related events, the accurate estimation of Chlorophyll-a (CHL) in the optically complex transitional and coastal (TrC) waters from remote sensing (RS) data is crucial. Therefore, this research introduces a novel data-driven framework incorporating the cubic polynomial third order function (Cub3) based modelling (Cub3-CHL) approach for estimating the CHL from RS data. By comparing a range of ML/empirical approaches, the Cub3 function provided the excellent performance in predicting CHL. For the purposes of the development model, the research utilized 2022 Sentinel-3 Ocean and Land Colour Instrument (S3-OLCI) Level 3 (L3) and Level 4 (L4) data for training, whereas four years (2019-2021 and 2023) of data (L3 and L4) were utilized to test the model, respectively. The EPA-Ireland's in-situ water quality database used for model validation. For model validation, this research utilized sixteen Irish TrC waterbodies data (S3-OLCI-L3 and S3-OLCI-L4 dataset for 2024) and Chesapeake Bay, USA (S3-OLCI-L4 dataset for 2023), which would showcase the model's generalized ability to work with local and global datasets, respectively.

Based on the ten S3-OLCI bands (Rhow_2 to Rhow_11) as crucial model input, the Cub3-CHL model demonstrated superior performance with minimum prediction error (average MSE: 0.015) and higher sensitivity (average R^2: 0.98) during both training and testing periods across the Irish TrC waterbodies. Moreover, the model validation results also revealed that the excellent performance with minimal prediction errors (average MSE 0.010) and high sensitivity (average R^2 0.98) for both local scale (across sixteen Irish TrC waterbodies during 2024); and global (Chesapeake Bay, USA) applications, whereas the model also outperformed (R^2 = 0.98) with 2023 S3-OLCI-L4 dataset. Additionally, the result of the research indicates that the Cub3-CHL model could be able to interpret the complex spatio-temporal dynamics of the CHL across various resolutions. Furthermore, the model continued to show superior performance (R^2 close to 1) with single-day RS datasets corrected using three atmospheric correction algorithms including Acolite, C2RCC and Polymer. However, the Cub3-CHL model demonstrated its effectiveness in estimating CHL accurately from RS data and providing the real scenarios of g the trophic state of four Irish TrC waterbodies with the Assessment Trophic Status Index (ATSI) model. Although this framework suffers from overfitting issue, this polynomial based framework proved its effectiveness for estimating CHL from RS data accurately. Therefore, this RS data-driven polynomial-based framework could be an effective tool for aquatic mangers and strategic planners to sustainably manage and protect the water resources by ensuring safe aquatic health and ecological services.

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Abstract

Key Trends and Analysis of Explainable Lightweight Neural Networks.

Mushtaq, M., Madden, M.G., Ullah, I.

School of Computer Science, University of Galway, Ireland

Insight Research Centre for Data Analytics, University of Galway, Ireland

INTRODUCTION

The increasing demand for deploying neural networks in resource-constrained environments has led to growing interest in models that are both lightweight and explainable. Lightweight neural networks (LNNs) aim to reduce model size and computation without sacrificing accuracy. However, transparency is equally critical in high-stakes applications such as healthcare, finance, and autonomous systems. This literature-based study investigates the trends, challenges, and future directions in Explainable Lightweight Neural Networks.

METHODOLOGY

We conducted a publication trend analysis to observe research activity from 2019 to 2024 across five key lightweight techniques: pruning, quantization, knowledge distillation, low-rank factorization, and weight sharing. The frequency of papers for each method was recorded and visualized to identify emerging research directions. From 2021 onwards, there has been a significant spike in publications on knowledge distillation, with the number of documents exceeding 1000 in both 2023 and 2024 as shown in figure 1. In addition, we reviewed studies applying explainable AI (XAI) techniques to LNNs across various teacher-student architectures, noting which XAI methods are commonly used and how they perform after distillation.

RESULTS AND DISCUSSION

Our findings show an increase in studies focused on explainable LNNs, with knowledge distillation emerging as the most widely adopted lightweight approach. Literature examples demonstrate efforts to integrate XAI tools such as SHAP, and LIME in student models. We highlight both qualitative and quantitative XAI evaluation metrics, including user trust, explanation satisfaction, and fidelity. However, challenges remain in preserving explainability after compression, adapting XAI methods to different model types, and evaluating explanations consistently. The lack of standardized evaluation framework strategies indicates a need for future research in explainable lightweight model design. Future research should aim to enhance the intrinsic explainability of lightweight models, establish rigorous methods for assessing the effectiveness of explanations, and explore the role of LLMs in improving AI explainability.

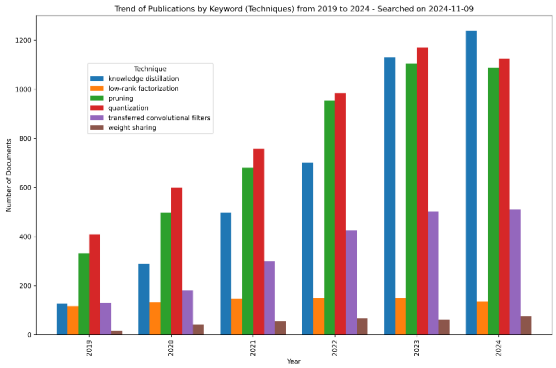

Figure 1. Trend of publications by keyword (techniques) in lightweight neural network research from 2019 to 2024.

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Abstract

Explainable Lightweight Neural Architectures

Mushtaq, M., Madden, M.G., Ullah, I.

School of Computer Science, University of Galway, Ireland

Insight Research Centre for Data Analytics, University of Galway, Ireland

INTRODUCTION

The increasing demand for deploying neural networks in resource-constrained environments has led to growing interest in models that are both lightweight and explainable. Lightweight neural networks (LNNs) aim to reduce model size and computation without sacrificing accuracy. However, transparency is equally critical in high-stakes applications such as healthcare, finance, and autonomous systems. This literature-based study investigates the trends, challenges, and future directions in Explainable Lightweight Neural Networks.

METHODOLOGY

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RESULTS AND DISCUSSION

Our findings show an increase in studies focused on explainable LNNs, with knowledge distillation emerging as the most widely adopted lightweight approach. Literature examples demonstrate efforts to integrate XAI tools such as SHAP [1], and LIME [2] in student models. We highlight both qualitative and quantitative XAI evaluation metrics, including user trust, explanation satisfaction, and fidelity. However, challenges remain in preserving explainability after compression, adapting XAI methods to different model types, and evaluating explanations consistently. The lack of standardized evaluation framework strategies indicates a need for future research in explainable lightweight model design. Future research should aim to enhance the intrinsic explainability of lightweight models, establish rigorous methods for assessing the effectiveness of explanations, and explore the role of LLMs in improving AI explainability.

[1]. S. M. Lundberg and S.-I. Lee, “A Unified Approach to Interpreting Model Predictions,” Advances in neural information processing systems, vol. 30, 2017.

[2]. M. T. Ribeiro, S. Singh, and C. Guestrin, “Why Should I Trust You?” explaining the predictions of any classifier,” in Proceedings of the 22nd ACM SIGKDD international conference on knowledge discovery and data mining, 2016, pp. 1135‑1144.

College of Science and Engineering, Inaugural Research and Innovation Day 2025

Abstract

The Missing Link: Enabling Data Space Interoperability through Agent Communication Systems

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INTRODUDCTION

Interoperability remains one of the most persistent challenges in realizing the full potential of data spaces—digital ecosystems where data is shared across organizational and technical boundaries. The ability to seamlessly access, understand, and use data from heterogeneous sources is critical for enabling innovation, collaboration, and value creation. This research explores the transformative role of AI agents powered by Large Language Models (LLMs), in achieving interoperability across and within data spaces. We believe that LLMs, with their advanced capabilities in understanding unstructured data, translating schemas, reasoning over ontologies, and generating executable code, represent the missing key to unlocking true semantic and operational interoperability. However, for LLMs and AI agents to operate eFectively in this context, there is a crucial need for a system that allows them to interface with existing tools, APIs, and connectors within the data space ecosystem. This research proposes an architectural and conceptual framework for such a system—one that enables AI agents to dynamically discover, understand, and interact with various components of a data space, facilitating data integration, transformation, enrichment, and governance in a highly automated and intelligent manner. Through experimental prototypes and real-world use cases, we aim to demonstrate how AI-powered interoperability agents can significantly reduce manual integration eForts, enhance data usability, and accelerate the creation of value-driven, interoperable data ecosystems.

METHODS

The prototype will be developed using MCP-Model Context Protocol and Agent 2 Agent protocol.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

A methodological framework for the development of scalable data-driven model for retrieving chlorophyll-a in transitional and coastal waters using remote sensing technology

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6. School of Computing, Mathematics and Engineering, Charles Sturt University, Wagga Wagga, Australia
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Abstract

To date, several models have been developed to estimate Chlorophyll-a (CHL) in transitional and coastal (TrC) waters using remote sensing (RS) data. However, recent studies highlight significant uncertainties and limitations in these models' performance, undermining their reliability and applicability. Many existing models were developed using single datasets without accounting for global attributes, independent datasets, or spatio-temporal variability. Even when independent datasets were used, the models often performed poorly, making them unsuitable for both local and global applications even there were no evidence reiterate the developed methods in any domains or origin ones. Moreover, the exclusion of critical evaluation metrics, such as the coefficient of determination (R^2), hinders model transparency and reliability.

To address these limitations, the study introduces a data-driven novel approach the Chlorophyll Normalize Spectral Index, it can be expressed as short term CNSI for estimating/ predicting CHL using RS spectral data. CNSI consists of four components: (i) band optimization using machine learning (ML) techniques incorporating with principal components analysis (PCA), focusing on four identical RS bands (Rhow_4, Rhow_7, Rhow_8, and Rhow_11); (ii) six sub-spectral indices (SSI) to normalize band information; (iii) an aggregation function to combine and convert SSI values into a single numerical value; and (iv) interpretation schemes for CNSI scores. The model was trained using 2016 Sentinel-3 (S3) Ocean and Land Colour Instrument (OLCI) Level 3 (L3) and Level 4 (L4) RS data and tested using seven years (2017–2023) of data (L3 and L4), whereas the EPA, Ireland in-situ data used for model validation. The model validation involved local applications across 16 Irish TrC waterbodies (S3-OLCI-L3 and S3-OLCI-L4 datasets for 2024) and a global application using 142 sampling sites for 2019 in Chesapeake Bay, USA (S3-OLCI-L4 datasets).

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Abstract

Induction Welding of Carbon Fibre Using an Additively Manufactured Susceptor

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2. School of Engineering, Advanced Manufacturing
3. School of Engineering,

INTRODUCTION

Induction welding of composite materials is a joining technique used in the manufacture of aerospace structures. This technique involves the application of heat via induction and pressure to weld composite parts together. To create a high strength welded joint, without damaging the composite, the temperature profile during welding must be tightly controlled. Several approaches have been used to achieve this control including adding metallic susceptors at the bondline. The use of metallic susceptors ensures that heat is generated at the bondline, eliminating or reducing the need for cooling. These susceptors add complexity to the process and makes recycling more difficult. This work aims to address these issues by additively manufacturing a susceptor from carbon fibre.

MATERIALS AND METHODS

Carbon Fibre Nylon, additively manufactured using a Markforged Mark Two 3D printer, was used in the current study. Initial trials showed that a concentric pattern generated heat in an induction field. Based on the initial results, 6 samples were manufactured with a unidirectional layup in the main body and a concentric pattern in the region to be welded, as shown in Fig. 1. These samples were then joined by induction welding and tested.

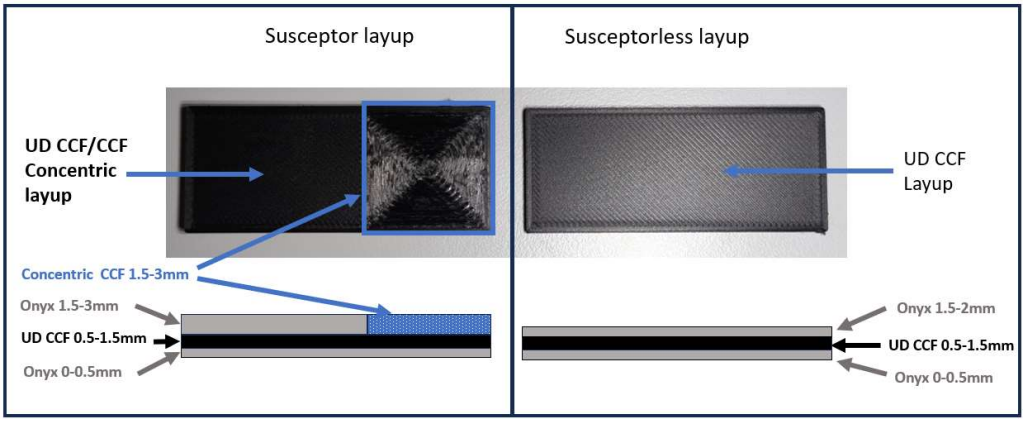

Figure 1 Top: Lap shear subcomponents prior to joining. Bottom: Side schematic of layup of subcomponents with the concentric Continuous Carbon Fibre (CCF) shown in blue, the unidirectional CCF shown in black and short carbon fibre (Onyx) shown in grey.

RESULTS AND DISCUSSION

The samples reached an average lap shear value of 14N/mm^2. This exceeds the values for adhesives recommended with this material system. The ability of additive manufacturing to create susceptors made entirely of carbon fibre nylon that enable induction welding offers similar advantages to metallic susceptors without the disadvantages of including a new material at the bondline. Future work will focus on modelling the heating behaviour of the laminate and investigating methods to fine tune heating during welding.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Revealing Determinants of National Biogas Industry Development

Mingze1, a1, Xinmin2, a1.

1. NEO Green Research Group, Civil Engineering, School of Engineering

INTRODUCTION

Global efforts toward net-zero emissions by 2050 have boosted renewable energy development. However, unlike solar and wind, biogas development remains regionally limited despite centuries of technological history. Countries such as Germany and Italy have vibrant biogas sectors, whereas others like China lag despite huge subsidies. Revealing key factors influencing biogas industry development is essential for global renewable energy strategies.

MATERIALS AND METHODS

We analyzed biogas industry growth factors by conducting a database covering 39 quantifiable indicators for 99 countries in the past 30 years and over 8,000 acts worldwide on renewable energy. The development index was measured by the ratio of the biogas production to potential. From an initial 39 candidate factors identified through literature review and association reports, Spearman correlation analysis, removing VIF and false positive factors, there are 16 significant determinants left (Machine learning ranked their relative importance).

RESULTS AND DISCUSSION

A particularly intriguing finding from my research suggests that technological factors may not constitute the primary determinants in advancing sustainable agricultural development. Specifically, technical factors account for less than 0.15 of the total determinants evaluated in my study (Importance Value Sum: 1.0). Machine learning highlighted farmer share (importance: 0.209) and environmental tax revenue per capita (importance: 0.141) as key determinants. These findings underline the importance of economic and fiscal policies in developing biogas sectors, providing policymakers with insights to effectively boost biogas adoption within renewable energy frameworks.

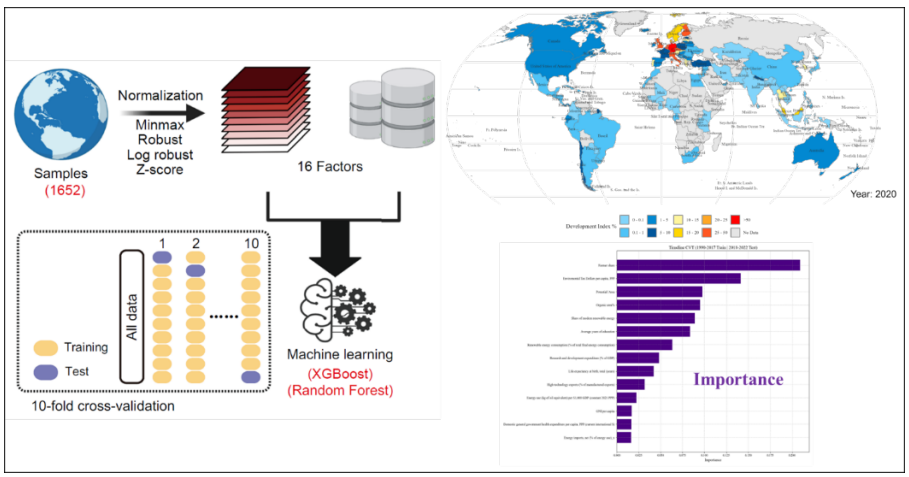

Figure 1: Global mapping of national biogas industry development and key factor importance

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Space Weather and Exoplanet Habitability: Proxima Centauri

Ní Chonchubhair, D.[1], Golden, A.[2].

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2. Physics, School of Natural Sciences

Proxima Centauri, the nearest stellar neighbour to Earth beyond the Sun, at a distance of 1.3pc, is an active M5.5 dwarf star with one confirmed and two candidate exoplanets. Flaring, an outburst of electromagnetic radiation, is common in magnetically active stars including the Sun and can be observed across the electromagnetic spectrum. Flares that produce coronal mass ejections from the Sun can interact with the Earths' magnetic field, causing aurorae around the poles, but can also cause disruption to power lines and satellites. Stellar flares can reach much greater energies than solar flares, which may have a significant impact on exoplanet habitability. Here we present results from high time resolution U-band observations of Proxima Centauri using the Sutherland High Speed Optical Camera (SHOC) on the 1.9m telescope at the South African Astronomical Observatory. These data were taken over seven contiguous nights in April 2019 and coincide with TESS (Transiting Exoplanet Survey Satellite) space telescope observations of Proxima Centauri at this epoch. Using SHOC's superior cadence, varying from 0.1 to 3 seconds, and comparing to the 120 second TESS cadence we explore flare incidence and frequency rates compared to that determined from TESS.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Relative applicability of diverse automatic speech recognition platforms for transcription of psychiatric treatment sessions.

RANA ZEESHAN, JOHN BOGUE, and MAMOONA N. ASGHAR

College of Science and Engineering

INTRODUCTION

Service delivery in mental healthcare involves documentation of sensitive patient-clinician conversations that require serious caution. Conventionally, clinicians take handwritten notes, which causes low readability and lack of database which hinders research. Having these conversations digitized via Automatic Speech Recognition (ASR) based Speech-to-Text (STT) transcription enables progressive analysis of mental health cases. The ASR applications usually require audio recording prior to the transcription, for labelling speakers or diarization. Although such models are good enough for most use cases, storing audio recordings in psychiatry complicates the data handling and adoption of ASR platforms in mental healthcare. This study involved a two-stage methodology, where at first, a list of 32 well-reputed STT transcription tools were evaluated in terms of applicability in psychiatry; followed by experimental testing using nine audio clips derived from three psychiatric session recordings of varying durations (1, 3, and 10 minutes) and speakers' gender. Metrics such as inference time, Word Error Rate (WER), and Diarization Error Rate (DER) were analysed. The results indicated that while WER was positively low (0-7%), DER varied significantly (2- 32%), influenced by the audio length and speaker characteristics. DER was notably lower for clips with speakers of differing genders or ages, but negatively increased for speakers of similar demographics. The study also compared synchronous and asynchronous diarization approaches, highlighting challenges in accuracy, privacy, and processing efficiency in psychiatry. These findings provide actionable insights for selecting ASR tools in mental healthcare and underscore the need for targeted improvements in ASR technology to address the unique demands of this field.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Empowering Dairy Farming with Semantic Interoperability

Rajput, Q.[1], Breslin J.[1], Asghar, M.[2]

1. Data Science Institute, University of Galway
2. School of Computer Science, University of Galway

INTRODUCTION

A vast amount of raw data is generated across various systems in dairy farms, often in heterogeneous formats. These farms rely on multiple monitoring systems, including those for livestock, pasture, soil, crops, food production, and weather control. However, these systems operate independently, limiting farmers, stakeholders, and policymakers from timely access to data and preventing them from utilizing its full potential in decision-making.

To enhance dairy farm systems, the VistaMilk project, funded by Research Ireland, focuses on addressing semantic interoperability challenges across various dairy farm systems—such as grass growth, feeding, calving, and milk production. This initiative introduces new complexities in data integration, knowledge management, and technology adoption, aiming to achieve semantic harmonization for effective use by farmers, researchers, policymakers, and private sector.

MATERIALS AND METHODS

This work proposes the use of domain ontologies for dairy farm systems to facilitate semantic interoperability through standardized data interchange formats. Figure1 illustrates the ontology development for dairy farm systems.

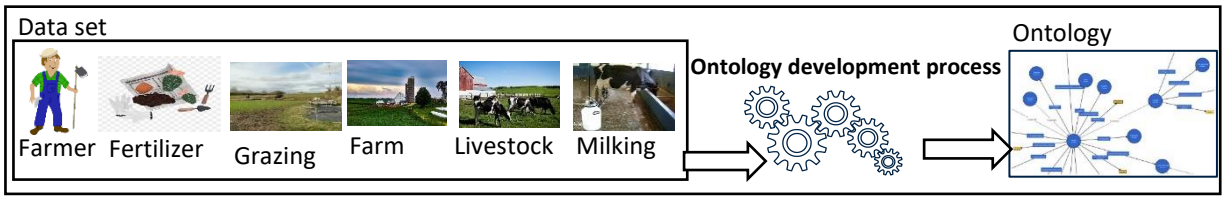

Figure 1. Dairy Farm Systems and Ontology Development

To construct the ontology model, data has been collected from the Irish Cattle Breeding Federation (ICBF) from 2021 to the present, encompassing livestock, milking, calving, and grazing systems. In addition, the ontology high-level concept terms are reused from established ontologies such as AGROVOC, Bioportal, and Agronomy. The ontology formally specified in OWL components, including classes, properties, and individuals, within the Protégé editor. Additionally, competency questions have been developed to demonstrate semantic interoperability across dairy farm systems.

RESULTS AND DISCUSSION

This work focuses on enabling the semantic interoperability that combine data from multiple dairy farm systems. For example, “What is the average milk yield in a farm with the maximum cover growth rate?” requires seamless integration of milking and grazing systems to generate results automatically. To achieve this, a set of competency questions has been developed and formalized as SPARQL queries, allowing stakeholders to plan future actions and make informed decisions. While query response times are reasonable for the sample dataset, further exploration is needed to assess performance on larger datasets.

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Abstract

RAG4DS: Retrieval-Augmented Generation for Data Spaces—A Unified Lifecycle, Challenges, and Opportunities

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1. Insight Centre for Data Analytics, University of Galway, Ireland
2. School of Computer Science, Shenyang Aerospace University,China

INTRODUCTION

Although the Retrieval-Augmented Generation framework is considered a successful approach for enhancing LLMs by providing a suitable retrieval mechanism to obtain appropriate external knowledge, it still has limitations in acquiring high-quality knowledge from diverse data sources. The complementary integration of RAG and data spaces is proposed to exploit RAG's capabilities within data spaces. Data spaces provide RAG with the ability to obtain diverse and high quality data sources from several data providers under secure data-sharing mechanisms and direct data exchange negotiations. At the same time, RAG enhances the support services of data spaces. In this paper, we present a high-level architecture for RAG data space models (RAG-DSMs) with a unified lifecycle for RAG and data spaces, highlight the possible challenges of the proposed integration while presenting potential opportunities.

METHOD

We identify the lifecycle of the proposed RAG-DSMs, illustrated in Figure 1, which highlights the required stages in which RAG-DSM is developed, shared, deployed, maintained, and adapted, and transitioned within data spaces and RAG. These stages are Creation, Sharing, Discovery/Use, Maintain, Improve/Curate, Query and Reterieval Optimisation, Embedding, Indexing, Post-Reterieving Optimisation, Adaptation, and Deployment.

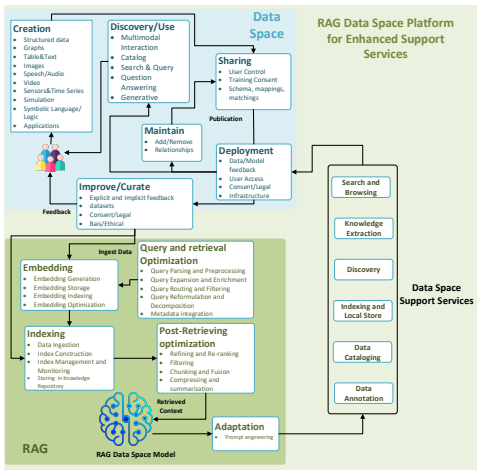

Figure 1: RAG-DSM life cycle.

CHALLENGES OF RAG AND DATA SPACES INTEGRATION

Several challenges can be raised during the integration of RAG and dara spaces and need to be considered, including interoperability, security and privacy compliance, performance and scalability, and data quality and consistency.

OPPORTUNITIES

RAG-DSM offered several opportunities, including advanced semantic interoperability, improved multimodal, robust cross-domain knowledge integration, the scalability and adaptability of data and model systems, and the trustworthiness of foundational models.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Multiscale Proteomic Assessment of Bioprosthetic Structural Valve Degeneration and Native Calcific Aortic Valve Disease

Cahalane, R.[1,2], Clift, C.[1], Turner, M.[1], Blaser, M.[1], Kasai, T.[1], Campedelli, A.[1], Billaud, M.[3], Muehlschlegel, J.[4], Hendrickx, A.[5], Van den Bosch, M.[5], Rega, F.[5], Aikawa, M.[1,3], McNamara, L.[2,6], Meuris, B.[5], Singh, S.[1,3], and Aikawa, E.[1,3]

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2. Mechanobiology and Medical Device Research group, Biomedical Engineering, College of Science and Engineering, University of Galway, Galway, Ireland.
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4. Department of Anesthesiology and Critical Care Medicine, Johns Hopkins, Baltimore, USA.
5. Department of Cardiovascular Sciences, KU Leuven, Leuven, Belgium.
6. CÚRAM, SFI Research Centre for Medical Devices, Galway, Ireland.

INTRODUCTION Bioprosthetic (BP) valve degeneration and native calcific aortic valve (AV) disease share risk factors and end-stage characteristics. In AV disease, an accumulation of extracellular vesicles (EVs) and lipids, thrombosis, fibrosis, and calcification occur. However, the processes governing BP degeneration are underexplored. Here we conduct multiscale tissue examinations and build proteomic comparison maps of BP degeneration versus AV disease.

MATERIALS AND METHODS Explanted BP leaflets (n=48) and AV valves (n=19) were segmented according to their diseased states (BP: non-degenerated, thrombotic, neotissue, calcified, AV: non-diseased, fibrotic, calcified), validated by histopathology. Segment-specific proteomics was performed. Laser capture microdissection enabled spatially resolved proteomics of distinct BP calcification regions. Valve EVs were enriched by enzymatic digestion, ultracentrifugation, density separation, and underwent proteomics.

RESULTS AND DISCUSSION Two-thirds of proteins were shared between BP and AV proteomes (2,176 and 2,400 proteins). Principle component analysis demonstrated that the proteome variation for both tissues was driven by the gross pathology. Correlations of segment proteome-wide abundances revealed the highest intra- and inter-tissue similarity between non-degenerated and calcified BP (r_p=0.98), and BP neotissue and calcified AV (r_p=0.95). Histological analysis confirmed the presence of distinct regions of BP calcification within pericardium, neotissue, plasma insudation, and surface thrombus. Importantly, differentially abundance proteins involved in the calcific remodelling of each distinct region did not overlap, suggesting different calcific mechanisms. For the first time, we confirmed the presence of EVs in explanted bioprosthetic tissues compared to non-implanted controls. We also validated a tissue-entrapped EV-enrichment protocol to extract EVs for proteomic profiling. This first multiscale proteomic comparison of BP degeneration and AV disease may inform more durable commercial valve tissue production.

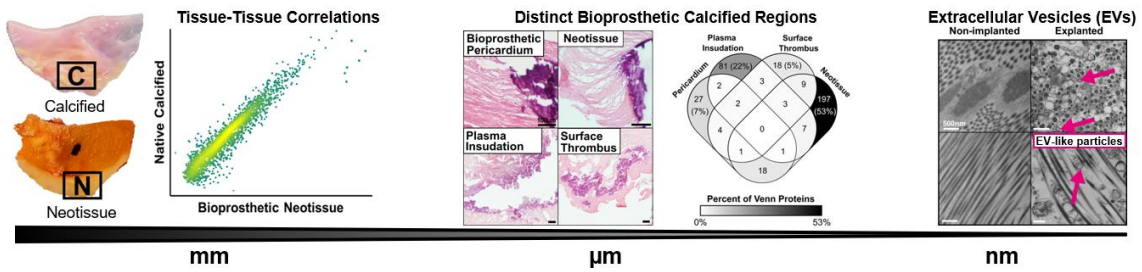

Figure 1: Multiscale proteomic assessment of bioprosthetic (BP) valve degeneration and native aortic valve (AV) disease

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Modelling The T Cell And Antibody Immune Response To SARS-Cov-2 Infection And Development Of A Statistical Mechanics Framework To Investigate Viral Spread In An Immunologically Heterogeneous Population

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1. Department of Biomedical Engineering, University of Galway
2. Data Science Institute and School of Computer Science, University of Galway

INTRODUCTION

The Covid 19 pandemic presented an unprecedented scientific and societal challenge, SARS-CoV-2 is a novel coronavirus, which spreads infectiously through inhalation or ingestion of viral droplets [1]. Heterogeneous response across a population to SARS-CoV-2 infection has been well established, and hospitalisation and mortality rates are reported to be highly age-dependent [2]. In this study a novel computational framework is developed to analyse the influence of heterogeneous immunity on the spread of SARS-CoV-2 in an age stratified population. Statistical mechanics is utilised to determine model parameters, trained with reported viral variant prevalence, as well as age-stratified hospitalisations and fatalities.

METHODOLOGY

We develop an immunological model to simulate a multi-layered response to viral infection, we develop a series of kinetic equations extending [3], describing the increase in viral load following SARS-COV-2 infection of respiratory tract cells, (Fig.1a). We next use our immunological framework to construct a virtual population, of a heterogeneously subdivided population. Key inputs to the SEIR model from our immunological model illustrated in Fig.1.b,c include: viral load, the fraction of a subgroup which presents symptomatically, the duration of infectiousness, which influence four pathways through which infection may occur modelled via Fig.1.d

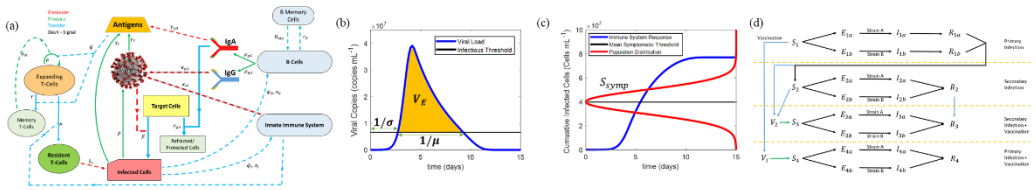

Figure 1: (a) Flow of key inter-linked components of mathematical immunology model. (b) Predicted viral response following infection, influencing resultant infectious population spread. (c) Effect of cell infection and resultant effect on symptomatic proportion of population. (d) Flowchart of possible infection pathways through infection, showing two possible strains.

DISCUSSION

We have developed a novel computational framework to analyse the influence of heterogeneous immunity on the spread of infection in an age stratified population, fundamentally based in dynamics of our immunological model, simulating a multi-layered response to viral infection. Our statistical mechanics framework, confirmed through Jeffrey's scale calibrations, provided evidence beyond reasonable doubt that including heterogeneous infectiousness in model simulations provided substantial evidence in accurate model predictions.

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Design and Implementation of an Intelligent Walking Aid for Visually Impaired Individuals

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INTRODUCTION

In Ireland, approximately one in 17 people is blind or visually impaired, representing 6% of the population. Globally, 295 million people live with moderate-to-severe visual impairment. This highlights the urgent need for effective assistive technologies that can create independence and safety. While advances in clinical care have improved vision preservation, mobility aids for visually impaired individuals have been limited to innovation. The white cane is the most used, but it lacks the ability to provide real-time feedback or hazard detection.

MATERIALS AND METHODS

This project introduces a Smart Navigation stick, a modern enhancement of the white cane that leverages embedded systems to offer real-time hazard detection. The proposed design integrates ultrasonic sensors for obstacle detection, a vibration motor for haptic feedback, and a water sensor coupled with a buzzer to identify wet surfaces. Through adaptive vibration patterns, users receive directional and distance-based alerts, enabling them to navigate safely in dynamic environments. By integrating smart features into a familiar aid, the Smart Blind Stick presents a solution for an affordable, easy to adapt, and portability aid to users.

RESULTS AND DISCUSSION

Several prototype tests demonstrate the effectiveness of the device in complementing the user awareness of surrounding obstacles. The device achieved over 90% accuracy in detecting obstacles within a range of 1.5 meters using ultrasonic sensors, with an average error rate of about ±0.6 cm. The water sensor showed 95% accuracy in identifying wet surfaces, triggering appropriate feedback through the buzzer. An estimated 6-7 hours of battery life during normal use is calculated to be achievable, meeting the goal of at least 7 hours of usage in a single charge. These results confirm the Smart Navigation Stick's effectiveness in improving user safety, confidence, and independence, offering visually impaired individuals a more intuitive and supportive navigation experience.

Figure 1: Smart Blind Stick

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Abstract

Towards the Irish Mobility Data Space: Challenges, Opportunities, and Requirements for Data Sharing

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INTRODUCTION

A collaborative study by Smart Dublin, Urban Foresight, and the Department of Transport highlights the critical need for Mobility as a Service (MaaS) in Ireland, identifying models best suited to the country's transport landscape. However, the study highlights that the major barrier of implementing MaaS ecosystem in Ireland is the lack of effective data-sharing mechanisms. Ireland's mobility sector remains fragmented and reliant on inefficient data-sharing methods, preventing the creation of a cohesive, integrated mobility ecosystem. Fragmented data-sharing practices hinder the development of robust MaaS solutions, and demand-response transit system, limiting their effectiveness. Therefore, addressing "data-sharing" challenges through secure and efficient data-sharing mechanisms is essential for creating smarter, more efficient and sustainable mobility ecosystems in Ireland. The goal of our research is to propose the establishment of the Irish Mobility Data Space (IMDS)—a comprehensive and collaborative data ecosystem designed to address the challenges associated with mobility data sharing in Ireland.

METHODS

We conducted three stakeholder workshops—MaaS4IRL-FMCI, MaaS4IRL-DSAI, and ITS Ireland-MaaSIRL—engaging public agencies, private mobility providers, regulators, and policymakers. A structured questionnaire was used to capture insights on existing data-sharing barriers, trust frameworks, and interoperability requirements.

RESULTS AND DISCUSSION

Findings reveal systemic barriers including lack of standardization, trust deficits among stakeholders, and unclear governance models. IMDS is positioned to mitigate these barriers by enabling a unified, standards-based data exchange ecosystem. IMDS will support key mobility related applications such as MaaS, electric vehicle (EV) charging coordination, and demand-responsive transit. It will facilitate to create trusted, interoperable, compliant, inclusive and user centric data sharing ecosystem for the mobility stakeholders in Ireland. It will serve as a single platform for regulatory authorities, government agencies related to transportation, and private operators for exchanging data. For the government, it will facilitate availability of data allowing for smarter policymaking. It allows mobility operators to maximize resource usage and improve user experience. The IMDS ecosystem consists of various types of participant roles, including data provider, data consumer, service provider, and data governance authorities. Data providers offer data products which are structured solutions that encompass datasets, access policies, delivery models, pricing and billing information, license terms, and other metadata. Figure 1 shows the high-level architecture of IMDS.

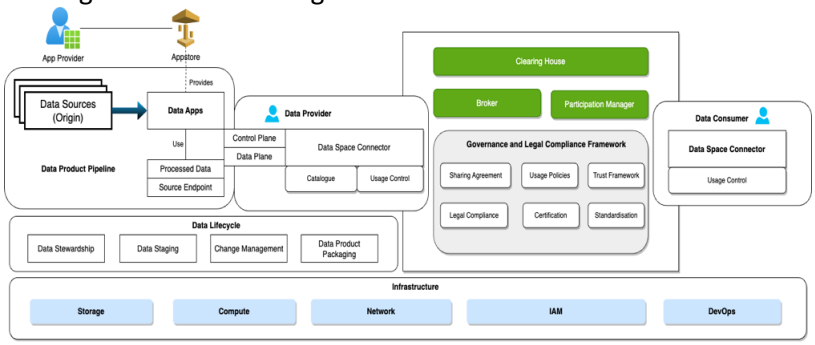

Figure 1: The high-level architecture of Irish Mobility Data Space

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INNOVATION FOR HEALTH

Oral Presentations

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Abstract

RoboHeal: Development of a soft robotic drug delivery system to improve treatment of diabetic foot ulcers

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INTRODUCTION

Annually diabetic foot ulcers (DFU) affect approximately 18.6 million people worldwide[1]. Current treatments include wound debridement, dressings, topical antibiotics/antiseptics, compression, offloading techniques, and surgical interventions[2–4]. However, 20% of individuals with DFU will undergo lower-extremity amputations[5]. RoboHeal aims to combine mechanotherapy with growth factor therapy to promote granulation and formation of new blood vessels to encourage DFU healing.

MATERIALS AND METHODS

We are developing wearable soft robotic devices that integrate an actuation reservoir to facilitate mechanotherapy and a therapeutic reservoir to enable controlled delivery of vascular endothelial growth factor (VEGF) and platelet derived growth factor (PDGF), to the wound surface (**Fig. 1A**). We are conducting *in vitro* wound healing assays on human umbilical vein endothelial cells (HUVECs) to determine optimal dosing and timing of VEGF and PDGF to stimulate endothelial migration an indicator of angiogenesis. We will perform *in vitro* drug release studies using a fluorescently labelled growth factor analogue, fluorescein isothiocyanate-Dextran, to model growth factor diffusion and release. The optimised device configuration will be implemented in rodent DFU models to evaluate the synergistic efficacy of mechanotherapy and growth factor therapy *in vivo*.

RESULTS AND DISCUSSION

The concentration of pro-angiogenic growth factors to be delivered by RoboHeal has been optimized through cell migration assays, identifying 10 ng/mL VEGF and 10 ng/mL PDGF as effective doses to promote angiogenesis (**Fig. 1B**). A preclinical study has been designed and has received ethical approval from the Animal Care and Research Ethics Committee (ACREC) at the University of Galway. The study protocol is now under review by the Animal Welfare Body (AWB) to finalise animal care and procedural guidelines prior to submission to the Health Products Regulatory Board (HPRA). Future *in vivo* studies will combine mechanotherapy and growth factor therapy to investigate potential synergistic effects in wound assays to improve clinical outcomes in diabetic foot ulcers.

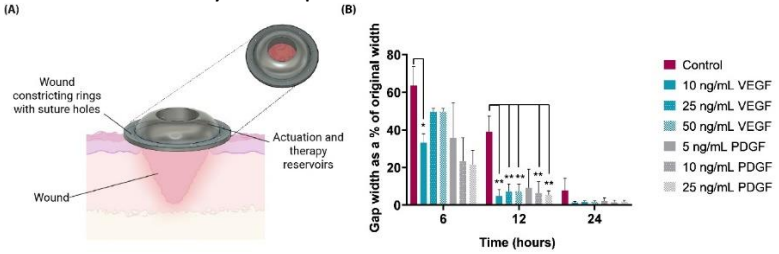

Figure 1 (A) *Schematic of RoboHeal for application of mechanotherapy and growth factor therapy to wound surface to encourage healing of diabetic foot ulcers.* ***(B)*** *Quantification of gap closure over 24 hours, n=3; *p<0.05, **p<0.01.*

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Abstract

The Design and Validation of an Actuatable Cell Encapsulation (ACE) Implant

Trask, L.[1], Ward, N.[1], Shokrani, P.[1], Wallace, E.[1], Prendeville, H.[1], Sheedy, A.[1], Roche, E.T.[3], Duffy, G.P.[2], Dolan, E.B[1].

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INTRODUCTION

Medical implants are being developed to encapsulate therapeutic cells to treat various chronic conditions[1]. Despite some success, many have limited long-term performance due to the foreign body response (FBR) impeding vital transport[2]. Our group previously demonstrated that cyclically actuating (inflating and deflating) an implant can reduce the FBR in rodents[3]. Here, we describe the development of an actuatable cell encapsulation (ACE) implant which leverages this concept (**Fig 1A**). We evaluated the performance *in vitro* with multiple cell types and conducted a preliminary *in vivo* study.

MATERIALS AND METHODS

The implant was manufactured using variations of procedures previously described in Whyte[3]. Cell viability of mouse mesenchymal stem cells transfected with firefly luciferase (F-cells, $1.67x10^5$ seeded) was measured *in vitro* using an IVIS® Spectrum In Vivo Imaging System. Function of pseudo-islets generated with the INS1E rat β-cell line was measured by GSIS index (ratio of insulin production) Day 4 *in vitro*. The implant was then placed subcutaneously in C57BL6 mice for 13 days. F-cells ($0.5x10^6$) were delivered via transcutaneous port after 72 hours and viability was measured via IVIS®. Actuation was applied 10 minutes/day in all cases.

RESULTS AND DISCUSSION

Actuation of the implant with F-cells did not impact cell viability at any time point with signal increasing ~10 fold by Day 13 *in vitro* (**Fig 1B**). Further, there was no statistically significant difference in pseudo-islets performance with or without actuation. However, the non-actuated group contained values below 1, a marker of improper function (**Fig 1C**). This suggested that actuation may rescue pseudo-islets performance *in vitro* (**Fig 1C**). In our preliminary *in vivo* study, we demonstrated progressive cell death in both male (non-actuating) and female (actuating) groups (**Fig 1D-F**). However, in the female (actuated) group there is recovery from Day 7 to 10 suggesting improved cell health. This work is ongoing.

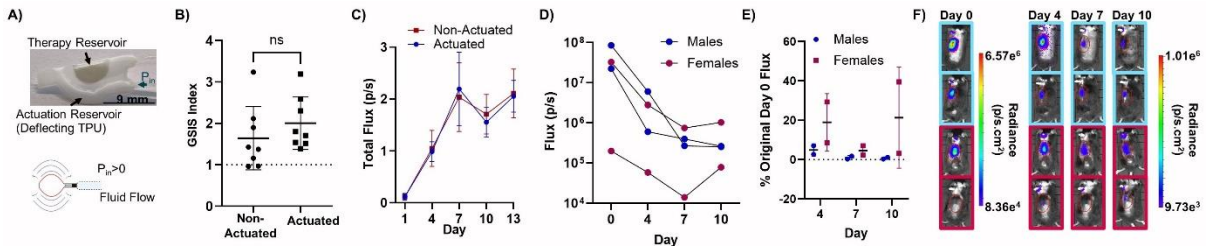

Figure 1: A) ACE implant. B) GSIS index (pseudo-islets function). C) *In vitro* F-luc cell flux. D) *In vivo* F-luc cell flux. E) F-luc cell relative *in vivo* flux. F) *In vivo* IVIS® images.

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Abstract

Computational Framework for Geometrical and Physical Skull Growth Model and Craniosynostosis-Related Dysmorphologies via Finite Element Analysis

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INTRODUCTION

Cranial growth is a complex process of biological, chemical, and probable mechanical signalling [1]. Craniosynostosis, a condition where cranial sutures fuse prematurely, leads to abnormal head shapes and facial features. Efficient treatment plan requires a deep understanding of normal craniofacial development that relies on insight into how growth dynamics interplay within the cranium [2]. This study aims to develop a finite element (FE) framework to simulate mechano-regulated calvarial growth within the first year of life for healthy and synostosis skull, exploring physical and geometrical constraints influence cranial development.

MATERIALS AND METHODS

The skull geometry was approximated with an ellipsoid, with a cephalic index (CI) of 78, containing 13 regions of brain, bones, and sutures. Sutures grow in longitudinal (red in Fig.1(A)), widening (grey) and both (blue) directions, based on ellipsoid material orientation defined. Brain volumetric growth applied the mechanical stimulus for suture and cranial growth, that are in contact with bone from the inner skull surface. Kinematically, finite growth was induced through the decomposition of deformation gradient matrix, where it consists of an elastic deformation, and a growth deformation term. Growth algorithm developed based on a healthy skull was applied on craniosynostosis cases, where individual sutures were fused.

RESULTS AND DISCUSSION

Fig. 1(A) shows FE craniosynostosis models and subsequent dysmorphologies the case has led to during 12-month growth process, according to the developed growth algorithm on a healthy skull. Fig. 1(B) shows growth in individual sutures for healthy and craniosynostosis cases. Fig. 1(C) is the quantitative analysis of the CI for the clinical data and predicted FE results. Overall, the results of the study showed that the growth model is capable to predict skull growth and dysmorphologies due to synostosis cases and is potential to predict useful data towards more accurate planning for the surgical intervention and correction techniques.

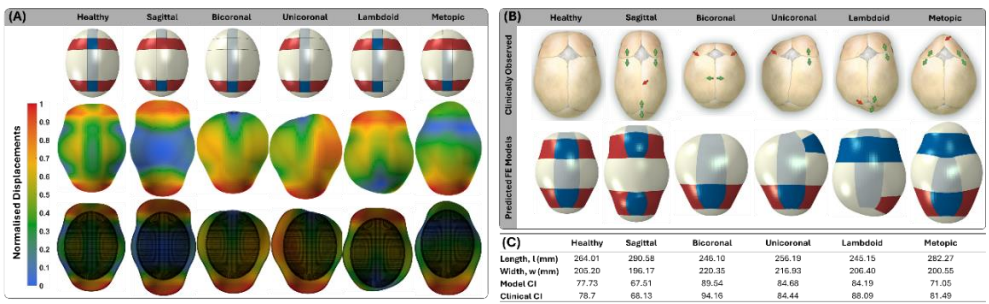

Figure 1: (A) FE models of healthy and craniosynostosis skulls, with normalised displacement contours, (B) Clinically observed skull malformations (recreated from [3]), vs FE predicted FE results for the same fused suture case, (C) Table of dimensional measurements and CI for the FE models vs clinical data [4].

References: [1] Malde et al., 2020; [2] Liang et al., 2023; [3] Kajdic et al., 2018; [4] Weickenmeier et al., 2017.

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Abstract

Oligopeptide-modified chimeric oligonucleotides as targeted therapeutics for the ESKAPE pathogens

Kelly, J.B.[1], Dhara, A.[2], Connolly, J.[3], Myers, E.[2], Reddington, K.[2], O'Gara, J.P.[2], Devocelle, M.[3], Murphy, P.V.[2], Zeden, M.S.[1]

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INTRODUCTION

Antimicrobial resistance (AMR) is a huge global issue and is projected to cause 10 million deaths per year by 2050. Thus, there is a need for novel and innovative therapies that can overcome the resistance developed by bacterial pathogens. Antisense oligonucleotides (ASOs) are RNA therapeutics that can hybridise to a target gene and prevent it from being translated. As part of my PhD project, I aim to develop ASOs that target resistance genes of some of the most prevalent bacterial species involved in AMR, the ESKAPE pathogens, to resensitize them to existing antibiotics.

MATERIALS AND METHODS

Target genes are selected by conducting bioinformatics analyses on the selected strains, and ASOs are designed to be complementary to the genes of interest. Delivery into bacterial cells is facilitated by conjugating the ASOs to a cell penetrating peptide (CPP), using click chemistry. CPPs are synthesised using solid-phase peptide synthesis and purified by HPLC. Fluorescently labelled CPPs are utilised to evaluate their uptake into different ESKAPE pathogen species using super resolution microscopy (Fig1) and flow cytometry.

RESULTS AND DISCUSSION

A list of target genes conserved in multiple strains of each species was obtained for each of the ESKAPE pathogens. Further *in silico* analyses are ongoing to assess their suitability as ASO targets. CPP pVEC was clicked to several fluorophores. Assessment of pVEC entry into different species of the ESKAPE pathogens revealed that uptake varied from species to species. Thus, pVEC is an ideal delivery molecule for some of the ESKAPE pathogens, but not others. Several CPPs are being considered as alternative delivery molecules in addition to pVEC. This interdisciplinary project is establishing chemical biology and molecular microbiology methodologies to enable the re-purposing of antibiotics for ESKAPE pathogens.

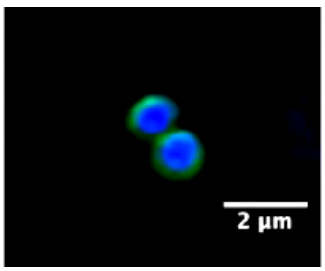

Fig.1: Super resolution microscopy reveals internalization of pVEC into *S. aureus* cells. pVec-Cy5 (**Blue**), Vancomycin-BODIPY (**Green**)

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Abstract

A Low-Power ECG Amplifier with Bioimpedance Monitoring and Lead-off Detection

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INTRODUCTION

The increasing demand for wearable and portable electrocardiogram (ECG) monitoring devices has heightened the need for front-end amplifiers that offer high signal fidelity at ultra-low power consumption. These systems must operate reliably in noisy environments, maintain diagnostic accuracy, and adhere to regulatory standards such as IEC60601-2-47 for safety and performance in medical electrical equipment. This work presents an ultra-low power ECG front-end amplifier that complies with the IEC60601 performance requirements, while introducing novel bioimpedance measurement techniques to enhance reliability in wearable application.

MATERIALS & METHODS

The proposed amplifier utilises two quad op-amps (AD8659, Analog Devices Inc.), chosen for their ultra-low bias current (<1 pA), low input offset voltage (<50 µV), and low supply current (~22 µA per channel), making them ideal for low-power design. The amplifier is ac coupled, operates from a single 3.7V battery supply and has its DC bias set to midrail. The overall gain of the amplifier is 46 dB, distributed across two stages, the input stage has a gain of 21 and output stage has a gain of 10. The lower cut-off frequency, determined by the input coupling capacitor (680nF) and the bias resistor (100MΩ), is set at 0.05 Hz to eliminate baseline drift. For real-time lead-off detection, a current source (LM334, Texas Instruments Inc.) was used, with node voltages at Vx and Vy buffered and fed to an AND gate that activates a status LED only when both leads are connected. Power consumption was measured using the Nordic Power Profiler Kit 2.

RESULTS & DISCUSSION

The amplifier operates from a 3.7 V battery and consumes less than 1300 µW, facilitating continuous cardiac monitoring. It achieves a common-mode rejection ratio (CMRR) of >75 dB at power-line mains frequency, input-referred noise below 40 µV peak-to-peak, and a midband gain of 46 dB. These parameters are maintained across the clinically relevant bandwidth of 0.05 Hz to 250 Hz, with phase distortion under 6°, ensuring minimal waveform deformation and complying with the IEC60601 performance standards. The proposed design also integrates bioimpedance measurement at each input to assess contact impedance—which can indicate degrading CMRR—and to detect lead-off, both of which are features not commonly available in conventional amplifiers.

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Abstract

Compounds used for treatment of cancer can improve treatment of bacterial infections

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INTRODUCTION

Infections caused by antimicrobial resistant (AMR) pathogens are currently on the rise causing significant burden on healthcare worldwide. By 2050 it is believed that 10 million deaths will be caused by AMR infections per year. There are dwindling options for AMR pathogens as most antibiotics are becoming ineffective for treatment of these infections. Using novel combinations of antibiotics with other antibiotics or non-antibiotic drugs may extend the usefulness of currently used antibiotics and provide some solutions for the upcoming post-antibiotic era.

MATERIALS AND METHODS

Compounds with the potential to treat cancer were evaluated for their bactericidal potential against methicillin resistant *Staphylococcus aureus* (MRSA). These compounds were assessed in combination with currently licensed beta-lactam antibiotics for their potential to resensitise MRSA cells using synergy plate assays. Confocal microscopy and RNA-seq analysis was performed to understand the molecular mechanism of bactericidal activity of compounds. Whole genome sequencing was performed on isolated suppressor mutants to compounds used.

RESULTS AND DISCUSSION

Confocal microscopy revealed morphological damage of MRSA cells grown in anti-cancer compounds (Fig 1). Our synergy experiments revealed that supplementation of some anti-cancer compounds can increase beta-lactam efficacy against MRSA. Identified suppressor mutations MRSA strains revealed mechanism of action of compounds. Assessment of the RNA transcriptome identified conserved transcriptional changes that may conclude why anti-cancer compounds alter the activity of beta-lactam antibiotics like penicillin.

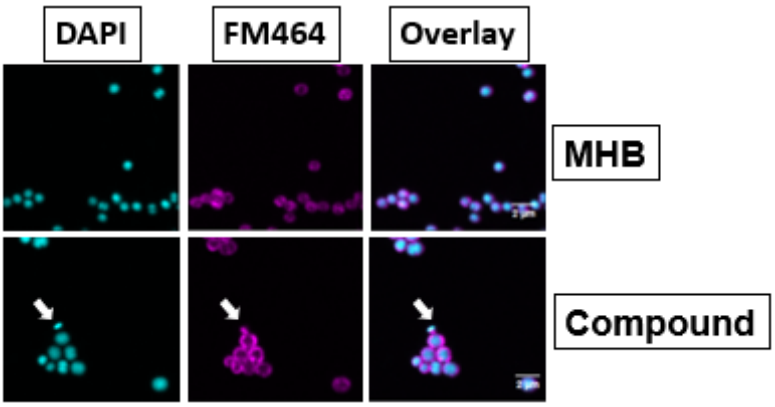

FIG 1. Exogenous anti-cancer compound increases damage to membrane (magenta) to MRSA cells viewed using Confocal Microscopy. Cells were grown in Muller Hinton broth (MH) (Top), or MH + 16 µg/ml anti-cancer compound (Bottom). DNA within cells was stained using DAPI and membranes were stained using FM4-64.

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Abstract

Designing Optimised Vascular Sensors for Next-Generation Health Monitoring

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[1]TMD Lab, UoG [2]Electrical & Electronic Eng., School of Engineering, UoG [3]School of Medicine, UoG

Implantable bioelectronic sensors enable minimally invasive, continuous monitoring of vital physiological parameters. As an example, magnetic-resonance-based sensors integrated with aortic stent grafts monitor Abdominal Aortic Aneurysm (AAA) progression[1]. The same physical principles also enable Wireless Power Transfer (WPT), allowing simultaneous wireless powering and sensing. However, biological tissues introduce frequency-dependent losses that affect WPT efficiency and sensor performance[2]. This work investigates optimal strategies to mitigate these effects and achieve maximum efficiency in vascular implants, providing physical insights and design guidelines for reliable, long-lasting implantable bioelectronics.

The coupling coefficient *k* between the on-body reader coil and the implanted sensor coil defines the power transfer efficiency to AAA sensors. Therefore, the optimum operating frequency of the system is found when *k* is maximal, enabling the most efficient wireless power transfer between the reader and the sensor. To determine this optimal frequency, the anatomical cross-section of the human abdominal region (Figure 1a) comprising tissues with frequency-dependent complex permittivities[3] was simulated using COMSOL, across a frequency range of 1 – 3000 MHz, which covers most frequencies used in medical devices. In this model, the reader is a magnetic loop conformal to the skin surface, while the implanted sensor is a loop conformal to the aortic wall (Figure 1a). Then, the self-inductances of the reader L_1 and sensor L_2, along with their mutual inductance M, are computed, where the coupling coefficient is defined as $k = M/\sqrt{L_1 L_2}$.

Figure 1b shows that *k* increases with the sensor radius due to enhanced magnetic flux linkage. Additionally, *k* reaches a maximum and remains nearly constant between 1 and 20 MHz. Then, *k* decreases at higher frequencies as a result of increased attenuation in biological tissue, caused by the exponential tissue conductivity increase. Moreover, at low *k* values, parasitic capacitance between the coils introduces anti-resonant behaviour, leading to observable dips in the *k* curve, most notably at 172 MHz. Finally, considering the frequencies standardised for medical applications[4], 6.78 MHz and 13.56 MHz are the most suitable, explaining their common use in cardiovascular sensing. Therefore, the sensing system must be designed to operate efficiently below 20 MHz while maximizing *k* through carefully selecting sensor and reader coil topologies to achieve reliable power transfer and sensing performance in deep-body biomedical applications.

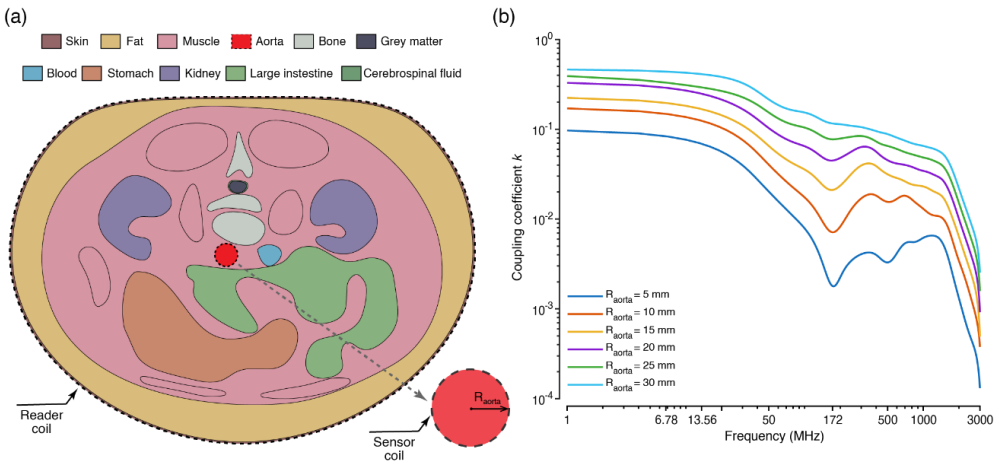

Figure 1: AAA sensing: (a) proposed model and (b) coupling coefficient vs. frequency.

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Abstract

Fatigue Detection in Running using Functional Data Analysis

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2. Research Ireland Centre for Data Analytics

INTRODUCTION

Fatigue affects athletes' performance, so monitoring it is vital in elite sports. Assessing fatigue helps optimise athletes' performance and their readiness to train. Objective assessment of fatigue is usually done in specialised laboratories that are expensive (e.g. facilities, personnel). Low-cost, lightweight sensors offer a compelling alternative, but the high-throughput data they collect are complex and functional in nature. In this study, we aim to predict fatigue onset during running using data from wearable sensors.

MATERIALS AND METHODS

Data from 19 athletes running 400M were collected under both normal (healthy) and fatigued conditions using a lumbar spine mounted sensor. The running involved three segments: running under healthy conditions, followed by a fatiguing protocol, and finally running when fatigued. The sensor captured six signals 256 times per second: the accelerometer in three directions (X, Y, Z) and the gyroscope in three directions (X, Y, Z). We broke these long, repeated time-series signals into individual strides, forming a series of functional strides arising longitudinally. We used multilevel functional principal component analysis to reduce dimensionality and capture features of the strides, which facilitate fatigue prediction. Functional Data Analysis uses all the collected data over the run and avoids wasting information. We analysed acceleration signals in the X, Y and Z directions and compared the fatigue prediction performance of each direction separately.

RESULTS AND DISCUSSION

Acceleration in the Y direction seems to be the best predictor compared to acceleration in X and in Z achieving an average accuracy of 0.95 (SD = 0.05) on an external dataset. These findings offer a foundation for creating a fatigue identification tool using wearable sensor technology.

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Effects of Estrogen Deficiency on 3D Vascularized and Humanized Bone Models under Mechanical Stimulation

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INTRODUCTION

Osteoporosis causes fundamental changes in bone mineralization dynamics and bone cell responses to mechanical loads. We recently developed an advanced 3D vascularized and humanized bone model by following endochondral ossification process, to provide insights into the mechanisms governing these changes. Our model showed that estrogen deficiency affects the mineralization process varyingly depending on the presence of vascular cells [1]. The current research seeks to build upon this study, particularly by providing advanced mineralized bone models that mimic bone tissue *in vivo*. Thus, here we followed the pre-established endochondral ossification approach to develop a 3D vascularized bone model and studied effects of estrogen deficiency and mechanical stimulation on bone mineralization and vascular development. Human bone marrow stem cells (HBMSCs) (P5) were encapsulated in gelatin-mtgase (3% V/V) and cultured with growth factors to develop a chondrogenic template. At day 22 (endothelial cells) HUVECs, osteoblasts and HBMSCs were added to the chondrogenic template to initiate vascularization. Constructs were cultured in osteogenic media with estrogen supplementation until day 56. Estrogen was withdrawn from the constructs at day 57 and then these were cultured for a further 21 days (until day 77). Mechanical stimulation was applied for 21 days (from day 57 to day 77) by compression in a bioreactor (MechanoCulture TX). Biochemical assays, histological staining and real time PCR analysed the effects of estrogen deficiency and mechanical stimulation on mineralization.

RESULTS AND DISCUSSION

The current study provides an *in vitro* 3D vascularized and humanized bone model that recapitulates estrogen deficiency representative of the osteoporotic bone phenotype. During endochondral ossification the vasculature infiltrates the lacunae and release chemokines to attract osteogenic cells and initiate bone formation. At day 21, there was significant decrease in the expression of angiogenesis marker (VEGF) and early osteogenesis markers (RUNX2, BMP2, OPN and COL 1) in the stimulated group compared to static (Fig 1 A, B, C, D, E,). But the late osteogenic marker DMP-1 was significantly upregulated under the stimulated estrogen withdrawal group compared to static estrogen supplemented and static estrogen withdrawal group, at day 21 (Fig 1 F). It is suggested that mechanical stimulation enhanced the osteogenic differentiation by driving the maturation of osteoblasts to osteocytes. Interestingly, there was significantly higher calcium present in the stimulated estrogen withdrawal group compared to static estrogen supplemented group. Calcium staining also showed higher mineral present in the stimulated compared to static group under estrogen withdrawal (Fig 1 I, J). These findings highlight the potential of mechanical stimulation to promote late-stage osteogenesis and mineralization, even under estrogen-deficient conditions, offering insights into postmenopausal bone pathophysiology.

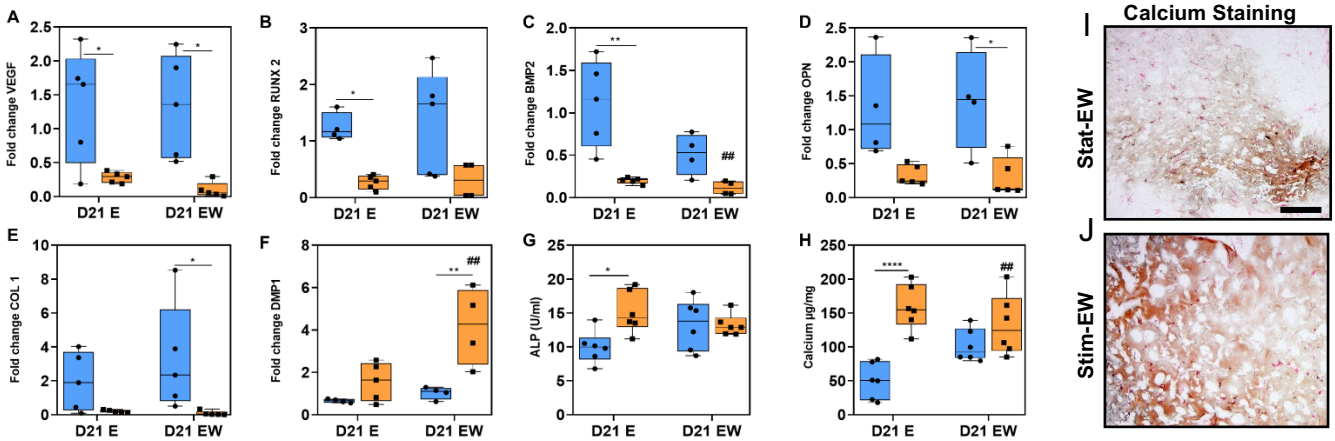

Figure 1: (A, B, C, D, E, F) Gene expression VEGF, RUNX2, BMP2, OPN, COL 1 and DMP1 normalized to static estrogen group. (G) ALP activity (H) Calcium content. (I, J) Von kossa calcium staining at day 21. Significant differences ($p < 0.05$) indicated relative to static (*) and estrogen (#).

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Abstract

Interactions of IPS cardiomyocytes on large area photopolymerized scaffolds produced by ultrashort laser direct writing

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INTRODUCTION

Cardiovascular diseases are a major cause of death. Myocardial infarction (MI), in particular, is a major disease resulting from a blockage in arteries or an insufficient blood supply to the heart, which contributes to almost one-third of global (worldwide) deaths every year. In recent years, it has been demonstrated that regeneration of myocardial function could be performed through tissue engineering via the development of laboratory-prepared cardiac patches to enhance the regenerative abilities of cardiomyocytes. Scalable high-speed fabrication of large area polymer-based scaffolds by ultra-short pulse laser direct writing (DLW) process is reported.

MATERIALS AND METHODS

The photopolymerized free-standing 2D scaffolds are intrinsically non-conductive in nature with interesting mechanical properties. A unique approach to produce conductive scaffolds enabling electrical stimulation of cells is developed by applying a nanometre-thin gold layer which is sputter coated and then laser annealed at room-temperature. The photopolymerization and annealing processes can produce various geometries with features down to a few microns over areas that are limited only by the manufacturing tools, operating at competitive speeds whereby 50 mm × 50 mm scaffolds are achieved within minutes with a single laser beam delivery. As deposited, ultra-thin gold coatings are highly resistive, hence the scaffolds are annealed with ultra-short laser pulses at very low fluences to enhance their electrical conductivity.

RESULTS AND DISCUSSION

Preliminary interaction of the scaffolds with human-induced pluripotent stem cell-derived iPSc and cardiomyocytes has been investigated, and results show good regenerative potential with cardiomyocyte cells. The development of reconfigurable structures can tailor the geometrical and mechanical properties of the scaffold to the size of the cell or cluster of cells of specific interest, thus enhancing their functional use in the laboratory and beyond.

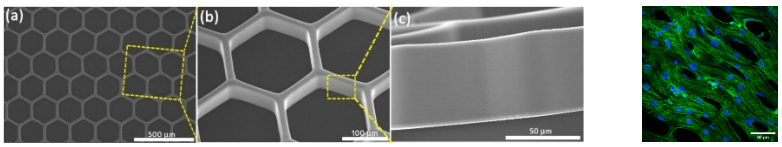

Figure 1: SEM images of scaffold (left) and IPS derived cardiomyocyte cells, stained with a green flourescent protein and washed with a phophate buffered solution, aligned on a gold coated fibrous photo-polymerised scaffold right.

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Abstract

Electrical and Spectroscopic Characterisation of Laser Induced Graphene in Polymers for Sensing

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Laser Functionalisation uses intense laser light to modify the properties of a material, causing chemical changes at the laser focus and translating the beam to create useful structures for sensing. An ultrafast laser beam delivery system has been constructed to thermally convert polymers to carbon using Direct Laser Writing (DLW) with a small footprint green laser. The carbon quality and function is controlled by digitally controlled laser parameters: intensity, pulse duration, repetition rate, beam profile and writing speed. The carbon conductivity is measured by plotting current-voltage characteristics using a precision pico-ammeter and is related to material conversion of polymer to carbon quality using Raman spectroscopy. The Raman spectrum provides a chemical signature indicating conductive sp2 hybridized carbon and quality of graphitic structures, defining their amorphous or crystallite nature [1,2]. The D, G and 2D spectral peaks can indicate defects arising from the 3D porous structures. Hence polymers and composites can be functionalised with carbon tracks to sense changes in pressure, temperature, moisture or pH, enabling use in the medical device industry. Using adaptive optics to control the DLW laser spatial and phase parameters will allow inscription of sensors on the micron and nano scale [3]. The novelty of the work lies in writing three-dimensional graphitic structures within the bulk of polymers, progressing from the highly investigated area of surface modification. The project aims to create 3D conductive pathways on and under the surface of the polymer, facilitating incorporation of sensors into medical devices, to enabling fabrication of pH, Glucose Biosensors [4] and other such systems. This laser-Induced Graphene (LIG) is widely used in energy storage applications due to its high electrical conductivity, large surface area, and lightweight structure. It is commonly employed in supercapacitors, where it enhances charge storage and rapid energy transfer. Additionally, LIG serves as an efficient electrode material in lithium-ion and sodium-ion batteries, improving battery performance and lifespan.

This work is funded by Research Ireland SFI Frontiers for the Future. “Laser Functionalisation of Flexible Polymer-Carbon Composites for Medical Sensing.”. 20/FFPP/ 8627.

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Abstract

EXPERIMENTAL AND COMPUTATIONAL MODELLING OF BRAIN TISSUE DAMAGE MECHANICS

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INTRODUCTION: The damage mechanism for concussion is unknown, and diagnosis hinges upon the lack of visible damage on MRI/CT [1]. The clinical hypothesis for the mechanism of damage, shear delamination at the grey/white matter (GM/WM) boundary [2], [3] has not been validated, though repeated concussion contributes to neurodegenerative conditions such as Parkinson's, CTE and Dementia [4]. Many publications refer to "brain tissue" as a homogenous material, neglecting regional and GM/WM variance [5], [6]. To understanding brain tissue behaviour in impact, this study performs mechanical testing on the GM & WM of ovine brain tissue, investigating variances between tissue types and location.

MATERIALS AND METHODS: Ovine brain tissue was dissected, isolating samples of each tissue type. Unconfined compression, tension, shear, stress relaxation, and volumetric analysis tests were then carried out for GM & WM, across each of the lobes of the brain. Tests were performed to 50% strain, at a load rate of 25% /s. Additionally, viscoelastic behaviour was investigated by varying the strain rate (100% and 500 % /s) and by performing stress-relaxation tests in tension and compression. Mode I and II fracture tests were performed to assess the above damage clinical hypothesis. Ogden (n=3) parameters were then fit to the fresh tissue behaviour for in silico modelling.

RESULTS AND DISCUSSION: WM is stiffer than grey in compression, both being compression/tension asymmetric. Shown in Figure 1, WM behaved linearly (R^2 = 0.9905), while GM displays strain softening behaviour. In-silico analysis shows a single Ogden constitutive law cannot capture key features of both GM & WM. Loading rate was observed to impact the tangent moduli of the tissues, higher load rates increasing stresses at lower, clinically relevant strains [7]. All tissues relaxed by ~73-86% at 50% strain. In mode I and II fracture, failure occurred not only at the tissue interface, also within the bulk tissues.

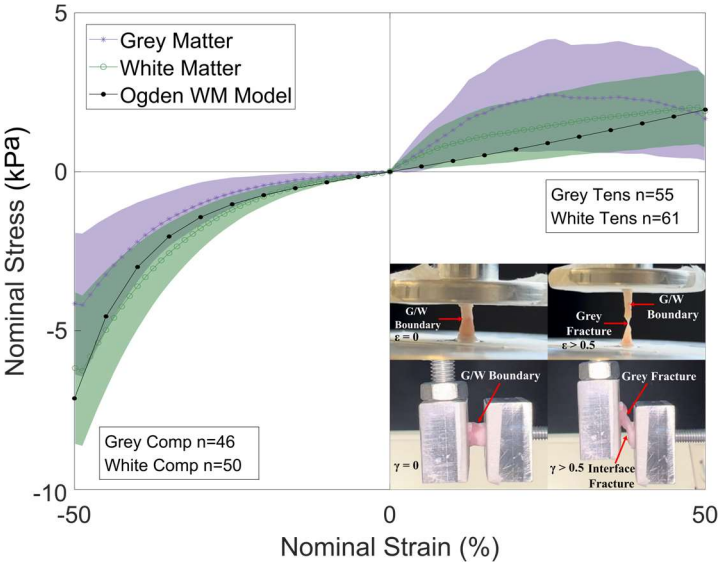

Figure 1:Stress-strain curves for GM & WM, with a WM fit Ogden model showing positive alignment with WM, while diverging from GM. Mode I and II interface fracture also presented, showing fracture occurrence in bulk tissue.

Grey/white and regional variation in mechanical behaviour indicates that brain tissues cannot be treated homogenously in computational modelling, evident in the divergence of the Ogden model fit to WM from the GM behaviour. Preliminary models using a phase field fracture approach have shown bulk material delamination, and future work will include incorporation of this model into a microstructurally-based hyperelastic framework.

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Abstract

NOVEL PATIENT-SPECIFIC BIVENTRICULAR HEART MODEL INTEGRATING PSEUDO-FLUID DOMAINS

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INTRODUCTION

We propose a novel FE-based approach to modelling a biventricular heart. We develop novel "pseudo-fluid domains" to model the blood in the right (RV) and left (LV) ventricles in response to the actively-contracting myocardium without resorting to Fluid-Structure Interaction (FSI) simulations. This novel approach allows for the simulation of a cardiac cycle in 30 minutes, 3-4 orders of magnitude faster than FSI heart models.

MATERIALS AND METHODS

Patient-specific biventricular meshes are developed from MRI images (Fig. 1A). Our myocardium material model incorporates passive isotropic and anisotropic components and actively contracting cardiac myocytes [1]. Fibre directions are prescribed using the Laplace-Dirichlet Rule-Based (LDRB) algorithm [2]. Our novel "pseudo-fluid domain" approach is used to determine ventricle volume and pressure changes in response to myocardial contraction. During systole, pressure and volume changes in each ventricle are governed by a Windkessel formulation.

RESULTS AND DISCUSSION

The fibre orientations produced by the LDRB algorithm (Fig. 1B) accurately resemble those observed in-vitro and allow our model to accurately demonstrate apicobasal shortening and twist (Fig. 1C). Fig. 1D shows the PV loops computed from a 7-cardiac cycle simulation of Inferior Vena Cava Occlusion (IVCO). The model correctly predicts reductions in end-systole (ES) and end-diastole (ED) pressure and stroke volume (SV) in both ventricles over a series of cardiac cycles. Finally, the total computing time for this 7-cycle simulation was 3.5 hours, orders of magnitude faster than traditional FSI approaches.

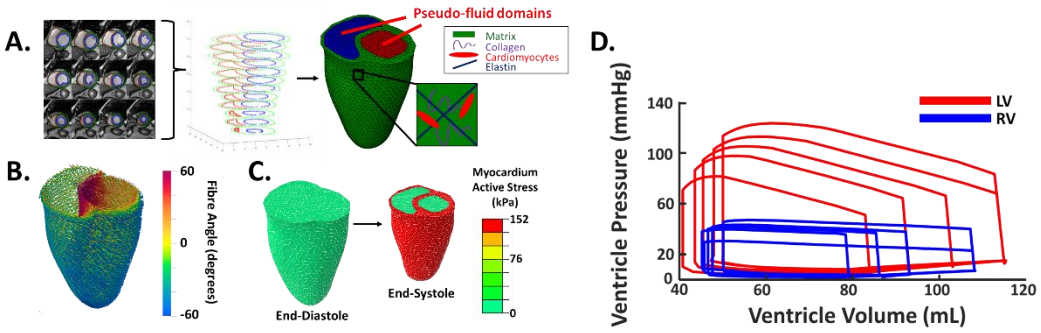

Figure 1: (A) Construction of 3D patient-specific meshes from MRI stacks; **(B)** Fibre orientations given by the LDRB algorithm; **(C)** Contour plots showing computed myocardium active stress; **(D)** Computed PV loops for the LV (red) and RV (blue) over a 7-cycle simulation of IVCO.

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Abstract

In Vitro Models to Explore Neutrophil Mechanobiology

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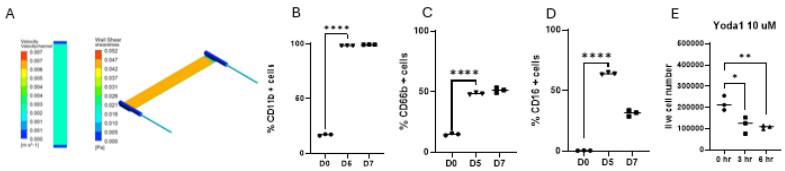
INTRODUCTION

The foreign body response (FBR) is the immune system's reaction to implanted materials, characterised by inflammatory processes. Neutrophils are one of the primary drivers of the FBR. They secrete enzymes and signalling molecules, resulting in the formation of the fibrotic capsule. This is particularly detrimental for implants which rely on interactive communication with their local tissue environment, such as cell encapsulation devices. The formation of a hypo-permeable fibrous capsule can impede the transport of molecules both to and from these implants [1]. Our group has shown that actuation of a mechanotherapeutic implant can modulate the FBR and improve therapy delivery over time [2, 3]. We show that actuation results in local tissue strain and fluid flow and is associated with early clearance of neutrophils. Neutrophils are mechanosensitive cells [4], therefore gaining an understanding of neutrophil mechanobiology is essential when mitigating the FBR.

MATERIALS AND METHODS

CFD: Parallel plate flow chambers (PPFCs) are used to apply fluid shear stress to cells in culture. A computational study was used to predict this shear stress. Using a finite volume approach, laminar steady-state flow was applied to the model. Fluid flow magnitudes representative of our therapeutic implant were used as inputs for our model: 2.4 – 3.04 mm/s velocity at 1 Hz [5]. **Differentiation:** Neutrophils are terminally differentiated cells and undergo limited expansion ex-vivo, therefore the acute promyelocytic leukaemia HL60 cell line was used as an alternative. HL60s were differentiated into neutrophil-like-cells (NLCs) using 1.3% DMSO over 7 days. NLCs were stained for myeloid marker CD11B and neutrophil markers CD16 and CD66B to confirm a NLC positive population. **Mechanostimulation:** Ongoing work is evaluating the activation of Piezo1, a mechanosensitive ion channel expressed by neutrophils. Piezo1 can be activated both mechanically via shear stress, and biochemically via Yoda1; a piezo-selective agonist. NLC activation, chemokine secretion and cell viability will be investigated to determine the effect of Piezo1 activation.



(A) CFD results of wall shear stress in PPFC, Expression of (B) myeloid marker CD11B, (C) neutrophil markers CD66B and (D) CD16, (E) NLC live cell number post 10 µM Yoda1 exposure

RESULTS AND DISCUSSION

CFD models predict that when fluid velocities in the PPFC are representative of our mechanotherapeutic implant, NLCs experience shear stress levels ranging from 0.45 to 0.6 Pa (Fig 1A). Results show the successful differentiation of HL60s to NLCs, with myeloid and neutrophil markers significantly upregulated on day 7 (Fig. 1B-D). Activation of the Piezo1 MIC via Yoda1 has shown to significantly reduce live cell number in NLCs 6 hours post exposure to Yoda1 (fig. 1 E).

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Abstract

ALTERED BONE MINERAL CRYSTALLINITY AFFECTS OSTEOGENESIS UNDER ESTROGEN DEFICIENCY

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INTRODUCTION

Postmenopausal osteoporosis (PO) is characterized by alterations in bone tissue microstructure, composition and mechanobiology because of changes in estrogen hormone level. In particular, the bone mineral nanostructure is also altered, with respect to the proportion of the hydrophilic amorphous layer (HAL) on the surface of nano hydroxyapatite (nHA) particles. This study aims to (1) develop an advanced 3D in vitro cellular bone model that mimics healthy and osteoporotic mineralized bone models, and (2) investigate how changes in HAL proportion in nHA under estrogen (E) supplementation and estrogen withdrawal (EW) condition influence mineralization and bone regeneration under mechanical loading.

MATERIALS AND METHODS

Novel bone-like proxies, composed of platelet-shaped carbonated nHA particles coated with different proportions of HAL, were prepared to represent the crystallinity of healthy (HE: 35%) and osteoporotic (OS: 20%) bone tissue. These proxies were incorporated with gelatin (8% wt.) at 12.5% w/w. Pre-osteoblast cells (MC3T3-E1) were pre-treated with 17β-Estradiol for 7 days and then encapsulated within the gelatin-nHA hydrogels. Over 42 days, these hydrogels were cultured with estrogen (E) or without estrogen (EW) in static (Stat) or mechanically stimulated (Stim) conditions within a bioreactor. TEM, XRD, SSNMR, biochemical assays (DNA, ALP, and calcium content), histological staining (DMP1/actin, Von-Kossa), mechanical testing, micro-CT and nano-CT scanning were conducted to assess osteogenic differentiation and mineralization.

RESULTS AND DISCUSSION

Nano HA characterization: TEM, XRD and SSNMR confirmed the formation of nHA platelet shape particles with different crystallinities. **Cell proliferation and differentiation:** By day 42 actin staining and DMP1 staining confirmed osteocyte differentiation for all groups. ***Osteogenesis and mineralization:*** SEM analysis confirmed new mineral deposition in all groups by day 42. ALP and calcium were lower for OS-Stim than HE-Stim under E at day 42. Also, mineral density (by micro-CT) and bone volume fraction (BV/TV, by nano-CT) were lower for the OS-Stim than HE-Stim under E. Our results revealed that the OS condition impaired osteocyte differentiation and mineral density under mechanical stimulation due to increased crystallinity and estrogen deficiency.

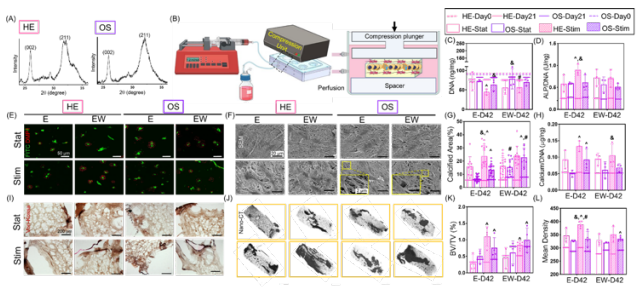

Figure 1: Osteocyte differentiation and osteogenesis are altered when bone cells are cultured on a mineral proxy with a hydrophilic amorphous surface layer representing osteoporotic bone. (A) X-ray diffraction patterns of synthetic healthy (HE) and osteoporotic (OS) proxies , (B) Experimental Design, (C) DNA content, (D) ALP activity, (E) Actin (green), DMP1 (red) , (F) SEM images, (G) Semi-quantification for calcified regions, (H) Calcium content, (I) Von Kossa staining, (J) Nano-CT scans, (K) BV/TV (%), (L) Mineral density analyses of nHA-gelatin hydrogels in healthy and osteoporotic conditions. Significant differences ($p < 0.05$) indicated relative to continuous estrogen (#), Healthy (&), Static (^).

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Abstract

OVERCOMING STIFFNESS-INDUCED CHEMORESISTANCE IN BREAST CANCER SPHEROIDS BY PROMOTING GAP JUNCTION ASSEMBLY

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INTRODUCTION

The organisation of the tumour microenvironment can restrict cell growth and proliferation. Recent evidence suggests that dense matrix may also reduce therapy efficacy for triple negative breast cancer (TNBC). In this study, we aim to uncover the dependence of TNBC spheroid chemosensitivity on hydrogel stiffness, and to identify pathways to mitigate mechanically induced drug resistance.

MATERIALS AND METHODS

4T1 cells were cultured in RPMI supplemented with FBS, penicillin and streptomycin. For spheroid formation, 4T1 Cells were seeded in gelatin crosslinked with 0.3% or 1.0% w/w microbial transglutaminase. To investigate drug-sensitivity, hydrogels were incubated at 37°C in a humidified 5% C02 environment and treated with doxorubicin (0.1-10µM) and aCT1 (100-300µM), a peptide that promotes gap junction formation.

RESULTS AND DISCUSSION

Stiff hydrogels (1.1kPa) produced significantly smaller spheroids with higher tolerance to doxorubicin compared to spheroids generated in soft hydrogels (0.58kPa). Treatment with doxorubicin and aCT1 decreased spheroid size, significantly more so than doxorubicin alone (**Figure 1**). This study confirms that tumours cultured in stiff microenvironments express higher levels of chemoresistance. By treating spheroids with doxorubicin and aCT1, chemosensitivity was rescued, suggesting compaction and aberrant gap junction expression play important roles in chemosensitivity, which can be overcome by promoting intracellular drug diffusion.

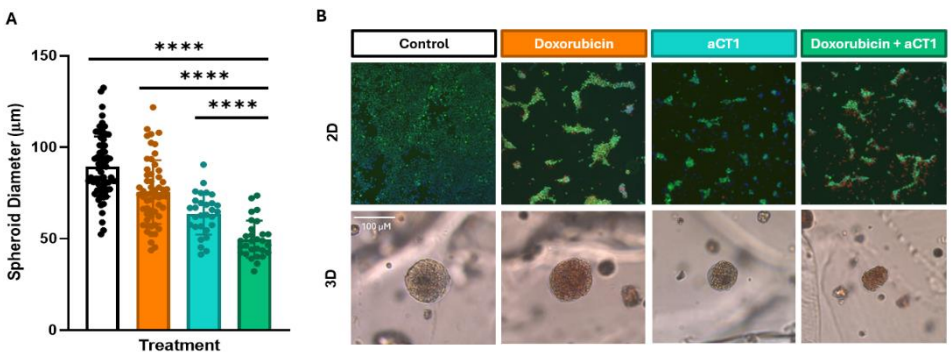

Figure 1. Hydrogel treatment with either 10µM doxorubicin (orange), 300µM aCT1 (blue) or 10µM doxorubicin and 300µM aCT1 (green) in combination A) Spheroid diameter 2 days following treatment, $P < 0.0001$. B) Fluorescence microscopy staining for DAPI (blue), Ki-67 (green), and doxorubicin (red) in 2D. Bright field microscopy of spheroids encapsulated in hydrogels. 100 µm scale bar (white).

ACKNOWLEDGEMENTS

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Abstract

Investigating the role of mechanobiological stimulation and matrix stiffness in breast cancer stemness and its effect on proliferation, migration, and differentiation of cancer cells.

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[1] School of Engineering, [2] School of Medicine, [3] School of Biological and Chemical Sciences

INTRODUCTION: Breast cancer is a highly heterogeneous disease, giving rise to aggressive subtypes such as triple-negative breast cancer (TNBC). Increasing evidence suggests that uncontrolled proliferation, epithelial–mesenchymal transition (EMT), and cancer stemness are orchestrated by the tumour's mechanical environment[1]. Key mechanobiological factors such as matrix stiffness and fluidic pressures(hydrostatic pressure, interstitial fluid pressure), activate mechanotransductive pathways that regulate invasiveness and cell fate[2]. This project investigates how mechanical stimulation and matrix stiffness influence breast cancer cell behaviour, using 4T1 murine breast cancer cell models.

MATERIALS AND METHODS: 4T1 cells were cultured in gelatin hydrogels that replicate the stiffness of both healthy and tumoural tissues. Constructs were exposed to either a static or stimulated condition (53 mmHg) and cultured for short- (2 hours) and long-term (5 days) periods. H&E and Immunohistochemistry were employed to assess spheroid formation, EMT and stemness markers.

RESULTS AND DISCUSSION: In Fig 1A, static constructs show fragmented spheroids, while stimulated constructs show denser spheroids, indicating that mechanical stimulation enhances cell proliferation and promotes a more aggressive phenotype[3]. Cell number quantification at 2 hrs showed higher counts in static groups, likely reflecting looser aggregates. At 120 hrs, matrix stiffness promoted cell proliferation (2-fold, Fig 1B). Adhesion markers revealed time-dependent mechanosensitive responses (Fig. 1C and D). At 2 hrs, ECAD expression was higher (21%) in static soft matrices, indicating absence of mechanical input initially supports epithelial characteristics. By 120 hours, ECAD increased (16.38%) in stimulated soft matrices, indicating a time-dependent adaptive response. At 120 hrs, NCAD expression was higher in stimulated groups, consistent with a shift toward a mesenchymal, invasive phenotype. Stemness markers showed inverse regulation by mechanical input (Fig. 1E and F). SOX2 expression was higher in static groups (39.51% at 2 hrs; 37.9% at 120 hrs), and NANOG expression followed a similar trend at 120 hrs, indicating suppression of stem-like traits under sustained stimulation[4]. Furthermore, NANOG expression in static conditions showed sensitivity to matrix stiffness at 120 hrs, with greater (17.98%) expression in soft matrices, indicating that a compliant microenvironment supports stemness.

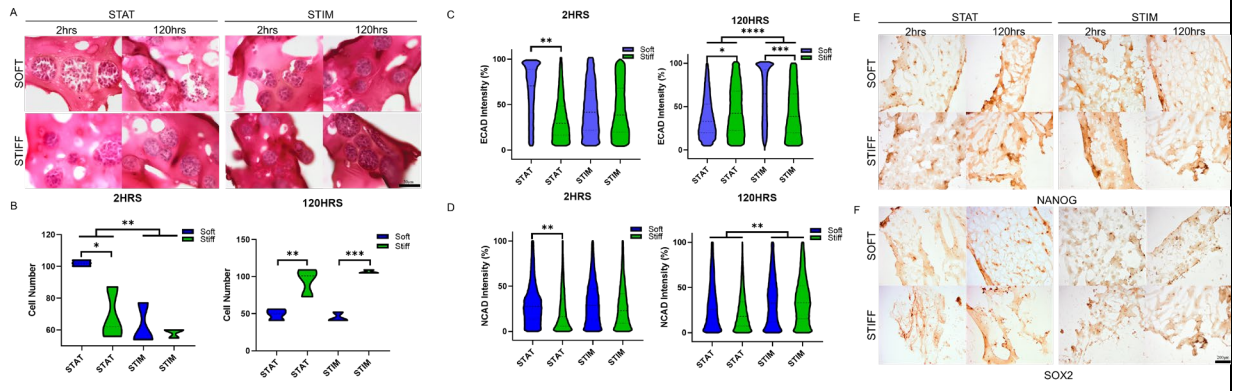

Fig. 1: (A) H&E staining (50 µm scale), (B) Cell count, (C-D) ECAD/ NCAD intensity, (E-F) NANOG/S0X2 staining (200 µm scale).

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Abstract

γδT-CELLS AND GAP JUNCTION EXPRESSION INFLUENCES TUMOUR CELL GROWTH AND IMMUNOTHERAPEUTIC OUTCOMES

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INTRODUCTION

Understanding tumour cell cytotoxic interactions is crucial in advancing cancer therapies and guiding treatment frameworks. This work aims to isolate, purify, and expand CD27$^+$ expressing γδT cells. Isolated cells are optimised in co-culture to investigate cytotoxic effects, with effector:target (E:T) ratios determining optimal gamma delta to cancer cell ratio.

MATERIALS AND METHODS

Isolation: Spleen and lymph nodes were harvested from C57BL/6 male mice and pooled in a single-cell suspension. Cells were cultured in 96 U-well plates at 37°C and propagated at a density of 2×10^5 cells/well. Cells were isolated using a γδ TCR$^+$ T cell Isolation Kit (Miltenyi Biotec). Cells were cultured in RPMI 1640 medium supplemented with FBS, penicillin/streptomycin, Sodium Pyruvate, β-ME, and murine IL-2, -7 and -15. Expanded cells were stained with anti-CD3, CD4, CD8, CD27 and TCRγδ and analysed on a Northern Lights 3000 cytometer.

Co-Culture: EO771 mammary carcinoma cells were plated at a density of 10^4 cells in a flat bottom 96-well plate. After 3 hrs, γδT cells were added to wells in E:T ratios of 1:1, 5:1, and 10:1. Doxorubicin was used as a positive control for cell death. Co-cultures were incubated for 24 hours at 37 °C. Cells were collected and blocked with FcX TruStain and stained with anti-CD3. Zombie Red™ was added as a viability marker to measure cell death.

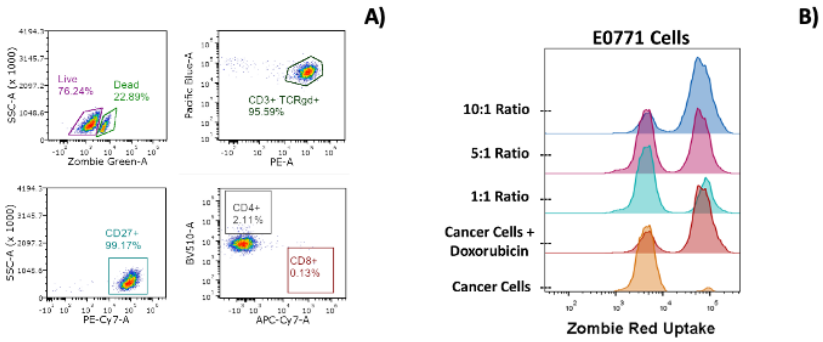

Fig 1: Flow plots express surface markers for γδT cells. Our cells express >95% CD3+TCRγδ+. *B)* Uptake of ZombieRed on cancer cells indicating positive/negative populations.

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Abstract

An All-Ireland Cancer Liquid Biopsy Portal

Hooshmand, Seyed Aghil[1], Ó Broin, Pilib[1].

1. School of Mathematical & Statistical Sciences

Introduction

Liquid biopsy (LB) is a minimally invasive technique that analyzes tumor-derived components in body fluids like blood, offering a safer and more convenient alternative to traditional tissue biopsies [1,2]. It enables repeated sampling throughout treatment, improving monitoring of tumor evolution, resistance, and relapse [1,3]. LB is increasingly used in cancer diagnosis, prognosis, and early detection, making it a powerful tool for personalized oncology [4].

Here, we present a web-based portal for the integration, standardization, and exploration of multi-modal liquid biopsy data. Developed under the All Ireland Cancer Liquid Biopsies Consortium (CLuB), the platform addresses key challenges in managing diverse biological and clinical datasets derived from breast, lung, ovarian, and pancreatic cancers.

Methods

Our workflow (Figure 1), begins with a web-based AI tool powered by BioBERT [5], which harmonizes clinical variables from CLuB studies with those in publicly available datasets. This harmonization step ensures semantic consistency across data sources and enhances interoperability for integrative and comparative analyses. The portal is designed to accommodate heterogeneous data types, including circulating tumor cells (CTCs), extracellular vesicles (EVs), and DNA methylation profiles. Dedicated REDCap [6] forms—deployed on AWS and tailored for each modality—ensure structured, standardized, and validated data entry, minimizing manual error and promoting data quality and governance.

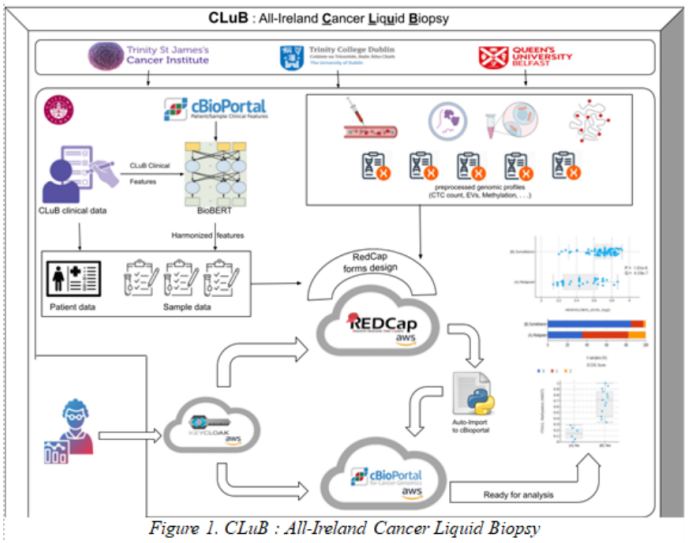

Figure 1. CLuB : All-Ireland Cancer Liquid Biopsy

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Abstract

Immunomodulatory Effect of Mesenchymal Stem Cell-Derived Extracellular Vesicles on Dendritic Cells

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Introduction

Dendritic cells (DCs) are professional antigen-presenting cells (APCs) that link the innate and adaptive immune systems. Overactive DCs are implicated in inflammation-related bone loss by activating T-cells as reported in rheumatoid arthritis (RA) and chronic periodontitis. Therefore, there is a need for therapies that can modulate DCs towards tissue-repair effectors. It has been shown that mesenchymal stromal cells (MSCs), and more recently their secreted extracellular vesicles (EVs), can influence the immune system. This study investigates the influence of MSC-EVs' potential to modulate dendritic cell differentiation and activation.

Methods

Murine MSCs were cultured on tissue culture plastic in EV-depleted media for 48 hours. EVs released by the MSCs were isolated by using differential centrifugation, ultrafiltration, and size exclusion chromatography (SEC). EVs were characterized by particle size and concentration using nanoparticle tracking analysis (NTA) and by protein content using bicinchoninic acid (BCA), for morphology, as well as surface marker expression. MSC-EVs were treated on monocyte-derived dendritic cells isolated from C57BL/6 mice. EVs were treated at increasing dosages (0, 4e+009, 8e+009, and 2.25e+010 EV particles per mL) on days 0, 3, and 6 for the differentiation assay and one day after activation for the activation assay. The uptake of the EVs by DCs was monitored by tracking palmitoylated-tandem dimer Tomato (PalmtdTomato) EVs using confocal microscopy. DC surface markers analysed by using flow cytometry, and cytokine secretion, were employed to assess the effect of MSC-EVs on differentiation, activation, and intracellular cytokine release by dendritic cells.

Results

The size of the isolated MSC-EVs ranged between 30 and 380 nm, with the majority of EVs having a size of 130 ± 40 nm. MSC-derived EVs caused a significant dose-dependent reduction in the expression of MHC-II, CD11c, CD40, and CD86 surface markers and increased expression of CD11b surface marker and PD-L1 immune checkpoint marker.

Discussion

MSC-EVs inhibited the differentiation and activation of monocyte-derived dendritic cells. To understand the underlying mechanisms behind these findings, we are currently investigating the role of EV-treated dendritic cells in the activation and proliferation of T-cells. Further, we will investigate the transcriptome, miRNA, and protein cargo profiles of the murine MSC-EVs.

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Abstract

Early Intermittent Low-Dose Therapeutic Intervention Prevents Osteocyte Dysregulation Associated with Estrogen Deficiency in Ovariectomized Rats

Naqvi, SM[1], Ali, W[1], Allison, H[1], O'Sullivan, LM[1], Holdsworth, G[3], Panadero-Perez, JA[1], Schiavi-Tritz, J[1,2], McNamara, LM[1]

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INTRODUCTION: Therapeutic strategies that preserve bone mass and promote bone formation are essential in reducing fracture risk in postmenopausal osteoporosis. Clinically, such treatments are often introduced years after menopause, despite the fact that the most rapid phase of bone loss occurs early, followed by longer-term changes in bone quality and mineralization. These changes are driven by altered osteocyte activity, including increased apoptosis, disrupted perilacunar remodelling, and impaired mechanosensation. The objective of this study was to evaluate whether a low-dose, intermittent regimen of a bone anabolic agent administered early after estrogen depletion could mitigate changes in (1) osteoclast activity and bone resorption, (2) perilacunar remodelling, (3) secondary mineralization, and (4) osteocyte mechanosensitivity.

MATERIALS AND METHODS: Female Wistar rats (6 months old) underwent ovariectomy and were assigned to either an untreated group or a group receiving monthly low-dose treatment (2 mg/kg). At 14 weeks, trabecular bone microarchitecture was assessed using nano-CT imaging, including ultra-high-resolution scans of lacunae and surrounding mineral density. Histology (H&E staining) evaluated osteoclast numbers, and immunohistochemistry quantified MMP14+ osteocytes. Gene expression of bone-regulating markers was measured using TaqMan® microarrays. Statistical analyses were performed using t-tests, Mann-Whitney tests, or ANOVA ($p \leq 0.05$).

RESULTS AND DISCUSSION: Early low-dose treatment enhanced bone formation (Fig. 1A) and reduced bone resorption (Fig. 1B), as shown by decreased expression of bone catabolic genes (e.g., Ctsk, Mmp9) and fewer TRAP+ osteoclasts. Treatment also reduced the number of empty lacunae, MMP14+ osteocytes, and the expression of genes involved in osteocyte-mediated mineralization (e.g., DMP1, PHEX, OPN) (Fig. 1C, 1D). Nano-CT revealed decreased perilacunar mineral density, indicating improved regulation of local mineralisation. Furthermore, expression of genes linked to mechanotransduction (e.g., Integrins α5, αV, CX43, Axin2, IFT88, Adcy6, Pkd1, Cav1) was also reduced (Fig. 1E). These findings suggest that early intervention with a low, intermittent dosing regimen can support new bone formation while limiting detrimental changes in osteocyte behaviour and mineral metabolism associated with estrogen deficiency.

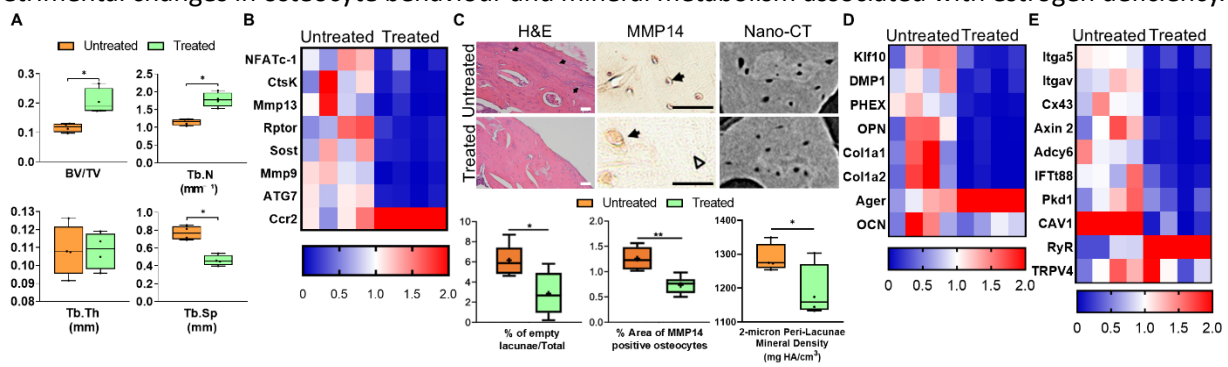

Figure 1: *(A) Bone mass and trabecular microarchitecture at week 14 via ex vivo nano-CT. (B) Cortical bone gene expression related to resorption and matrix degradation. (C) H&E and MMP14 staining with quantification of empty lacunae and MMP14+ osteocytes (black arrows: empty lacunae/MMP14+; white triangle: MMP14–). (D) Gene expression of matrix formation and anabolic markers. (E) Gene expression related to osteocyte mechanotransduction. *n = 4 rats/group. *p < 0.05, *p < 0.01. Scale bar: 20 µm.*

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Abstract

A peritoneal implant for monitoring of ovarian cancer

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INTRODUCTION

Ovarian cancer is a lethal malignancy with 5-year survival rates of <50%[1]. Over 90% of patients with advanced ovarian cancer present with ascites[1], fluid build-up in the abdominal cavity containing tumour and immune cells, DNA, and signalling molecules[1]. Ascites contributes to metastasis, chemoresistance, and symptom burden. Currently, repeated long-term access to the peritoneal cavity is invasive and difficult and as such little is known about the dynamic local environment in peritoneal malignancies. Understanding the local peritoneal environment is essential to understand the disease and inform therapeutic intervention. Here, we describe a novel, replenishable implant that enables both repeated local therapy delivery and intraperitoneal sampling, enabling us to ask fundamental research questions that have not been explored due to the inability to readily access the peritoneal space.

MATERIALS AND METHODS

The mono-material implant was manufactured using thermoplastic polyurethane (TPU) as previously described[2]. NSG mice received the implant and were inoculated with ovarian cancer cells (DlucOVCAR8). Treatment group received a Natural Killer (NK) cell immunotherapy regimen (eNK + IL15) or saline 4x/week for 6 weeks. Tumour burden was monitored by bioluminescence imaging (BLI) weekly, and peritoneal fluid was sampled via the implant on day 7.

RESULTS AND DISCUSSION

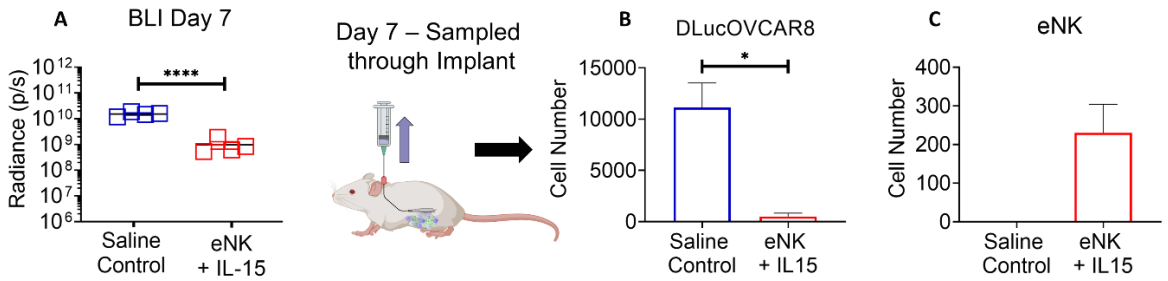

Figure 1 A: Tumour burden was quantified by BLI on day 7. Peritoneal fluid was collected minimally invasively on day 7 and the number of DlucOVCAR8 **(B)** and NK **(C)** cells in the peritoneal fluid were quantified.

Tumour burden (BLI) was significantly higher in saline control compared with eNK + IL-15 group ($p<0.0001$) on day 7 **Fig. 1A**. On day 7, sampling and subsequent peritoneal fluid analysis identified both D-luc+OVCAR-8 cells and eNK cells ($hCD56^+hCD3^-$, **Fig. 1B-C**). Significantly more tumour cells were found in saline control group vs eNK + IL-15 group (11,155±1,196 vs 733±119, $p<0.05$ **Fig. 5B**), aligning with a significantly higher BLI on day 7 (**Fig. 1A**). $hCD56^+$ cells were detected only in eNK + IL-15 group (231±74 **Fig. 1C**). This proof-of-concept study demonstrates that our implant allows minimally invasive, real-time monitoring of disease and immune cell dynamics, offering a powerful tool to inform and adjust therapy.

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Abstract

A wireless pressure sensing technology for wound monitoring

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INTRODUCTION

Wound healing progress is directly linked with the external pressure (0 – 60 mmHg) on the wound [1], [2]. An optimal external pressure can boost neovascularization and cellular proliferation to speed up the recovery [3]. Compression therapy has been widely used to treat the chronic wound ulcer. However, applying consistent optimal pressure without a monitoring device is challenging. Therefore, continuous pressure monitoring is critical to achieve optimal pressure [2]. In this work, we have developed an LC (inductor-capacitor) sensor to monitor the external pressure on a wound as shown in Fig. 1a.

MATERIALS AND METHODS

The sensor was developed using method reported earlier [2]. A mask containing squared inductor sensor pattern was designed and directly printed on the copper-coated polyimide sheet using the LaserJet printer. The mask-printed sheet was etched using Ferric Chloride. After the etching process, the electrodes were cleaned with acetone wipes and rinsed with a hot water to remove the mask layer. Capacitive part of the sensor was achieved by combination of a premade polydimethylsiloxane (PDMS) sheet cut into a size of 7.8 mm x 7.8 mm and placed at the centre of the bottom electrode, secured with a double-sided tape. The top electrode was carefully folded and aligned to the bottom electrode to achieve a fully functioning LC sensor.

RESULTS AND DISCUSSION

The developed sensor was placed in a premade pressure chamber [4] and an external reader coil connected with a calibrated vector network analyser (VNA) was placed outside the chamber near the sensor. The inside pressure was varied between 0-200 mmHg with 5 mmHg steps. The VNA data was recorded using predeveloped software. The sensor showed a resonance frequency (f_o) of 72.268 MHz and a sensitivity of 26.7 kHz/mmHg with good linearity up to 200 mmHg, successfully covering the pressure range (0-60 mmHg) for wound monitoring as shown in Fig. 1b.

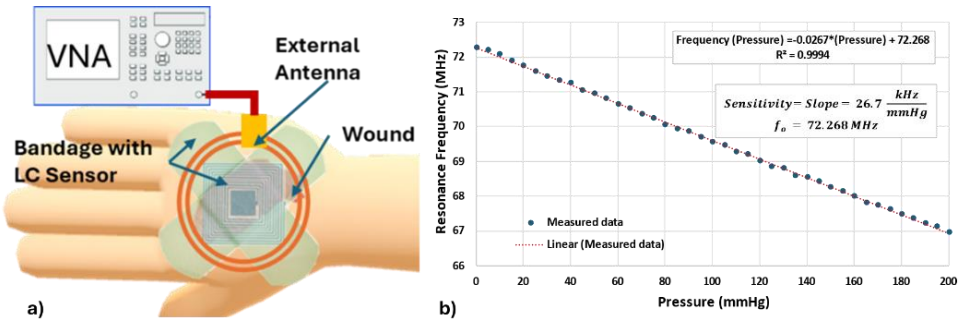

Fig. 1 (a) Wireless pressure sensing system for wound monitoring (b) Sensor response

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Abstract

Developing a Barnacle Cement Protein as an Adhesive Coating for Biomedical Applications

Sawant, S[1, 3], Power, AM[2], Wall, JG[1, 3].

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2. School of Natural Sciences, University of Galway
3. SFI Research Centre for Medical Devices

INTRODUCTION: In wet environments, marine organisms are capable of adhering to various natural and man-made materials. Cell-Tak, a commercially available adhesive used in suspension cell adhesion, extracted from the marine mussel *M. edulis*, is environmentally toxic, expensive and unsuitable for in vivo application. We predict that the adhesive coating of barnacle cement protein cp19k from *P. pollicipes*, expressed in *E. coli* possesses strong adhesive properties, making it suitable for coating surfaces in vitro and /or in vivo and a sustainable avenue for various biomedical applications.

METHODOLOGY: The cp19k protein is expressed in *E. coli BL21DE3* and purified using Metal affinity chromatography and Ion exchange chromatography. Using Transmission Electron Microscopy (TEM) the Beta-amyloid fibre formation of cp19k is analysed in different conditions (pH and NaCl concentration). The cell viability of suspension cell line THP-1 Monocytes on cp19k-his coating in pH 8 is performed using MTS assay. Surface adhesion experiments of purified cp19k in different pH and NaCl conditions after various incubation periods are performed on tissue culture polystyrene plates (both hydrophilic and hydrophobic) surfaces to determine the role of fibre formed or assembled cp19k and the suitable adhesion conditions.

RESULTS: The optimization of cp19k protein expression and purification procedures resulted a pure and 2.5-3 mg/L of culture yield. TEM analysis showed fibre formation in all the conditions, but it was denser in low pH and high salt and also in high pH and low salt conditions. The fibre morphology varied between conditions after 21 days of incubation. Cell viability assay showed viable THP-1 cells on cp19k-his coating in pH 8, even after 72 hours.

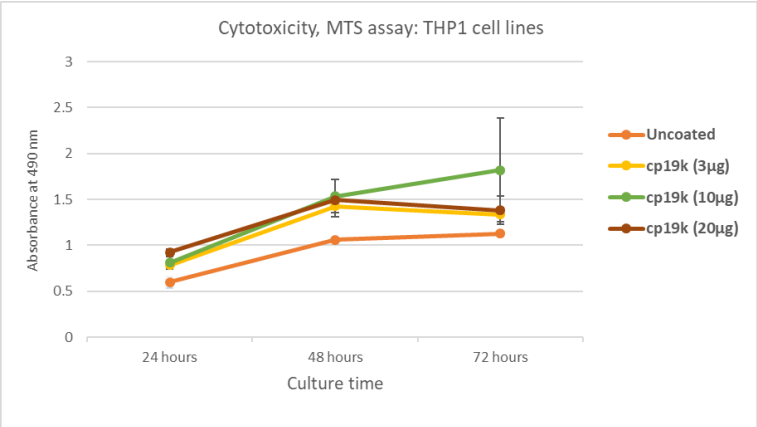

Figure 1. Cytotoxicity testing of THP1 suspension cell lines by MTS assay

CONCLUSIONS: The adhesiveness of the cp19k with hexa-histidine tag displays effective surface coating for cell adhesion, suggesting its potential for in vitro biotechnology applications.

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Abstract

Beyond Classical Approaches: Fine-Tuning Clinical BERT Models on Structured Data for Alzheimer's Disease Diagnosis

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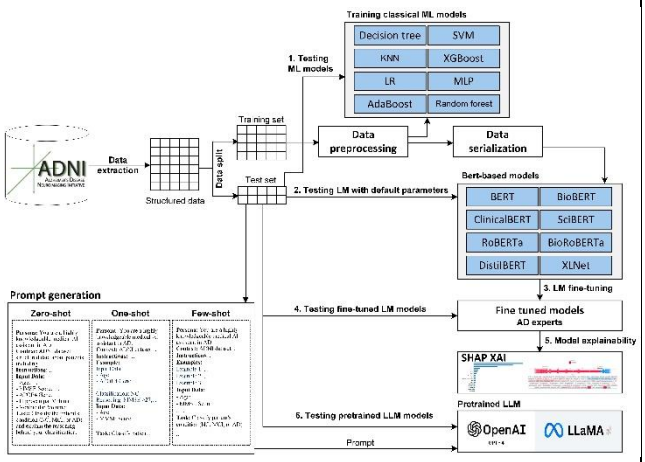
2. Department of Computing, Atlantic Technological University, Letterkenny, Ireland
3. Faculty of Computer Science and Engineering, Galala University, Suez, Egypt

INTRODUCTION

Alzheimer's disease (AD) is a neurodegenerative disorder that requires early diagnosis for effective intervention. The study proposed a CDSS based on LM for the diagnosis of AD. In addition, it presents a comprehensive evaluation of classical machine learning models, fine-tuned BERT-based models, and large language models (LLMs) for AD diagnosis through CN, AD, and MCI classes.

MATERIALS AND METHODS

Figure presents the proposed architecture of the LM model for the diagnosis of AD.



Dataset

We used a structured, tabular dataset extracted from the Alzheimer's Disease Neuroimaging Initiative. It contains features from different modalities, such as demographic, genetic, and neuropsychological features. The dataset is split stratified into a training set (80%) and a test set (20%).

Data serialization

LM and LLM models can not work directly with tabular and numerical data. As a result, in this step, we serialize the numerical data of all cases as text data. The serialization process was done by programming and converting the vector of each example into a description of the case as a paragraph**.**

Models

We compared different approaches to machine learning models, the different BERT models, including BioBERT, ClinicalBERT, SciBERT, RoBERTa, BioRoBERTa, TabNet, TabTransformer, and DistilBERT, and LLMs, including GPT-4o and LLaMA-3, using various types of prompts: Zero-shot, One-shot, and Few-shot.

Model explainability

We extend the BERT model to provide XAI for each decision AD, CN, and MCN using the SHAP tool, which offers local and global XAI features.

RESULTS AND DISCUSSION

We evaluated models using different evaluation metrics: accuracy, precision, recall, and F1-score. The comparative analysis demonstrates that fine-tuned BioBERT and ClinicalBERT achieve superior performance. BioBERT attains an accuracy of 94.48%, precision of 94.64%, recall of 94.48%, and an F1-score of 94.52%. These models outperform classical approaches such as random forest and AdaBoost, which achieved accuracies of 91.87% and 91.41%, respectively.

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Abstract

Computational and Experimental Optimisation of the Corrosion and Mechanical Performance of Bioabsorbable Mg/Zn Ureteral Stents

O'Connell, S., Concannon, J.

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INTRODUCTION:

Ureteral stents are widely used to alleviate urinary obstruction caused by conditions such as ureterolithiasis, ureteral tumours, or strictures, facilitating urine drainage and stone passage post-intervention [1]. The most common configuration is the double-J or "pigtail" stent, which prevents migration [2]. Despite their effectiveness, permanent stents are associated with complications including encrustation, patient discomfort, "forgotten stent" incidences, and the need for a removal surgery [1],[3]. Bioabsorbable ureteral stents present a promising alternative; however, localized corrosion, potentially caused by the coiling and straightening processes, has been reported by industry partners HydruMedical S.A. This project's initial phase focuses on developing a computational framework to assess the mechanical performance and corrosion behaviour of bioabsorbable ureteral stent designs.

MATERIALS AND METHODS:

Computational analysis was performed in ABAQUS/Implicit, using geometries generated via MATLAB by sweeping sketches along predefined guide curves (Fig. 1a), and meshed using functions within the Gibbon toolbox. The stent comprised of a hollow tube with a 180° pigtail loop at the proximal (kidney) end. A frictionless, hard contact interaction was initially defined. The simulation involved insertion of a stainless-steel guidewire (Ø = 0.899 mm) through the stent lumen (ID = 1 mm) to replicate the straightening during deployment.

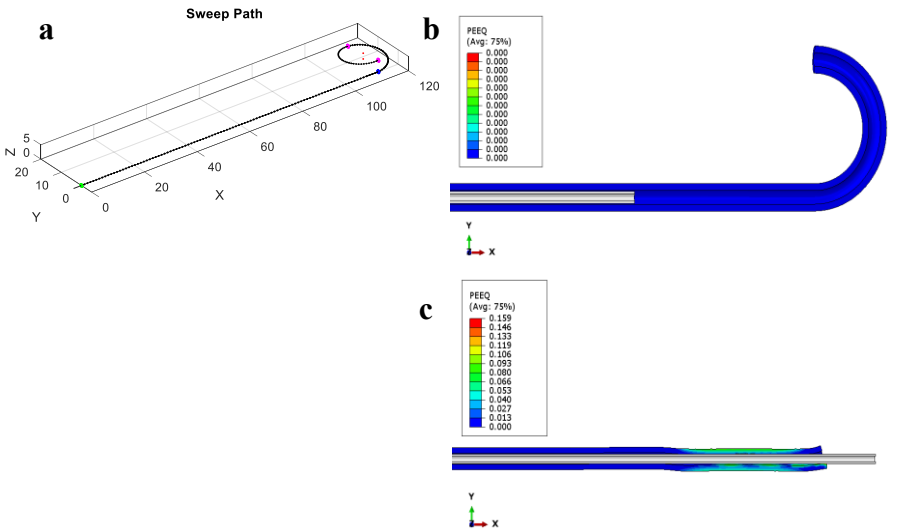

***Figure 1**. (a) Initial guide curve for stent, (b) Stent-Guidewire pre-deployment, (c) Stent-Guidewire post-deployment*

RESULTS AND DISCUSSION:

Figure 1b shows a cross-sectional view of the undeformed stent–guidewire assembly, while Figure 1c depicts the deformed configuration post-guidewire insertion. Peak stress during straightening reached 321.25 MPa, above the specified yield strength of magnesium (Mg), thus plastic deformation was observed, with peak plastic strains of 15.9%. This indicates that straightening induces localized plasticity, which may compromise stent anchorage and accelerate corrosion. The analysis was limited to a single 180° pigtail loop; however, ureteral stents typically feature 2–3 full coils. Additionally, the plastic strain caused by the coiling manufacturing process was not accounted for in this simulation. Future work will incorporate a computational model of the coiling process to quantify residual stress and strain in the Mg wires, thus informing design optimisation for enhanced mechanical and corrosion performance.

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Abstract

Sm16 (also known as SPO-1 and SmSLP), an immunomodulatory peptide secreted by cercariae and eggs (liver and intestinal) of Schistosoma, has vaccine and biotherapeutic potential.

Winrow, D.[1], Donnelly, S.[1], Dalton, JP.[1], Hoffmann, KF.[2], Forde-Thomas, J.[2], and Lalor, R.[1].

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2. Department of Life Sciences, University of Aberystwyth

Sm16, a ~16kDa protein (Smp ID AAD26122) secreted by *Schistosoma mansoni* belongs within a family of helminth defence molecules (HDMs), exclusive to trematode species and first described by our group in *Fasciola hepatica*. It is secreted from the acetabular gland of the cercariae during skin invasion and is believed to perform an immune-suppressive function, protecting the invading parasite from innate immune cell attack. It represents a potential vaccine target to prevent infection either alone or within a cocktail.

We found that Sm16 is also highly expressed in eggs and their secretions, confirmed by PCR, immunoblot and immunohistochemical analysis of Sm16 in eggs within both intestinal and liver tissue of infected mice. However, Sm16 was not associated with male or female adult worms, suggesting that the molecule is of significant importance in the inflammatory response to eggs.

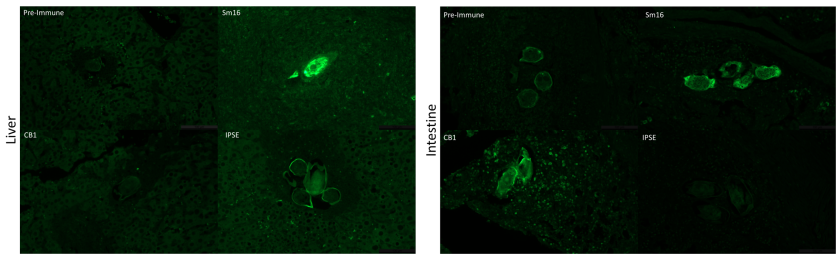

Figure 1. Staining of Sm16 in eggs found in the liver and intestine of mice at seven weeks post-infection with *S. mansoni*. CB1 is present in just the eggs of the intestine and popular target IPSE is only found in small amounts in liver eggs.

The immune-suppressive effects of a recombinant Sm16 and a synthetic derivative of Sm16 were characterised and found to preferentially bind phagocytes and internalised into the endosomal/lysosomal system, suppresses pathogen and damage associated inflammatory responses *in-vitro*, and ameliorated the inflammatory effects of dextran sulfate sodium (DSS)-induced colitis in a mouse model of inflammatory bowel disease (IBD).

These results offer new insights into the structure and function of a well-known immunomodulatory molecule, Sm16, and places it within a wider family of trematode-specific small molecule HDM immune-modulators with immuno-biotherapeutic possibilities. We are currently investigating the function of Sm16 in schistosomes, particularly it's immunomodulatory role in the induction of inflammation and in facilitating egg release into the gut lumen. These studies could open up new strategies for novel vaccine or drug design aimed at alleviating the inflammatory responses induced by schistosomes.

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Abstract

Optimised Cole-Cole Model for Dielectric Properties of Diseased Human Trabecular Bones at Microwave Frequencies

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The dielectric properties (permittivity and conductivity) of biological tissues determine how electromagnetic waves interact with the tissue. These dielectric properties are routinely integrated into electromagnetic numerical simulations using parameteric models, such as Debye and Cole-Cole models. Owing to the multiple relaxations in the relative permittivity of the biological tissues, the Cole-Cole model is widely used for accurately capturing the relative permittivity. The aim of this study was the optimisation of one-pole Cole-Cole model parameters to model the dielectric properties of cortical, normal trabecular, and diseased human trabecular bones (osteoporotic and osteoarthritic) over the frequency range of 0.5 – 8.5 GHz. The dielectric properties of cortical and normal trabecular bone were acquired from the study of Gabriel et al [1]. whereas the dielectric properties of the diseased human trabecular bones were previously measured by the authors. Our study employs the weighted least squares (WLSM) method to optimise the one-pole Cole-Cole model parameters. The accuracy of the developed Cole-Cole model is validated by comparing the measured dielectric properties with the calculated results. Fig. 1 shows the measured and calculated dielectric properties of cortical, normal trabecular, and diseased trabecular bones over the range of 0.5 – 8.5 GHz. It can be observed that the calculated properties from the one-pole Cole-Cole model are in good agreement with the measured properties. The proposed one-pole Cole-Cole model parameters will provide a reliable approach for accurately characterising the dielectric properties of normal and diseased human trabecular bones, supporting a wide range of electromagnetic simulations and device designs for bone health monitoring applications.

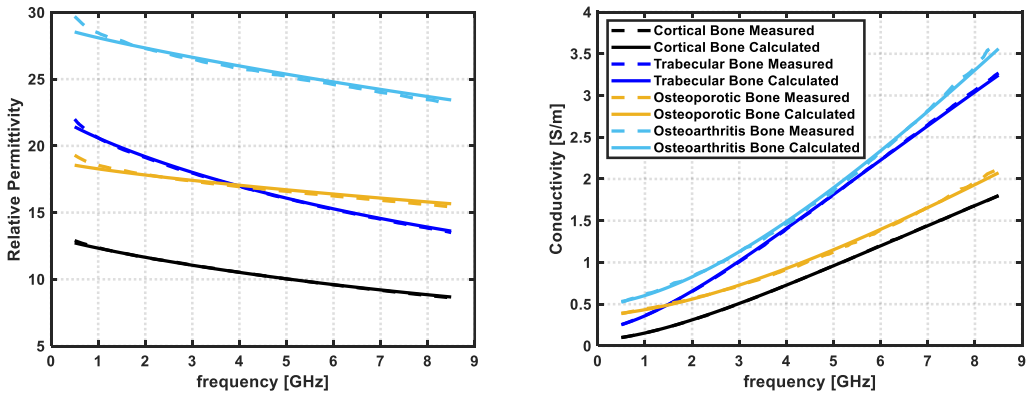

Figure 1: Measured and calculated dielectric properties of cortical, normal trabecular, and diseased trabecular bones over 0.5 – 8.5 GHz frequency band: (a) Relative Permittivity (b) Conductivity.

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College of Science and Engineering, Research and Innovation Day 2025

Abstract

Serpins of the human trematode parasites *Schistisoma mansoni* and *Fasciola hepatica*

Kilbane, T [1], Lalor, R [1], López Coralles, J [1], De Marco Verissimo, C [1], Dalton, JP [1].

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Schistosomiasis is a neglected tropical disease caused by the trematode *Schistosoma* spp. Schistosomiasis has been reported in 78 tropical countries; in 2018 it was estimated that at least 290 million humans were affected by the disease. One of the main species affecting humans is *Schistosoma mansoni*. At least eight serpins have been identified in the *S. mansoni* genome of which only one serpin is specific to the infectious skin-penetrating cercariae. This is known as *S. mansoni* serpin C (SmSrpC) and it known to be secreted as the parasite migrates to the blood vessels.

In this study, we have functionally expressed a recombinant SmSrpC and shown that its inhibitory profile against a panel of serine proteases, especially Bovine Thrombin (BT). Thrombin is an enzyme central to the coagulation cascade where it converts fibrinogen into fibrin which forms an extensive meshwork that surrounds the aggregated platelets to form blood clots. The recombinant SmSrpC exhibits inhibitory constant (K_i) against BT is <2 nM. A related trematode parasite studied by our laboratory is the *Fasciola hepatica* (liver fluke), a globally distributed infecting a wide range of mammalian hosts, including humans and their livestock. Seven distinct are expressed by this parasite as it develops within its definitive host. *F. hepatica* serpin-1 (FhSrp-1) is an inhibitor of Kallikrein (K_i = 40 nM), whilst *F. hepatica* serpin-2 (FhSrp-2) potently inhibits chymotrypsin (K_i = 0.07 nM) and serpin-6 (FhSrp-6) showed a similar inhibitory profile to FhSrp-2, where its K_i was 1.38 nM against chymotrypsin. Of note, the serpins found in the liver fluke do not show any inhibition towards Thrombin.

This ongoing research will focus on the novel inhibitory profile of SmSrpC compared to previously characterized serpins of other trematode parasites and the future of these unique serpin as a potential, vaccine target or bio-therapeutics.

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Abstract

Design, Synthesis and Evaluation of Novel Glycomimetics as Galectin Inhibitors

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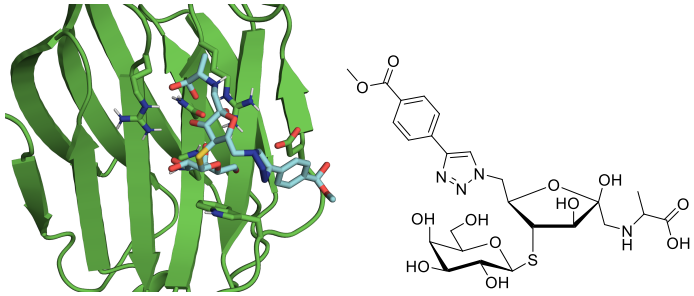

Figure 1. (Left) Molecular docking pose of Thiolactulose derivative bound to gal-3 CRD (PDB Code: 2NMO) using Autodock Vina. (Right) Chemical structure of the Thiolactulose derivative drawn using ChemDraw.

Galectins are carbohydrate-binding proteins that contain at least one carbohydrate recognition domain (CRD) with an affinity for β-galactoside containing carbohydrates. Galectins play key roles in normal physiological functions including modulating the immune system and in inflammation, but are also implicated in many pathophysiological processes including cancer progression and metastasis, heart failure and rheumatoid arthritis. Although the highly conserved nature of the galectin CRDs enables the specificity for β-galactosides, it simultaneously makes the design of selective antagonists challenging. A promising strategy to target these proteins demonstrated by the Blanchard group is using glycomimetics.

Glycomimetics are compounds that mimic the structure and function of endogenous carbohydrates with strategic modifications to improve binding affinity and other drug-like properties such as metabolic stability and oral bioavailability. PyMOL and AutoDock Vina were used to explore the structure of the gal-3 CRD and to evaluate predicted binding affinities and protein-ligand interactions of potential compounds using molecular docking. These computational studies guided the structure-based design and optimisation of target compounds. A library of these compounds has been synthesised using established synthetic methodologies such as amide coupling and copper-catalysed azide-alkyne cycloaddition (CuAAC), and characterised through NMR and mass spectrometry. The binding affinities of the synthesised compounds will be assessed against a panel of galectins, and protein-ligand interactions will be investigated using techniques such as STD-NMR and X-ray crystallography. The resulting data will inform the structure-based design of the next generation of ligands.

Acknowledgements: College of Science and Engineering PhD Scholarship, University of Galway.

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Abstract

FOXP1 Dysregulation and its Association with Schizophrenia and Cognitive Function

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INTRODUCTION

Rare mutations in FOXP1 (Forkhead-box protein P1), a transcription factor crucial for cortical neural development, cause FOXP1 syndrome, characterized by developmental delays, intellectual disability, with or without autistic features. Common SNPs within the gene are associated with schizophrenia (SCZ) and cognitive function. In this study, we investigated FOXP1's contribution to these phenotypes using RNA-seq data from FOXP1 loss-of-function models.

MATERIALS AND METHODS

We analyzed transcriptomic data from mouse and human models of FOXP1 loss-of-function at different developmental stages, including neural stem cells from embryonic mice (E14.5) and human brain organoids (equivalent to second trimester), and cortical tissues from different postnatal stages P0, P7, and P47 (equivalent to newborn, childhood and adolescence respectively). Linkage disequilibrium score regression assessed if FOXP1-regulated genes were enriched for SCZ, IQ and EA heritability. Gene-set enrichment analysis investigated if FOXP1-regulated genes were enriched for SCZ-associated genes reported as differentially expressed in single cortical cell studies. SynGO analysis mapped FOXP1-regulated genes to synaptic locations and functions.

RESULTS AND DISCUSSION

FOXP1-regulated genes are enriched for SCZ heritability, with significant results for E14.5, P7 and P47 but not P0. The P7 gene-set showed the strongest enrichment for SCZ-associated genes from single cortical cell studies. FOXP1-regulated genes at both P7 and P47 were involved in multiple synaptic functions and were mainly enriched within glutamatergic excitatory neurons, with P47 also showing enrichment within GABAergic inhibitory neurons across regions of the postnatal cortex. Prenatal FOXP1-regulated genes were enriched in progenitor cells and also mapped to the synapse. Genetic risk for SCZ within FOXP1-regulated genes follows a dynamic trajectory across developmental stages, showing stronger effects at timepoints that map to second trimester, childhood, and adolescence.

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Abstract

DEVELOPMENT OF A MICROWAVE BONE IMAGING DEVICE: TOWARD NON-INVASIVE BONE HEALTH ASSESSMENT

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Osteoporosis, characterised as low bone mass, causes continuous systematic deterioration of the trabecular bone structure and leads to bone fragility and fractures. Approximately 300,000 people over the age of 50 years suffer from osteoporosis in Ireland. Currently, a dual-energy X-ray absorptiometry (DXA) scan is employed to measure the bone mineral density of the trabecular bone. However, DXA is not cost-effective, as the scan is time-consuming, and the device is not portable. Moreover, DXA uses ionising radiations, and therefore, frequent DXA scans are associated with long-term health risks. Therefore, a portable diagnostic device that does not use ionising radiation is required for the monitoring of osteoporosis. Recent studies have highlighted that bone demineralisation alters the dielectric properties of bone tissue. Microwave imaging (MWI), a non-invasive modality capable of reconstructing dielectric profiles *in vivo*, offers the potential for detecting these changes and monitoring bone health. Despite this potential, no dedicated MWI system currently exists for *in vivo* bone imaging in the microwave frequency range. To address this gap, we have developed a novel MWI prototype at the Translational Medical Device Lab (TMDLab), University of Galway, tailored specifically for bone health assessment, including osteoporosis and other degenerative bone conditions. Moreover, we have developed a customised microwave tomography (MWT) reconstruction algorithm. As part of this development, we have fabricated and tested our first set of anthropomorphic calcaneus phantoms, representing both osteoporotic and osteoarthritic conditions. Using the specialised bone imaging prototype, we achieved promising results: the two types of phantoms were differentiable with an average dielectric contrast of approximately 25%. Furthermore, the target region—trabecular bone—was accurately localised in all cases, and its condition was correctly identified from the reconstructed dielectric maps, demonstrating a Structural Similarity Index (SSIM) of at least 82%. We are currently refining the prototype by integrating dedicated bone imaging antennas to enhance spatial resolution and improve the accuracy of the reconstructed tomographic images. These developments bring us closer to realising a clinically viable, portable MWI system for non-ionising, longitudinal monitoring of osteoporosis and related bone disorders.

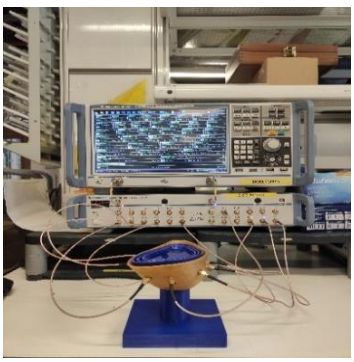

Figure 1: Imaging setup with multilayered calcaneus phantom.

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Abstract

TIGIT blockade may enhance Natural Killer cell cytotoxicity against Ovarian Cancer cell lines.

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Introduction: Ovarian Cancer is the most lethal gynaecological malignancy[1]. Chemotherapy is effective initially; however, most women relapse and develop chemotherapy-resistant tumours. Thus, there is a pressing need to develop novel therapies to increase patient survival. While immunotherapies have revolutionised the treatment of many cancers, Ovarian Cancer has benefitted little from the success. We sought to uncover the mechanisms of immune dysfunction in Ovarian Cancer, to uncover novel immunotherapeutic targets. Natural Killer (NK) cells are an attractive candidate for immunotherapy. However, expression of inhibitory receptors, i.e. TIGIT, within the tumour may inhibit NK cell cytotoxicity[2]. We investigated TIGIT expression on NK cells and hypothesised that TIGIT blockade may enhance NK cell cytotoxicity.

Materials and Methods: NK cells were expanded from murine spleens with IL-15. TIGIT expression was analysed by flow cytometry. A co-culture assay was used to examine NK cell cytotoxicity against mouse ID8 Ovarian Cancer cells. The proportion of dead tumour cells, and CD107a expression on NK cells was analysed by flow cytometry. Using an anti-TIGIT monoclonal antibody, we examined the effects of TIGIT blockade on NK cell cytotoxicity against ID8 cells.

Results and Discussion: NK cells express high levels of TIGIT when cultured with IL-15 (**Fig.1a**). NK cells are highly cytotoxic against ID8 cells, resulting in significant tumour cell death (**Fig.1b**). TIGIT blockade enhances NK cell cytotoxicity, resulting in increased tumour cell death (**Fig.1c**) and CD107a expression. These results suggest that TIGIT is a potential therapeutic target in Ovarian Cancer. TIGIT blockade may reduce Ovarian Cancer burden *in vivo* by promoting potent NK cell cytotoxic responses. Importantly, TIGIT is also expressed by CD8 T cells and thus TIGIT blockade may have dual functions in enhancing cellular cytotoxicity to limit tumour growth. Ongoing work is using tumour conditioned media to understand the mechanisms of NK cell suppression in Ovarian Cancer.

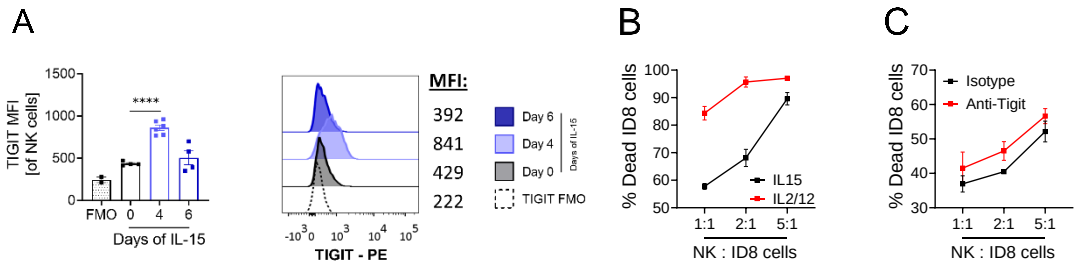

Figure 1. NK cells are highly cytotoxic against mouse ID8 Ovarian cancer cells.

TIGIT expression was analysed by flow cytometry (**A**). NK cells were purified and stimulated over night with IL15 or IL-2 and IL-12. NK cells were co-cultured with ID8 Ovarian Cancer cells for 24 hr and tumour cell death was analysed by flow cytometry (**B**). NK cells were co-cultured with ID8 tumour cells +/- anti-TIGIT monoclonal antibodies for 4 hr and tumour cell death was analysed by flow cytometry (**C**).

References: [1] Coburn et al. *Int. J. Cancer* (2017). [2] Zhang et al. *Nat Immunol* (2018)

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Abstract

Modulating macrophage behaviour in the Foreign Body Response

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INTRODUCTION

Macrophages are pivotal in initiating and modulating the foreign body response (FBR)[1]. They exhibit high flexibility in polarisation states in response to environmental cues such as mechanical stimuli[2]. They can function as pro-inflammatory (M1) or pro-healing (M2) phenotypes. The proportion of these subsets is an important determinant in the fate of the wound healing response[3]. Our group has shown that actuation of a mechanotherapeutic implant causes strain of the implant and underlying tissue, and results in fluid flow at the tissue interface, which modulates the FBR and improves therapy delivery[4,5]. Knowing that macrophages are mechanosensitive cells[6], in this study, we aim to apply fluid shear stress to macrophages and study their resulting behaviour. We hypothesise that the applied fluid shear stress will promote the pro-healing phenotype.

MATERIALS AND METHODS

Bone marrow derived macrophages (BMDMs) were isolated from C57BL6/J mice. Briefly, the bone marrow of femur and tibia bones was extracted into DMEM, red blood cells were lysed, and cells were filtered and resuspended in media. Then cells were plated in DMEM with 20% L929 conditioned media and cultured for 7 days. Cells were harvested, resuspended at $4x10^6$ cells/mL and seeded on Superfrost™ Plus microscopic slides. After 24 h, 0.1 Pa fluid shear stress at 0.5 Hz was applied to the cells for 10 minutes daily for 2 days (fluid flow) using a parallel plate flow chamber and compared to static controls. Microscopic images were taken and two macrophage activation markers (CD11b, and F4/80), and viability (live/dead Aqua dye) were measured using flow cytometry and presented as mean fluorescent intensity (MFI).

RESULTS AND DISCUSSION

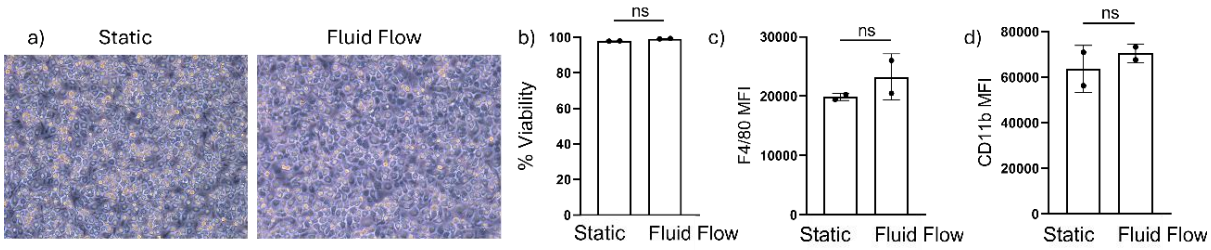

Figure 1. a) Microscopic images of Static vs Fluid flow groups at day 2. Flow cytometry results showing **b)** cell viability, **c)** CD11b, and **d)** F4/80 at the end of the study. Ns = not significant.

Preliminary data (n=2/group) showed that there is no significant difference in cell viability in response to the fluid flow regimen, Figure 1 a-b. Interestingly no difference was seen in both CD11b and F4/80 markers, Figure 1 c-d. It has been shown that interstitial flow (3 µm/s), and oscillatory shear stress (0 ± 4 dyn/cm²) polarises macrophages into an M2[7], and M1[8,9] phenotypes respectively. The fluid flow profile we are using induces a mild to moderate shear stress, so we hypothesise that it will promote a pro-healing M2 phenotype. Ongoing work is interrogating M1 (CD11c and CD86) and M2 (CD163 and CD206) macrophage markers, as well as TNF (an inflammatory cytokine produced by M1 macrophages) levels to explore this hypothesis.

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Abstract

Analysis of a Patient Backlog-Resources Model for Pandemic Surge and Response

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INTRODUCTION

Healthcare systems face mounting challenges from aging populations, chronic illnesses, and disruptions like the COVID-19 pandemic. These factors increase demand on healthcare services, leading to growing concerns about access, quality, and backlog management. Modelling approaches such as system dynamics help capture the interplay of demand, resources, and policy through the means of identifying feedback loops. A key tools for understanding feedback-driven behaviour in such systems is the Loops That Matter (LTM) algorithm. This study applies the loop dominance analysis to explore feedback loop dominance in a healthcare backlog model, offering insights into system behaviour during a pandemic surge.

MATERIALS AND METHODS

We developed a system dynamics model simulating pandemic-driven backlogs in regular care, incorporating surge resources, work pressure, and quality of service. A pandemic surge is modelled as a temporary increase in treatment time, triggering backlog growth. The model includes feedback loops reflecting overtime and quality-induced rework. Loop dominance was analysed using the LTM algorithm, implemented in Stella.

RESULTS AND DISCUSSION

Simulation results show that pandemic-induced increases in treatment time significantly raise patient backlog levels. Overtime work and surge resources help mitigate backlogs, but the latter leads to quality-related rework, increasing revisits. Loop dominance analysis reveals shifts in feedback control during the surge: B5 dominates under normal conditions, B7 under overtime, and B1/R1 when low-quality surge resources are added. The LTM method effectively captures these transitions. These insights support the design of adaptive policies that balance short-term relief with long-term system resilience.

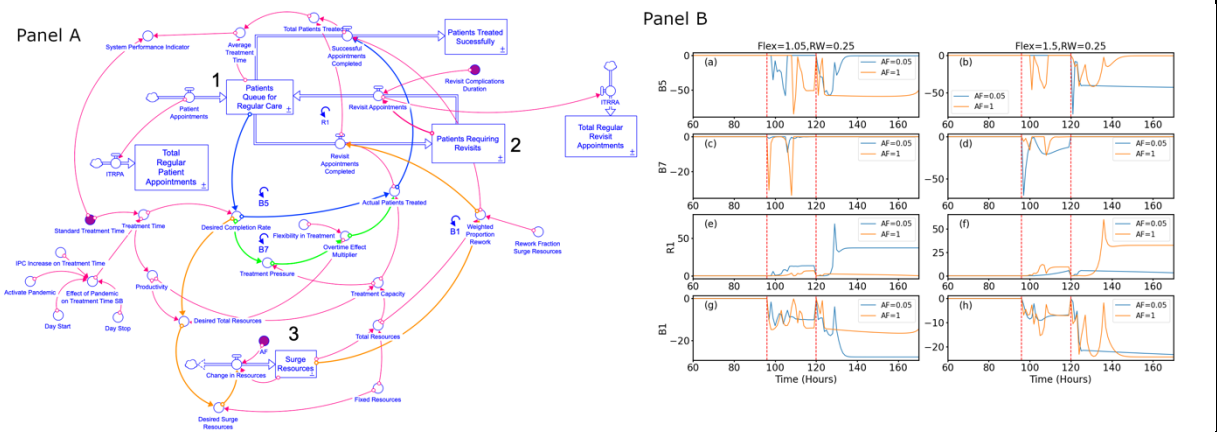

Figure 1. ***Panel A****: The Patient Backlog-Resource model showing the feedback loops and important variables driving the dynamics during pandemic driven surge in demand.* ***Panel B****: Loop dominance scores over time under flexible work and rework conditions due to quality of surge resources..*

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Abstract

Covariate-Adjusted Adaptive Reference Ranges in Longitudinal Data Monitoring

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INTRODUCTION

Clinical reference ranges are crucial for interpreting laboratory test results, particularly biomarkers, in medical diagnostics. In particular, in recent years, the introduction of adaptive reference ranges has played a crucial role in personalized monitoring, allowing for the detection of abnormal values while accounting for an individual's biomarker variability over time. However, when tracking biomarkers longitudinally, other clinical and physiological factors may influence biomarker fluctuations. Existing literature on adaptive reference ranges has yet to incorporate such covariates effectively, which is essential for achieving more accurate and reliable diagnoses.

MATERIALS AND METHODS

In this presentation, we propose a novel statistical method based on a Mixed Effects Modelling framework to integrate relevant clinical and physiological factors into the generation of adaptive reference ranges, enhancing their diagnostic utility and precision. Specifically, the Expectation-Maximization (EM) algorithm will be employed to estimate model parameters, enabling the derivation of covariate-adjusted adaptive reference ranges. The proposed method was implemented on real data collected from the longitudinal monitoring of athletes in the sports science domain, considering both constant and time-varying covariates.

RESULTS AND DISCUSSION

The results demonstrated that the proposed covariate-adjusted dynamic reference ranges effectively monitor individual biomarkers, particularly when a strong correlation exists between the covariates and the primary biomarker. However, in the absence of such a strong correlation, the covariate-adjusted and regular adaptive reference ranges yielded similar results. We believe, our proposed method strengthens personalized monitoring, offering a more effective tool not only for clinical and sports science applications but also for any domain involving longitudinal monitoring (e.g., environmental monitoring).

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Abstract

VIRAL INACTIVATION (VIN) PROCESS MONITORING BY POLARIZED FLUORESCENCE SPECTROSCOPY

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INTRODUCTION

Monoclonal antibody (mAb) therapeutic manufacturing is a highly intricate process that requires meticulous control of cell cultures, purification, and quality assurance to ensure therapeutic efficacy and safety. One step of mAb purification is viral inactivation (VIN), which incorporates a low- pH incubation of mAb feedstock to reduce the levels of infectious enveloped viruses. However, this can also impact protein stability, destabilising the mAbs and lead to unwanted aggregation. Here we explore the use of a multichannel spectrofluorometer (Aqualog, Horiba) capable of rapid (<1 min.) polarized Excitation Emission Matrix (pEEM) measurements as a robust tool for on-line monitoring of protein aggregation during VIN.

MATERIALS AND METHODS

Polarized Excitation Emission Matrix (pEEM) is a sensitive, non-destructive, spectroscopic method can be used to rapidly assess aggregation, stability, and protein concentration in one measurement. pEEM provides several sources of information: Rayleigh scatter for aggregate/particle formation, fluorescence emission to assess chemical and structural changes, and absorbance of UV light to assess protein concentration. This data can be compared to conventional measurements from dynamic light scattering (DLS) for particle size, UV-Vis Spectroscopy (concentration), and size exclusion chromatography (SEC) for aggregation profiles.

RESULTS AND DISCUSSION

The fluorometer operating in vertical-vertical (VV) polarization mode is more sensitive to early- stage aggregation indexes than traditional UV-Vis spectroscopy. The ratio of the Rayleigh to Fluorescence (I_R/I_F) from EEM_{VV} spectra increases with the degree of aggregation and correlates non- linearly (Figure 1) with the Polydispersity Index (PDI) width (nm) from DLS, showing an increasing level of aggregates. These results show that aggregation can be monitored by a single, on-line polarized fluorescent spectroscopy method via the Horiba Aqualog and show robust data comparable to traditional measurement methods.

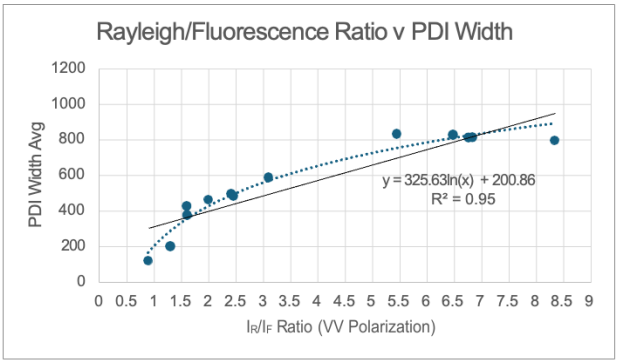

***Figure 1**: Plot of I_R/I_F ratio (VV polarization) versus PDI width (from DLS). The correlation is non-linear but fits to a simple function.*

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Abstract

nf-hlamajority: a Nextflow pipeline for consensus MHC class I genotyping and its application to neoantigen identification in breast and lung cancer stromal cells

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* These authors jointly directed this work

INTRODUCTION

Cancer-associated fibroblasts (CAFs) in the tumour microenvironment can support tumour progression and therapeutic resistance, representing potential therapeutic targets. Here, we aim to identify neoantigens resulting from somatic mutations in CAFs. HLA genotyping, a critical step for neoantigen prediction, can be performed using DNA sequencing data, with various tools available. Claeys et al. (PMID:37161318) found that a majority voting approach improved HLA typing performance. No end-to-end pipeline exists to apply this approach, making it difficult to implement. We aimed to: 1) develop a Nextflow pipeline implementing majority voting for MHC class I typing from DNA sequencing, and 2) identify neoantigens in CAFs using these HLA calls.

MATERIALS AND METHODS

We performed whole-exome (WES) and bulk RNA sequencing on cultured CAFs and matched normal fibroblasts from 11 breast and 10 lung cancer patients. Using our pipeline, *nf-hlamajority*, we conducted HLA typing on WES data from these patients and 12 NCI-60 Cancer Cell Lines using four tools. The pipeline assigned the HLA genotypes using majority voting. These genotypes were input to Landscape of Effective Neoantigens Software (LENS), along with the WES and RNA-sequencing data, to identify CAF-specific neoantigens.

RESULTS AND DISCUSSION

Pipeline validation on NCI-60 data showed 97% accuracy compared to PCR-based genotyping. LENS identified potential neoantigens from missense mutations, with more high-confidence expressed mutations in lung cancer CAFs versus breast cancer CAFs (FDR-adjusted $p = 0.00997$). All mutations were private, although two lung cancer CAF samples had a mutation in the *COASY* gene. Notably, affected genes implicated lipid metabolic pathways, relevant to CAF biology and tumour immunogenicity.

We developed an automated pipeline for consensus HLA genotyping, enabling the identification of candidate neoantigens in breast and lung cancer CAFs. Future work includes validation using T-cell immunogenicity assays and single-cell RNA sequencing to investigate the subpopulation distribution of our candidate neoantigens.

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Abstract

Single-cell transcriptomic profiling of human bone marrow-derived mesenchymal stem cells in type 2 diabetes

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INTRODUCTION

Diabetes is a chronic disorder affecting 589 million people worldwide (IDF Diabetes Atlas 2025). It presents a persistent increase in blood glucose levels as a result of ineffective production or utilisation of insulin. Among the three types of diabetes, the most widespread, type 2 diabetes mellitus (T2DM), is marked by beta cell dysfunction along with insulin resistance (Abel et. al., 2024, PMID: 39059357). Diabetic osteopathy, or bone disease, is a significant comorbidity of diabetes and is characterised by changes in bone microarchitecture that lead to increased fracture risk through impaired bone formation and increased bone resorption (Sharma et. al., 2024, PMID: 39606009; Shu et. al., 2021, PMID: 21424265). Current studies that consider osteopathy as a complication of diabetes, focus on lifestyle changes and pharmacological therapy to control hyperglycemia (Wu et. al., 2022, PMID: 36589835). Most of the available therapies are reactive, hence the need for therapies with preventative and/or rejuvenating potential.

AIMS AND OBJECTIVES

This study aims to identify miRNA-based therapies for T2DM-induced osteopathy. To do this, single-cell transcriptomic profiling of human bone marrow-derived mesenchymal stem cells (hBM-MSCs) will be performed. The analysis of this data will help identify miRNAs that regulate T2DM-induced differentially expressed genes (DEGs). Subsequently, we propose to develop an interactive web-based application that provides a platform for users to upload and visualise single-cell RNA sequencing datasets for miRNA target prediction and study their effects under different disease conditions.

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Abstract

Uncovering the adult *Fasciola hepatica* glycoproteome: Distinct N- and O-glycan features of the mature stage

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INTRODUCTION

We recently published a comprehensive glycoproteomic study of *Fasciola hepatica* newly excysted juveniles (NEJs), revealing a highly heterogeneous glycosylation profile across 123 glycoproteins, 71 of which are secreted by the parasite into the host environment. Given the dynamic and non-template-driven nature of glycosylation, and its crucial role in host-parasite interactions, developmental changes in protein glycosylation are likely essential for parasite survival within different host niches, such as the gut and liver (NEJs) and the bile ducts (adults). In this study, we characterized the glycoproteome of adult *F. hepatica* using an integrated glycomics and glycoproteomics approach on somatic and excretory/secretory (ES) parasite extracts. We identified 244 glycoproteins (44 in the ES fraction) and mapped 478 glycopeptides with their associated glycans. Similar to NEJs, adult worms exhibit extensive glycan heterogeneity generated by 1,914 N- and O-glycoforms. NEJs and adults co-express 82 glycoproteins, although with strikingly different glycan profiles. The present study expands the liver fluke glycan repertoire to 121 N- and 22 O-glycan structures. Some unique structures previously identified in NEJs glycoproteins, such as pentosylated O-glycans, are absent in adults. In contrast, adult express their own specific N-glycans, which are usually uniquely modified with phosphate, glucuronic acid, and phosphoethanolamine, features rare or inexistent in other worm parasites. Additionally, like identified in NEJs, adult parasites also express glycoproteins carrying phosphorylcholine-containing N- and O-glycans. While the functions of these anionic and zwitterionic glycans remain unknown, their stage-specific expression suggests developmental regulation and therapeutic potential. Altogether, we observed important differences in the glycosylation of proteins in the two major life-stages of *F. hepatica*, as well as a significant level of compartmentalization of structures (i.e., presence in Somatic and ES extracts). Many identified glycoproteins are linked to tissue invasion, immune evasion, and virulence, making them promising candidates for further functional studies and vaccine development.

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Abstract

Design and Electrical Characterisation of a Microfabricated, Shielded Impedance Spectroscopy Probe for Cancer Detection

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INTRODUCTION

Early cancer detection significantly improves patient outcomes. However, direct methods like biopsy are labour-intensive and time-consuming[1]. Electrical Impedance Spectroscopy (EIS) offers a promising alternative for rapid screening, particularly for endoscopically accessible malignancies such as cervical, colorectal, and oral[2,3] cancer. But, EIS performance is affected by factors such as temperature, probe layout[4–6], contact force[5,7], and requires further advancement to enable successful application. In our previous work, we explored different electrode configurations and layouts for EIS-based tissue characterisation[4,8]. We also developed detailed protocols for the electrical characterisation of such probes[9]. However, probe miniaturisation remains a key limitation, narrowing the frequency range and limiting EIS use in cancer diagnosis[6,8]. A promising solution based on concentric ring geometry was proposed by Veil *et al.*, providing increased electrode surface area for improved tissue contact[6]. In this study, we investigate a custom-designed concentric probe inspired by this layout, aimed at improving performance while maintaining low-cost manufacturability.

MATERIALS AND METHODS

Building on the work by Veil *et al.*, who developed a <2 mm concentric ring probe via microfabrication, we manufactured 4.1 mm and 6.2 mm versions using standard PCB processes. Four rings make up the Kelvin-type EIS sensor (aka probe) with an additional outer ring added to assess the effect of shielding on measurements. This outer ring increases the overall probe diameters to 8.5 mm and 13.3 mm for the small and the large probes, respectively (Fig. 1a). The probes connect to a custom designed adapter (Fig. 1b) for impedance analysers (e.g. Keysight E4980AL/E49990A) and can be operated similarly to an open-ended coaxial probe[10]. The dimensions of the ring electrodes were matched for equal surface areas, 1.45 mm² (small) and 4.52 mm² (large), with constant spacing (0.3 mm for both probes). Connections were made using PCB vias and soldered enamelled copper wires. The probes were mounted to stainless steel (type 304) shielding tubes (Fig. 1c) with silver paint (RS123-9911).

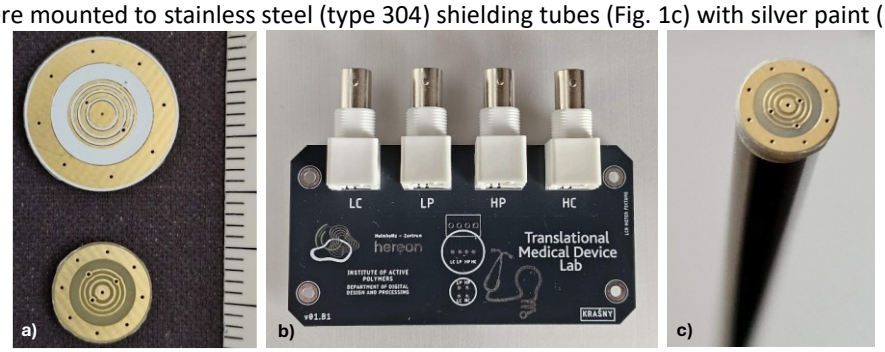

Fig. 1 a) Top view on the two (small and large) concentric probes demonstrated in this study, The outer ring with multiple vias is the shield, while inside rings (each with only 1 via) forms a 4 electrodes of the bioimpedance probe b) a custom designed adapter for probe connection to impedance analysers with the use of a standard BNC connectors; c) top view on the small version of the probe mounted on the stainless steel shielding tube.

RESULTS AND DISCUSSION

Both probes were characterised following the procedure described in our previous work[9], using four saline solutions (0.01, 0.025, 0.05, and 0.1 mol/L) with known conductivities of 1.0, 2.8, 5.5, and 9.6 mS/cm, measured by a reference conductivity meter (Hanna HI99301). Measurements were performed across a frequency range of 100 Hz to 500 kHz using an LCR meter (Keysight E4980AL). The probe demonstrated reliable performance across the whole frequency range, highlighting its potential as a promising tool for bioimpedance applications including cancer diagnosis where broader frequency range is desired[11]. Future work will involve evaluating these probes through detailed tissue measurements, including ex-vivo tumour tissue.

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Abstract

Pulsatile Flow Test Rig for Implantable Vascular Sensors Bench-Top Testing

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INTRODUCTION

Abdominal aortic aneurysm (AAA) is a life-threatening condition involving the dilation of the aorta in the abdomen. AAA models are crucial for improving the understanding and assessment of disease and rupture risk to facilitate better management and treatment. In-vitro, bench-top vascular test rigs of AAA typically employ circulatory, or flow loop models driven by pulsatile pumps to simulate blood flow using fluids like glycerine-water mixtures [1,2]. These setups often use simplified rigid or compliant AAA models made of materials such as glass[1–3], polyurethane[1] or silicone[2,3]. Flow measurements are conducted using electromagnetic flowmeters[1] or particle image velocimetry (PIV)[1–3]. Current models frequently adopt idealised average geometries and may not incorporate patient-specific variations or features like the iliac bifurcation, which, in addition to unrealistic mechanical properties, can significantly influence the flow dynamics and the resulting mechanical stresses on the aneurysm wall. Understanding these conditions is key to improved treatment approaches and their validation, thus, there is a recognised need to utilise more accurate test rigs based on anatomical models[4].

MATERIALS AND METHODS

This work presents a custom-designed bench-top test rig (overview model shown in Fig. 1a), providing a versatile platform for detailed testing of vascular models and implantable sensors. Key features include a custom-designed rectangular tank (Collins Plastics Ltd.) with two circular inlets/outlets for the main supply of the pulsatile pump (UnitedBiologics FlowTek 125). Custom-designed, 3D-printed pipe adapters (Fig. 1b) enable integration with pressure sensors (Honeywell MPRLS0300YG). A dedicated data acquisition system (DAQ), based on an Arduino Nano Sense evaluation board, monitors system conditions in real-time (Fig. 1c). This DAQ can also record data from up to two rotary flow sensors (RS511-4772) and two Millar pressure sensors (SPR-524) on 1.2 mm catheters.

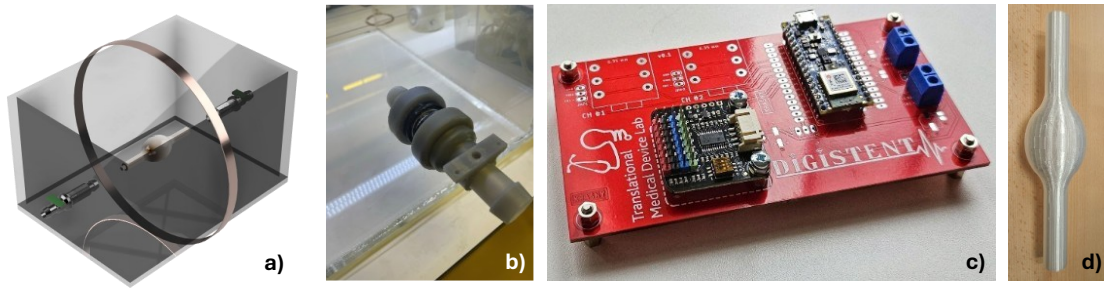

Fig. 1 Components of the described test flow rig. a) System overview with visible tank, AAA model and system components b) Custom designed and 3D printed tank inlet with insert for pressure sensor mounted to the tank wall; c) Overview of the DAQ for real-time recording of rig parameters, d) Example of simplified AAA model 3D printed from a transparent thermoplastic polymer (Sunlu TPU-95A).

RESULTS AND DISCUSSION

The modular design of the rig facilitates easy transitions between testing with simplified 3D-printed AAA models (e.g., the TPU model shown in Fig. 1d) and, in the future, more sophisticated, patient-specific 3D printed/moulded anatomical models. This setup will enable testing of implantable sensors and a detailed analysis of intra-aneurysmal pressures, flow dynamics, and 'endoleak'-related parameters. Furthermore, the rig is not limited to AAA models; it also allows application with a wider range of vascular models within a simulated physiological environment. Real-time data acquisition from multiple sensors is facilitated, with the capacity of the system for expansion to accommodate additional sensors as needed. In summary, the rig serves as a versatile platform for comprehensive testing of complex vascular models.

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Abstract

Thermodynamic Modelling to Predict Intracranial Aneurysm in Patient-Specific Geometries

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INTRODUCTION

Intracranial aneurysms (IAs) are localised dilations of cerebral arteries that pose serious health risks upon rupture, often leading to subarachnoid haemorrhage. Unruptured IAs affect 2–5% of the population, with risks influenced by factors like age, gender, genetics, hypertension, and smoking [1]. During IA evolution, significant extracellular matrix (ECM) changes occur, including elastin degradation, collagen remodelling, and loss of smooth muscle cells (SMCs) [2]. Despite advances in imaging, rupture risk assessment remains qualitative, lacking integration of patient-specific biological and biomechanical data. We present a computational framework to predict IA growth by modelling arterial tissue remodelling driven by cell-level processes.

MATERIALS AND METHODS

A constitutive law is implemented to describe; elastin and collagen pre-tension, a passive hyperelastic matrix, and active smooth muscle cell (SMC) contractility, using a model proposed in [3]. A subcellular-scale thermodynamically based framework is developed which models SMC transitions from contractile to synthetic phenotypes, as well as cellular remodelling. Growth is predicted as a competition between cell remodelling, against tissue deposition, motivated by changes in the free energy of the system relative to the homeostatic free energy. A patient-specific mesh of the internal carotid artery is created using image segmentation with SimVascular (Fig.1A), and a mesh of the vessel is created using the GIBBON toolbox (Fig.1B). A finite element model in Abaqus, incorporating the growth law via UMAT, predicts arterial behaviour under hypertensive pressures, predicting vessel growth and remodelling. Further analysis investigates elastin and SMC degradation to examine their effects on vessel growth.

RESULTS AND DISCUSSION

The effect of elastin and SMC digestion leads to an increase in vessel radius of 14% in the local fusiform patch (Fig.1C). Growth amplifies vessel dilation, highlighting the role of growth in IA development (Fig.1D). Further development of the thermodynamic framework will enable efficient and accurate modelling of patient-specific geometries. Future work will also involve capturing ECM remodelling processes including collagen deposition. In addition, cohesive zone models will be implemented to predict rupture risk. These advancements will bridge cellular and tissue-level phenomena, enabling accurate predictions of IA initiation, progression, and rupture.

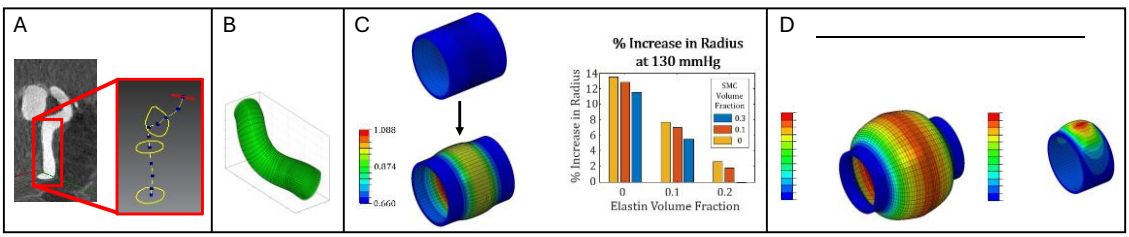

Figure. 1 (A) Image segmentation, (B) patient specific meshing, (C) Elastin and SMC degradation cause vessel dilation and aneurysm growth, (D) Thermodynamic growth predictions.

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Abstract

MACHINE LEARNING PREDICTS TRAUMATIC EXPERIENCES TO BE A RISK FACTOR FOR AUDITORY VERBAL HALLUCINATIONS IN BOTH THE GENERAL POPULATION AND INDIVIDUALS DIAGNOSED WITH PSYCHOSIS

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INTRODUCTION

Auditory verbal hallucinations (AVHs) are a core symptom of psychosis but also have a prevalence in the general population ranging from 5% to 28%.

MATERIALS AND METHODS

We aimed to identify the most strongly associated predictors of AVH from 41 sociodemographic, environmental, biological, and psychological and health measure predictors in two samples from the UK Biobank; a sample of individuals diagnosed with psychosis (n=305 voice-hearers, n=637 non-voice-hearers) and a general population sample with no diagnosis of psychosis (n=1,778 voice-hearers, n=130,771 non-voice-hearers). A third, combined sample was used to identify key predictors for distinguishing those with and without psychosis among voice-hearers. We used the machine learning (ML) XGBoost classification algorithm to develop predictive models in these samples.

RESULTS

All three models performed reasonably well with balanced accuracies of 70%, 67% and 79% in the general population sample, psychosis sample and voice-hearers only sample models respectively. For predictors of voice-hearers, there were consistent results for both the general population and psychosis samples where passive suicidal ideation, measures of distress and traumatic experiences were strong predictors of voice-hearing in both samples. In addition, smoking cannabis was a predictor of voice-hearing in the general population sample, while anxiety was a predictor of voice-hearing in the psychosis sample. Among voice-hearers only, mental distress, seeking professional help, self-harm, deprivation index, and employment status were predictors of psychosis

DISCUSSION

ML analysis indicates that traumatic experiences are useful temporal predictors of AVHs, confirming hypotheses put forward in the literature that these are contributory factors for AVHs.

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Abstract

A Multi-method Study Evaluating the Inference of Compartmental Model Parameters from a Generative Agent-Based Model

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INTRODUCTION

Compartmental models are a common tool in modelling the spread of an infectious disease. In these models an equation represents the movement of the population between each compartment and a set of parameters drive the dynamics of the model. The parameters in the model can be found through calibration. Although we can understand how well our calibrated model fits to the reported data, we do not know how well the model fits to the reported and unreported data or the true parameter distributions of the system. We propose using data generated from an agent-based model for different isolation and vaccination scenarios, where we will know all underlying parameters and data, to understand what methods of model calibration are most accurate compared to the ground truth and to understand how changing contact patterns can impact the effective parameters.

MATERIALS AND METHODS

An agent-based model is used to generate synthetic datasets of infectious disease outbreaks. A set of two estimation models, Nelder-Mead with bootstrapping and Hamiltonian Monte Carlo (HMC), are used to calibrate the synthetic data sets to a compartmental model. Model accuracy and calibrated parameter distributions are compared.

RESULTS AND DISCUSSION

The two calibration methods perform similar in terms of accuracy. However, HMC is better able to capture the ground truth parameters then Nelder-Mead. As can be seen in Fig. 1, the effective infectious period is sensitive to the changes in isolation and the proportion of susceptibles.

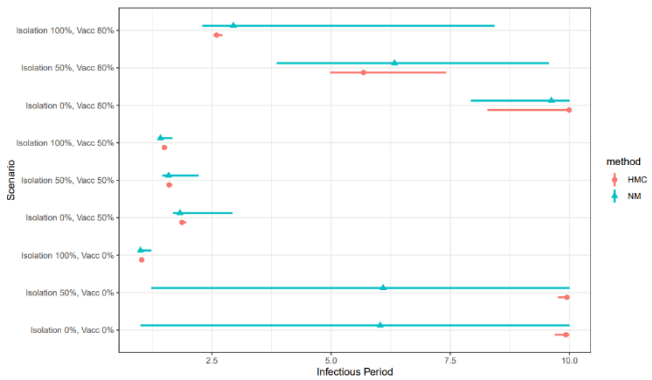

Figure 1. 95% Quantiles for the calibrated model parameter for both the infectious period HMC and Nelder-Mead calibration methods across nine different vaccination and isolation scenarios

Understanding how the effective parameters change as contact patterns and vaccination rates change can provide valuable information in understanding how to interpret parameters calibrated from real world data.

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Abstract

Development of a liquid biopsy test for Ovarian Cancer using Fragmentomic Characterization of blood samples.

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INTRODUCTION

Liquid biopsies are non-invasive tests that detect genetic material shed from tumors into bodily fluids, such as blood, urine, or tears. This approach allows for real-time or longitudinal monitoring of cancer dynamics, enabling early detection, tracking of disease progression, and assessment of treatment response. Fragment analysis of cell-free DNA (cfDNA) in the biological fluid of interest allows the detection and classification of the circulating tumor DNA (ctDNA), fragments released from cancer cells following apoptosis or necrosis. The characteristics of these fragments, for example, their size and distribution, as well as their molecular profiling (mutations, methylation status etc.) may indicate the type of cancer or its stage, as well as providing a measure of tumor heterogeneity, a crucial step for providing personalized treatment strategies.

MATERIALS AND METHODS

This study includes plasma samples from 7 non-cancer controls and ascites samples from 7 ovarian cancer patients. Library preparation and sequencing was carried out using PacBio's Onzo sequencing protocol and computational analysis was performed using the FinaleDB, cfDNApipe, and OpenGene ctDNA workflows.

RESULTS

Results are grouped into four main categories: fragment profile (fragment length), fragmentation patterns (window protection score, WPS), end-motif analysis, and variant analysis. A significant distinction in fragment length distribution was observed between the cancer and the normal plasma samples as well as significant differences in their end motif k-mer usage. A number of SNPs were also identified for further follow-up.

DISCUSSION

Fragmentomic analysis can determine the presence of cancerous cells without the need for invasive biopsies, and may prove especially useful for early detection and continuous monitoring of cancer. Future work will focus on additional multi-omic analysis including the integration of window protection score and methylation profiles.

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Abstract

Manipulation of nucleotide pools to resensitize *Staphylococcus aureus* and *Pseudomonas aeruginosa* to existing antibiotics

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2.

INTRODUCTION

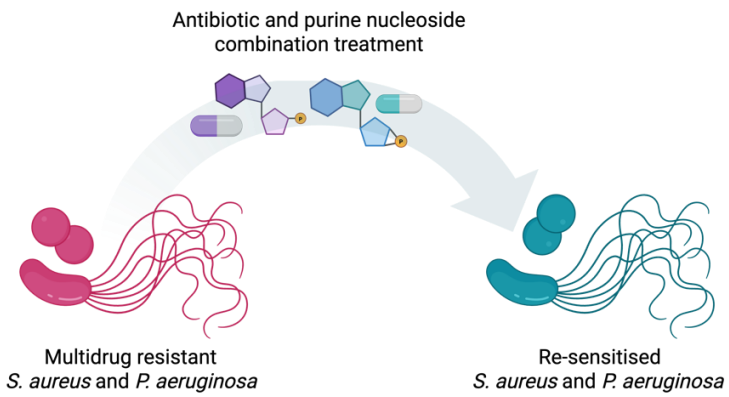
Finding novel, innovative and sustainable ways to preserve the efficacy of currently-licensed antimicrobial drugs is a central part of efforts to address the antimicrobial resistance (AMR) crisis. This project aims to enable re-purposing of antibiotics as part of efforts to overcome resistance in *S. aureus* and *P. aeruginosa* as model Gram-positive and Gram-negative bacterial pathogens, whilst also investigating the effects of purine supplementation on bacterial growth. Uncovering the capacity and physiological impact of purine nucleosides on metabolism, growth and resistance of bacterial pathogens represents an exciting research avenue to be explored.

MATERIALS AND METHODS

Minimum inhibitory concentrations (MICs) of antibiotics are determined for different strains of *S. aureus* and *P. aeruginosa*. Synergistic and antagonistic activity of exogenous purine nucleoside supplementation are tested in with differing antibiotics. Growth of *P. aeruginosa* and *S. aureus* are investigated in chemically defined media (CDM) w/wo supplementation of purines to assess their effect on bacterial growth rates.

RESULTS AND DISCUSSION

Purine supplementation lead to altered growth and antibiotic resistance profiles of *S. aureus* and *P. aeruginosa* strains. C-di-AMP levels were linked to Fosfomycin and beta-lactam antibiotic resistance and growth phenotypes in *S. aureus* strains used. Uncovering the capacity, molecular and physiological impact of purine nucleosides and nucleotide signalling molecules on bacterial metabolism, growth and virulence represents a research avenue to be explored further. Purine nucleoside adjuvants will be used in new drug combinations with other antibiotics currently under investigation in our laboratory, using both *in vitro* and *in vivo* approaches, to further enhance the eradication of AMR bacteria, and to understand the fundamental molecular mechanisms behind the antibiotic resistance profiles.



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An agent-based artificial intelligence-driven 3D deformable cell framework to investigate mechanisms underlying mechanosensitive tumour growth

Senthilkumar I.[1,2,3], Vangheel J.[4], Kumar V.[3], McNamara L.[3],Smeets B.[4], Howley E.[1,2], McEvoy E.[3]

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INTRODUCTION

Tumour growth is a mechanosensitive process influenced by biomechanical feedback between the cells and the surrounding extra-cellular matrix (ECM). In this study, we developed a novel hydromechanical cell growth model, integrated with an agent-based 3D particle modelling framework and a novel artificial intelligence-driven finite element (FE) solver, to uncover the biomechanisms underlying such mechanosensitive behaviour.

MATERIALS AND METHODS

Cell volume is regulated by competing ion-driven osmotic and load-dependent hydrostatic pressures [1] (Fig. 1a). Osmotic pressure increases with impermeable biomolecule synthesis, and cell division occurs as volume approaches the critical mitotic threshold V_{crit} (Fig. 1b). We integrate our cell growth model with MPacts [2], a particle-based framework. The ECM is modelled via a deep neural network (DNN) with cell-matrix feedback captured through a linear force contact model. DNN-based FE achieves predictions 500,000x faster than CPU-based FE (Fig. 1c).

RESULTS AND DISCUSSION

Cell volume is driven by increasing osmotic pressure onset by impermeable biomolecule synthesis. Confinement elevates hydrostatic pressure, causing fluid loss and reduced proliferation by limiting mitotic entry. Simulation of T47D spheroid growth using our AB-AI-FE model accurately predicts the reduction in spheroid size with increasing matrix stiffness (Fig. 1d, e). Our computationally efficient framework offers new insight into tissue-scale mechanics and mechanosensitive growth, with potential for patient-specific cancer modelling.

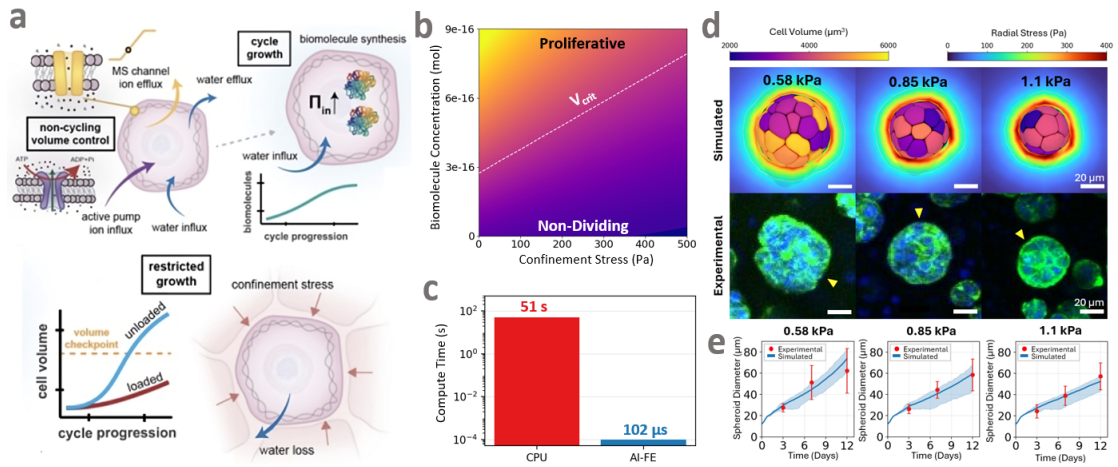

Figure 1: (a) Biomolecule synthesis drives cell growth; (b) Loading restricts cell division; (c) AI-FE framework is 500,000x more efficient than CPU operations. (d, e) Predicted T47D spheroid size decreases with increased matrix stiffness, in agreement with experimental data.

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Abstract

Transcriptomic Dysregulation of Bone Marrow Mesenchymal Stromal Cells in Type 2 Diabetes Mellitus

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic disease, characterized by elevated blood sugar levels, leading to complications such as osteopathy. Notably, the risk of osteopathy in individuals with T2DM is significantly influenced by sex. Bone marrow mesenchymal stromal cells (BM-MSCs) play a crucial role in bone regeneration and have been widely studied for their therapeutic potential in tissue engineering and regenerative medicine. Recent studies have reported that T2DM-induced osteopathy is associated with impaired bone quality, primarily due to a reduction in BM-MSC numbers and their diminished differentiation capacity. However, the underlying transcriptomic mechanisms driving these impairments remain unclear.

MATERIALS AND METHODS

In this study, BM-MSCs were collected from 27 donors, including 13 individuals with T2DM (7 females, 6 males) and 14 without T2DM (8 females, 6 males), for bulk RNA sequencing. Gene expression profiles were analysed across all donors, as well as within sex-specific subgroups. Differentially expressed genes (DEGs) were identified using DESeq2, followed by gene set enrichment analysis (GSEA) on the log2 fold-change values of all genes to explore differentially regulated pathways.

RESULTS AND DISCUSSION

No distinct separation was observed between BM-MSCs from T2DM and non-T2DM donors on a PCA plot, however, 82 DEGs were identified in the overall T2DM donor group compared to controls, with 195 DEGs identified in female T2DM donors and 115 DEGs identified in male T2DM donors during sex-specific comparisons ($\log2\ FC \geqslant 2$, $p < 0.05$). Differentially regulated pathways related to cell proliferation, immune response, and osteogenesis/adipogenesis were identified, but these pathways were not uniformly dysregulated in male and female T2DM donors. Interestingly, male and female T2DM donors exhibited distinct gene expression patterns within the osteoclast differentiation pathway.

In conclusion, this study provides novel insights into the transcriptomic dysregulation of BM-MSCs in T2DM, highlighting potential mechanisms contributing to BM-MSC dysfunction. Furthermore, our findings underscore the impact of sex-specific differences on BM-MSC transcriptome regulation, which may have implications for developing targeted therapeutic strategies.

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Abstract

MICROFLUIDIC ASPIRATION DEVICES FOR HIGH-THROUGHPUT ANALYSIS OF TUMOUR CELL BIOMECHANICS

McSweeney, O., McEvoy, E.

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INTRODUCTION

Breast cancer is the most common cancer globally, and many existing therapies ignore the important role of mechanobiology underpinning the cell response. This project aims to characterise the heterogeneous biomechanical behaviour of tumour cells via a microfluidic-based aspiration. By trapping cells via a pressure gradient across microchannels, ΔP, their behaviour can be analysed to motivate multi-scale models of tumour growth and drug delivery.

MATERIALS & METHODS

Cells can be trapped via micropipette aspiration when a ΔP across microchannels of ~100 Pa is achieved. Using Autodesk Inventor, microfluidic chips were designed to understand the influence of key design variables on achieving a target ΔP. First, a U-bend model (UB) was tapered from wide inlet to narrow outlet, with ΔP across microchannels arising from an associated change in flow rate. We analysed the sensitivity of ΔP to inlet velocity v_{in} (1–5 m/s) and the inlet/outlet diameter ratio (D_i: 2.25–3.25 mm, D_o: 1–1.5 mm). Next, a Wheatstone bridge (WB) analogue was designed to manipulate channel flow resistance. The number of "open" microchannels (N: 0-3) and inlet flow rate (Q_{in}: 20-120 µL/h) were varied to investigate the influence on ΔP. Finally, flow rate (Q: 0-0.8 µl/min) and macrochannel length (L_2: 8000-11000 µm) were studied in a loss-based system (LB). Computational predictions were validated by analytical analyses.

RESULTS & DISCUSSION

The UB model showed ΔP increasing with higher v_{in} and D_i/D_o ratios, with greater sensitivity to geometry at higher v_{in} (Fig. 1(A)). WB (Fig. 1(B)) and LB (Fig. 1(C)) simulations showed a positive flow-ΔP relationship, matching analytical results within 15%. At higher flow rates, macrochannel length has a more significant impact on ΔP (Fig. 1(D)).

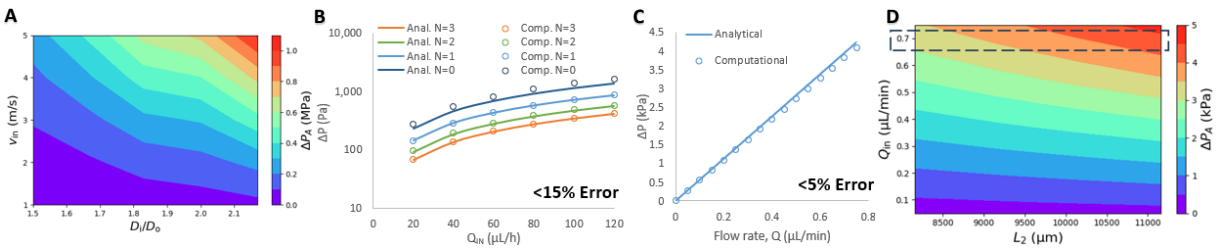

Fig. 1 (A) ΔP phase diagram: UB. (B) ΔP comparison: analytical-WB model. (C) ΔP comparison: analytical-LB model. (D) ΔP phase diagram: LB.

These findings demonstrate the dependence of ΔP on geometry and support analytical model validity. In ongoing work, we are fabricating microfluidic devices to aspirate cells for biomechanical characterisation.

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Abstract

A BIOPHYSICAL MODEL OF STRESS-DEPENDENT YEAST CELL GROWTH

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INTRODUCTION

Cell growth is reduced under mechanical loading and confinement, but the mechanisms remain unclear. A volume checkpoint restricts proliferation of small cells, potentially governed by diluting key cycle inhibitors. We propose a biophysical model coupling transcriptional-translational kinetics with cell hydromechanics to examine how these inhibitors, biomolecule synthesis, and mechanical loading, regulate cell growth and division.

MATERIALS AND METHODS

We modelled cell fluid volume as a balance between hydrostatic and osmotic pressures, linking free amino acids to translation and driving osmotic pressure for cell-cycle growth. Volume changes from water flux are influenced by membrane tension, external loading, and charged protein synthesis, regulating ion transport. We implemented this model in PhysiCell, an open-source agent-based platform, coupled with a finite element solver for cell-hydrogel mechanics.

RESULTS AND DISCUSSION

Simulations show that biomolecule synthesis during the cell cycle elevates osmotic pressure, driving cell growth and diluting the key inhibitor Whi5 in yeast, see Fig. 1. Under external loading, increased hydrostatic pressure restricts water influx, limiting Whi5 dilution and cell division. When cells contact a deformable hydrogel, growth is suppressed by insufficient Whi5 dilution and lower biomolecule synthesis, consistent with [1]. These findings underscore volume-dependent checkpoint regulation in yeast, with parallels for Rb in higher eukaryotes, providing insights relevant to tumour progression.

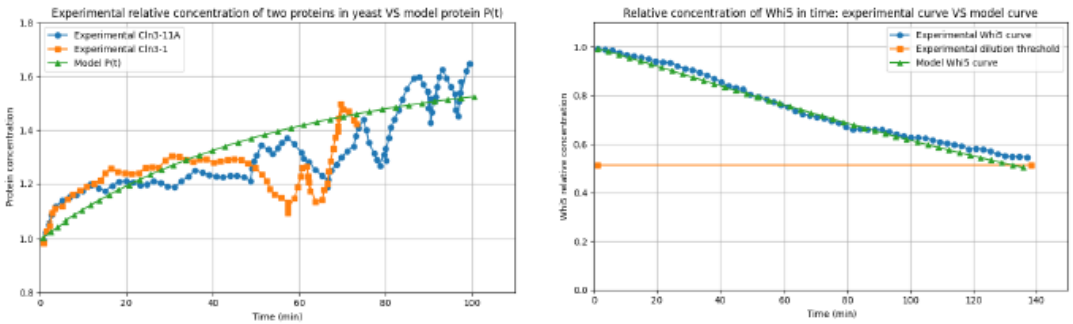

Fig. 1: Comparisons between experimental data in [4] and our model's outcomes for a single coarse-grained yeast protein P(t) (Left) and Whi5 dilution (Right).

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Abstract

Exploratory analysis of Type B Aortic Dissection (TBAD) segmentation in 2D CTA images using various kernels

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Background

Type B aortic dissection (TBAD) occurs when a tear develops in the descending part of aorta. This tear results in the separation of the inner and middle layers of the aorta, creating a second pathway for blood flow known as a false lumen (FL), which can also obstruct blood flow in the true aortic channel, i.e., the true lumen (TL). The diagnostic and prognostic process of TBAD involves the segmentation of FL, TL, and the false lumen thrombosis (FLT). Manual segmentation of TL, FL, and FLT is challenging and time intensive.

Aims

The ImageTBAD study [1] addresses the challenge of segmenting aortic dissection structures by introducing a dedicated dataset and employing a 3D U-Net model to segment TL, FL and FLT. However, we hypothesize that two-dimensional (2D) segmentation methods can achieve comparable performance while being more lightweight and computationally efficient.

METHODS

In this work, we investigate the feasibility of using 2D Convolutional Neural Network (CNN) models for accurate slice-by-slice segmentation. Specifically, we explore three 2D U-Net variants: a standard 2D U-Net, a U-Net with atrous convolutions, and a custom U-Net incorporating a position-oriented, partially shared kernel weighting scheme. These models were trained and benchmarked against a state-of-the-art 3D U-Net baseline. Furthermore, we conducted an ablation study using different pretrained backbones to evaluate their impact on segmentation performance.

RESULTS AND DISCUSSION

From our experiments, we found that 2D U-Net models can outperform 3D U-Net in the segmentation of TL and FL, but performance dropped slightly in the case of FLT.

Method	TL	FL	FLT
3D U-net ImageTBAD [1]	79.0%	68.0%	50.0 %
2D U-net	83.14%	84.90%	30.41%
2D U-net with Atrous Convolution	75.72%	80.06%	23.47%
2D U-net with Custom Layer	78.51%	81.89%	6.72%
Vgg19-U-net	87.92%	89.55%	44.48%

Table 1: Mean Dice Score (DSC) achieved by Proposed Models on Testing Dataset

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Abstract

Alterations in morphometry, mineral distribution and biomechanical properties of vertebral bones of Type 2 Diabetic rats

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INTRODUCTION

Type 2 Diabetes (T2D) affects millions globally and significantly increases the risk of bone fractures, despite many patients exhibiting normal or elevated bone mineral density. T2D weakens bone in multifactorial manner, inducing changes in growth and development, turnover, architecture and quality. However, the exact underlying mechanisms of this fragility, particularly in vertebral fractures that are associated with morbidity, remain poorly understood. In this study, we provide novel insights into age-dependent, vertebrae-specific and region-specific alterations induced by T2D.

EXPERIMENTAL METHODS

A longitudinal study (12, 46 weeks) of male Zucker Diabetic Fatty rats was conducted. Vertebrae (L3, L4, L5, L6) were scanned by X-ray based CT imaging (Zeiss Xradia Versa 620) at a voxel resolution of 17.78 µm. Each vertebra was analysed separately using DragonFly software (Comet) to measure vertebrae body height, depth and width. Bone morphometric analysis (Bone Analysis Module) quantified structural alterations in trabecular and cortical features. Bone Mineral Density Distribution analysis was performed with python script. Hydroxyapatite phantoms (PTW dosimetry) were used to calibrate mineral densities. Compression tests were performed on the vertebral body of L5 vertebrae. Statistical analysis was performed by three-way ANOVA followed by Tukey tests.

RESULTS AND DISCUSSION

T2D rats exhibited a significant reduction in vertebral dimensions at 46 weeks of age, but not at 12 weeks. With increasing age, significant bone loss was observed in cortical bone of diabetic rats as depicted by low cortical area fraction (Fig. 1a). T2D rats had significantly higher trabecular bone fraction at 12 weeks but not after 46 weeks (Fig. 1b). Mean BMD was unaffected by age and disease, but alterations in mineralization kinetics were evident from mineral distribution analysis revealing that T2D increased BMD values at the 95th percentile. This study highlights the age- and region-dependent detrimental effects of T2D.

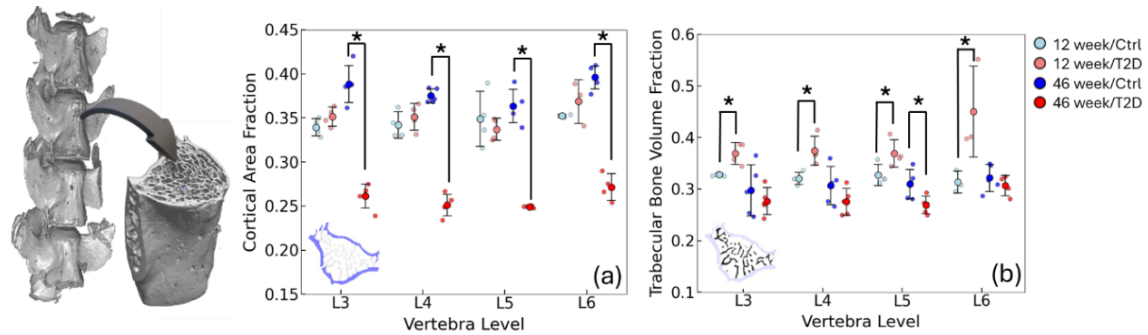

Figure 1. (a) Cortical area fraction and (b) Trabecular bone volume fraction of 12- and 46- week old control and diabetic rats

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Abstract

Simulation study comparison of approximate linear mixed models for application in high dimensional Genome Wide Association Studies with longitudinal outcomes

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INTRODUCTION

Genome Wide Association Studies (GWAS) aim to identify genetic variants - such as single nucleotide polymorphisms (SNPs) - in the population that are associated with common complex traits and diseases. The majority of such studies consider cross-sectional outcomes using linear regression, but there are growing numbers that investigate longitudinal outcomes. These studies benefit from increased power when considering multiple timepoints of outcome measurements. For low dimensional data of this structure and a linear outcome the Linear Mixed effects Model (LMM) is suitable for investigating cross-sectional and longitudinal SNP effects; a typical LMM for a single SNP, taking ~ 2 seconds. However, there are millions of SNPs targeted in the current generation of arrays, making the traditional LMM highly computationally intensive, and potentially infeasible.

Statistical methods to approximate the LMM have been developed, including Genome-wide Analysis of Large-scale Longitudinal Outcomes using Penalisation (GALLOP) and Simultaneous Correction for Empirical Bayesian Estimates (SCEBE), which greatly decrease computation time and provide unbiased estimates for cross-sectional and longitudinal SNP effects. SCEBE fits a LMM to the longitudinal outcome, ignoring SNP effects, and analyses the random effect predictors in a cross-sectional GWAS with linear regression. The effect estimates in this model are biased due to shrinkage to the population mean, however this bias can be quantified and corrected for. GALLOP estimates the variance of the outcome intercept, slope and residuals using a LMM without SNP effect terms. Assuming these variances do not change once the SNP terms are included, the variances can be used to construct a system of linear equations which are solved to yield cross-sectional and longitudinal SNP effect estimates.

We compare GALLOP, SCEBE and a LMM in a simulation study to evaluate average computation times per SNP, bias and variance in the SNP effect estimates. In a semi-factorial design, we evaluate the methods by varying the SNP effect parameters, number of repeated outcome measurements, time-varying covariate effects, variance over time and by incorporating non-linear SNP effects. We use empirical height data from the Avon Longitudinal Study of Parents and Children (ALSPAC) to inform our simulations.

In this study we compare existing approximate LMM methods for GWAS of a longitudinal outcome in a simulation study, informed by real ALSPAC data. We use these simulations to inform and develop a novel method that accounts for time-varying covariates. Our novel method is suitable for application with epigenetic data, where there will soon be more than one million biomarkers measured.

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Abstract

PREDICTING ACUTE MYELOID LEUKAEMIA SURVIVAL TIME USING DEEP LEARNING ON CROSS-PLATFORM GENE EXPRESSION

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INTRODUCTION

Acute myeloid leukaemia (AML) is an aggressive bone marrow cancer characterized by a high rate of therapy resistance and variable patient outcomes, necessitating accurate prognosis to guide treatment. Machine learning models such as LASSO have been used on AML gene expression data to evaluate prognostic factors including cancer stemness and treatment resistance. However, these models use aggressive feature selection, including a prior selection of drug metabolism genes, and do not perform well on some patient cohorts, possibly due in part to mixed use of normalized microarray and RNA-seq training data.

METHODS

In this study, we propose a custom neural network architecture that accommodates both microarray and RNA-seq gene expression data as input. This architecture features a sparse hidden layer in which each node represents the expression of a gene, each of which is connected to a pair of nodes in the input layer, one for each assay of that gene. Patients are expected to have data from one gene expression assay or the other, but not both. This model avoids normalization or conversion of data between technologies, and instead assumes that each method captures its own representation of the same gene expression. The network can then learn the relationship between these technologies, as well as between gene expression and patient outcomes including survival. In this way, the learned weights of the network essentially supplement patient data in a flexible combined model that is potentially more accurate than using either technology alone.

DISCUSSION

This cross-platform model is useful in clinical settings where RNA-seq is cost-prohibitive despite its advantages. By training on both RNA-seq and microarrays, we aim to extend the insights of RNA-seq research to resource-limited environments where microarrays remain prevalent. Additionally, this approach can be scaled to include technologies like small targeted gene expression panels as sequencing efforts advance.

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SUSTAINABLE FUTURES

Oral Presentations

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Abstract

Methane mitigation in ruminants using peroxide-based additives: Effect of grass composition and doses increase

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INTRODUCTION

Peroxide-based additives have been designed to mitigate methane emissions in ruminants and validated using silage, concentrate or pellet feeds. However, pasture-based diets have not been studied. The objective of this research is to evaluate methane mitigation using CaO_2 additives as affected by changes in grass composition during seasons alongside increases in the frequency of additive supplementation.

MATERIALS AND METHODS

In-vitro experiments using 100 mL rumen fluid from cattle, 100 mL anaerobic buffer, substrate 12.5 gDM/L and CaO_2 additive 2.25% DM were used. In experiment 1 the effect of grass from different seasons was evaluated. In experiment 2, the effect of increasing the application frequency of the additive, using summer grass as a substrate, was studied.

RESULTS AND DISCUSSION

In experiment 1, biogas and methane production were higher from summer grass (327 and 53mL, respectively) than from other seasons (184-197 and 29-26mL, respectively). The reduction in methane production in treated bottles was between 72-96% with a maximum in spring (96%). Total VFA production was higher in untreated (4636-7893mgCOD/L) than in CaO_2 treated bottles (3990-7537mgCOD/L). In experiment 2, an increase in the frequency of additive application from 3 to 9 doses in a period of 21 days improved the methane mitigation from 68% to 82%. No effect was observed on the hydrolysis of the grass (solubilization of phenols: from 263 to 180mg/L in the control and 275 to 142mg/L with 9 doses; and reducing sugars: from 0.41 to 0.43mg/L in the control and from 0.9 to 0.35mg/L with 9 doses), dry matter disappearance, pH and ORP. However, the volatile fatty acid production was higher from day 7 to 21 in the controls (from 8512 to 10071mgCOD/L) in comparison with 9 doses of CaO_2 (from 6238 to 7992mgCOD/L). This information is valuable for the optimization of additive application without negatively impacting the biochemistry of the rumen.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

ADSORPTION OF METHANE AT ATMOSPHERIC PRESSURE UNDER DRY AND AQUEOUS CONDITIONS

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School of Biological and Chemical Sciences, and Ryan Institute, University of Galway.

INTRODUCTION

Methane is a major greenhouse gas contributor, with a global warming potential 84 times higher than carbon dioxide over twenty years. As such, researchers are investigating novel approaches to utilise methane and avoid its continued release to the atmosphere. Methane is considered a sustainable energy alternative to fossil fuels, as well as biological conversion to high value compounds in aqueous systems. In this study, we investigated the adsorption of methane at atmospheric pressure under: 1) dry conditions, for fuel storage and; 2) aqueous conditions, for biological processes.

MATERIALS AND METHODS

Nine biochars (from three feedstocks, pyrolysed at two temperatures and with two atmospheric gases) and two activated carbons were investigated. Adsorption kinetics and isotherms were determined experimentally at 10 °C, and data was modelled using pseudo-first and pseudo-second order models (kinetics), and Langmuir and Freundlich models (isotherms).

RESULTS AND DISCUSSION

Under dry conditions, all the adsorbents adsorbed methane within 15 minutes, while 240 hours was required under aqueous conditions. The kinetic parameters indicate that adsorption under dry and aqueous conditions best fitted the pseudo-second order and pseudo-first order, respectively. These suggest that surface adsorption and intraparticle diffusion were the rate limiting steps for both dry and aqueous conditions, respectively.

Under dry conditions, the greatest adsorption capacity was found for granular activated carbon (3.35 $mg.g^{-1}$), while under aqueous conditions the greatest capacity was found for a biochar produced from beech wood at 700 °C under a carbon dioxide atmosphere (5.84 $mg.g^{-1}$).

These findings suggest that the adsorbents investigated have the capacity to store methane for multiple sustainability focused applications.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Towards Lifetime Prediction of Composite Tidal Turbine Blades Under Marine Exposure

Tenis Ranjan Munaweera Thanthirige[1], Michael Flanagan[1], Ciaran Kennedy[1], Jamie Goggins[1], William Finnegan[1]

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INTRODUCTION

Tidal stream energy, as a reliable and predictable source of renewable power, depends heavily on the structural integrity and longevity of turbine blades. Composite materials, particularly glass and carbon fibre-reinforced polymers, are widely used to manufacture tidal turbine blades due to their high strength-to-weight ratios and their resistance to corrosion. However, current structural testing frameworks don't fully replicate the actual operational environment of the blades, neglecting key degradation factors such as water absorption, corrosion, and erosion. In this context, this study highlights the dominant role of water absorption in material degradation and proposes two novel approaches for integrating these effects into fatigue life prediction.

MATERIALS AND METHODS

The research investigates the key factors that influence the operational lifespan of tidal turbine blades. Through a detailed assessment, four primary parameters were identified as critical to determining blade durability: loading conditions, material degradation, design and manufacturing quality, and unexpected or extreme environmental events. Each of these factors plays a significant role in the structural performance and failure mechanisms of the blades over time. Following this classification, an extensive assessment of existing literature and available experimental data was conducted. The aim was to gather insights into how these parameters interact and influence blade failure in real-world marine environments. Based on this study, the focus is on identifying approaches to develop vulnerability curves as predictive tools for assessing the long-term performance of tidal stream turbine blades during operation stage.

RESULTS AND DISCUSSION

Building on the four main life impact categories, this study integrates literature findings and experimental data on composite materials to formulate two predictive approaches for generating vulnerability curves. These curves are intended to serve as practical tools for estimating the operational lifespan of tidal turbine blades. In the first approach, fatigue testing data from accelerated-aged composite coupons were combined with operational assumptions to develop a vulnerability curve based on a finite element (FE) model of a prototype tidal turbine blade. The second approach focused on integrating water diffusivity data and environmental loading scenarios into a detailed FE analysis. This method included the implementation of a material degradation model, allowing for the progressive update of material properties over time in response to moisture absorption. As a result, the vulnerability curves expected to develop using these two approaches are capturing the time-dependent effects of environmental exposure on blade integrity. Together, these two approaches can provide a comprehensive framework for predicting the structural performance and durability of tidal turbine blades throughout their service life.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

The impact of climate change on the design and operation of Irish dwellings

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3. Construct Innovate, University of Galway, Galway, Ireland
4. MaREI Centre, University of Galway, Galway, Ireland

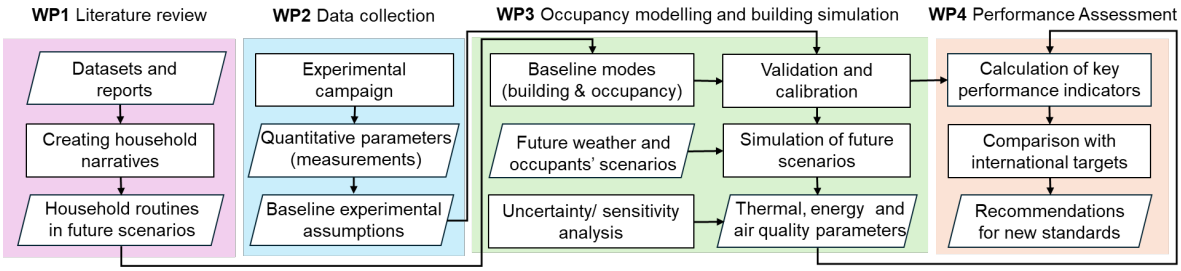
INTRODUCTION

This project investigates how to futureproof Irish dwellings against the impacts of climate change. It aims to ensure that new and retrofitted buildings meet net-zero energy standards, while ensuring safe, healthy, and comfortable conditions for occupants. The research focuses on the development of occupancy and occupant behaviour (OOB) models that can be integrated into future building standards.

MATERIALS AND METHODS

The project methodology combines physical measurements, computational simulations, statistical analysis, and machine learning (Fig. 1). The completed literature review (WP1) investigated the typical Irish household characteristics and developed lifestyle storylines to guide the simulation assumptions in future scenarios. Next, an experimental campaign in operating buildings (WP2) will monitor indoor environmental quality and energy use, providing data for model calibration. The modelling phase (WP3) will create OOB models and apply them in simulations of current and future climate scenarios. These models combine occupants' household habits and assumptions on their interaction with building elements (e.g. windows, blinds, thermostats). The performance assessment (WP4) will calculate key performance indicators (overheating risk, energy consumption, indoor air quality) and compare them with national and international standards. The goal is to estimate how building performance varies with diverse occupancy patterns.

Figure 1: Methodology.



RESULTS AND DISCUSSION

The literature review resulted in proposed guidelines to create future occupant behaviour models, which will be embedded in the Irish context next. The OOB models are currently being developed using the United Kingdom Time Use Survey (2014-2015), and similar data from Ireland (available from 2005). Data stratification focuses on household composition, age group and working status. The monitoring campaign is in progress, with sensors installed in an apartment complex in Wicklow, Ireland. Combining measured and simulated data, as well as newly developed OOB models, will allow for performance assessment of the residential building with a focus on occupants.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Microstructure-driven fatigue life prediction of additive manufactured NiTi aerospace actuators

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NiTi alloys are ideal candidates for aerospace and biomedical actuators due to their superelasticity and shape memory effects. The actuation mechanism depends on the change in temperature which reduces the complexity of system while enabling a lightweight and compact design. Additive manufacturing technologies, such as laser powder bed fusion (L-PBF), can be used to produce complex parts using data from 3D models. However, significant uncertainties and challenges exist in relation to mechanical properties of additively manufactured parts due to the strong influence of process parameters on microstructure and mechanical behaviour, e.g. residual stresses, anisotropy. The present work is focussed on development of micromechanical models for fatigue crack initiation of NiTi aerospace actuators. The work is part of a larger project on the development of a computational model for process-structure-property-performance relationships to optimise the design of additively manufactured NiTi actuators.

In this work, we focus on establishing the relationship between microstructure and mechanical behaviour (especially fatigue) for NiTi using crystal plasticity finite element (CPFE) modelling. This work aims to predict the structure-property relationship with the help of grain morphology captured using electron backscatter diffraction (EBSD).

A realistic CPFE model of L-PBF NiTi was generated by converting the EBSD-measured microstructure into finite element models. MTEX (open source) was employed for initial grain reconstruction using EBSD data and sample regions of interest (RoIs) were extracted for micromechanical CPFE modelling. The extracted RoIs were imported into DREAM3D (open source) where the metal grain morphology was discretised.

The low cycle fatigue behaviour of NiTi micromechanical samples was simulated using a CPFE user-material (UMAT) subroutine in Abaqus™. Moreover, a microstructure sensitive fatigue indicator parameter (FIP) was also implemented to predict the fatigue life. The methodology presented provides a basis for predicting the effect of microstructure on the fatigue life of NiTi, using EBSD data. The current method will be further implemented for micromechanical modelling of a defined NiTi actuator design to optimize the fatigue response under extreme conditions.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Wave-Based Numerical Simulation of Rain Droplet Impact and Surface Fatigue in Wind Turbine Blade Coatings

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2. Construct Innovate, University of Galway, H91 TK33 Galway, Ireland;

INTRODUCTION

Rain erosion on wind turbine blades, particularly along the leading edge, causes gradual surface degradation that reduces their aerodynamic efficiency and increases maintenance costs. This issue is especially critical in offshore and high-wind environments, where turbines are exposed to frequent and intense rain events. As the global reliance on wind energy grows, improving the durability of blade coatings is essential for ensuring long-term performance and cost-effective operation. Gaining a deeper understanding of the stress mechanisms during droplet impact is crucial for predicting erosion onset and guiding the design of more resilient protective systems.

MATERIALS AND METHODS

In this study, a numerical framework is developed to simulate the impact of rain droplets on coated wind turbine blade surfaces. The droplet is modelled as a compressible fluid using the acoustic wave equation, with nonlinearity incorporated via Tait's equation [1] of state to account for realistic pressure-density relationships. The resulting velocity potential is used to compute the transient pressure distribution at the droplet–substrate interface. This pressure field is applied as a time-dependent boundary load to the solid domain, which is modelled as an elastic medium governed by Lame's equations[2]. This approach enables the capture of transient stress wave propagation, including the formation and evolution of Rayleigh surface waves that dominate far-field stress behaviour and contribute to fatigue damage. Surface stress histories are extracted and analysed using a power-law-based fatigue model derived from the Palmgren–Miner rule [3], allowing estimation of erosion incubation periods. The model is implemented in MATLAB, offering flexibility to explore the effects of varying droplet size, impact velocity, substrate stiffness, and coating thickness on stress response and erosion potential.

RESULTS AND DISCUSSION

This study explores multi-layer coatings for the prevention of leading-edge erosion. The formation of surface waves and their movement after droplet hit is derived, where the resulting stress histories are applied to a fatigue-based erosion prediction model. This can bridge the gap between theoretical wave mechanics and practical coating design.

References

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College of Science and Engineering, Research and Innovation Day 2025

Abstract

Design of a scalable microbial electrosynthesis process for efficient industrial CO2 recycling

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INTRODUCTION: Carbon Capture and Utilization (CCU) technologies like microbial electrosynthesis (MES) convert CO_2 into green chemicals. MES employs biocatalysts under mild conditions, delivering high selectivity and sustainability. Its scalability is restricted by mass transfer limitations, reactor design, and product accumulation. To address these issues, we designed a flow-pattern MES reactor. Using a computational fluid dynamics (CFD) model, we optimized the electrolyte and CO_2 circulation. The new reactor was then compared to a previously developed one. The reactor's outlet was subsequently treated using electrodialysis to evaluate its potential as a downstream process.

MATERIALS AND METHODS: The CFD was done in ANSYS, with a pressure-based coupled solver. Boundary conditions were set as the inlet electrolyte and CO_2 flow, pressure resistance, temperature, and operating pressure. A microbial community previously enriched was used to inoculate both three-chamber reactors operated galvanostatically (1.0 mA cm-2) and fed with pure CO2 (2.0 mL min-1). The electrodialysis system consisted of a five-cell pair system using different pH for the feed stream, applying different current potentials, and modifying the operating mode of the system.

RESULTS AND DISCUSSION: The CFD model demonstrated a decrease in dead space in the flow pattern cell, facilitating the exploitation of the entire electrode area. This leads to improved CO2 delivery to the GDE and enhanced contact between CO2, catholyte, and microorganisms on the GDE surface. As a result, the average production rate increased 129.5%, on a 16-day linear production period, and its Coulombic efficiency increased by 57.56%. Additionally, the electrodialysis process increased the initial concentration of the feed stream from 5 to 15 g L-1. These findings highlight the potential of CFD for optimizing MES reactor design and the use of ED as a separation process. Ongoing studies are evaluating the performance of the flow pattern cell in continuous mode and using gas mixtures that mimic flue gas from concrete plants.

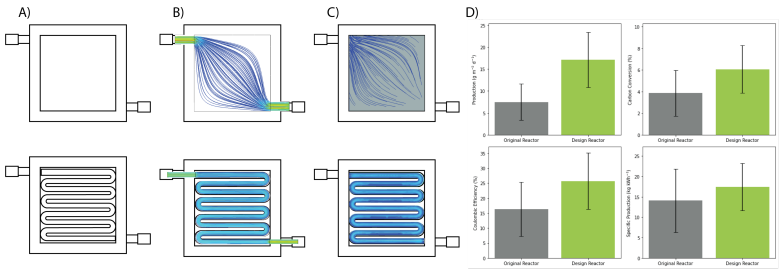

Figure 1 A) Scheme of the square-shaped and flow-pattern cells; B) Liquid flow dynamics; C) Contact CO2-GDE; D) Average performance parameters obtained with the two cell designs.

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Abstract

In-vitro and *in-vivo* assessment of novel oxygen-releasing feed additives to reduce enteric ruminant methane emissions

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INTRODUCTION

Ruminant livestock contributes significantly to global methane (CH_4) production, where its mitigation is of utmost importance. Feed additives represent a cost-effective means of achieving this. Previous research demonstrated that slightly elevating the rumen oxidation reduction potential (ORP) using oxygen-releasing feed additives hinders methanogenesis. This is due to the niche specialisation of methanogens, which are typically only active at ORPs below -300 millivolts. *In-vitro* assessment of these compounds, including calcium and magnesium peroxide (CaO_2, MgO_2), demonstrated their effective CH_4 mitigation potential, while *in-vivo* trials revealed no negative impacts on animal performance when supplementing CaO_2 at inclusions of up to 1.7% of dry matter intake (DMI).

MATERIALS AND METHODS

This research evaluated the *in-vivo* effects of various doses of CaO_2 on animal performance for the first time in beef cattle. Nine cannulated Aberdeen Angus × Friesian steers (739 ± 67 kg BW) were used in an 84-day Latin Square design trial (n=9). Several CaO_2 inclusion rates were evaluated during once-a-day and twice-a-day feeding. *In-vivo* ORP (continuous), static ORP, static pH, ammonia, volatile fatty acids (VFAs), *in-sacco* diet digestibility, feed intake, palatability, and rumen microbiome were monitored, while a portable CH_4 analyser provided preliminary CH_4 emission indications.

RESULTS AND DISCUSSION

Positive indications of reduced enteric CH_4 emissions were observed from animals receiving treatment vs. controls. Equivalent rumen ORP elevations were observed at both higher and lower doses applied during once-a-day feeding, alongside similar levels of CH_4 suppression. Consistently greater ORP values of >100 mV were observed in the rumen of treatment vs. control animals during twice-a-day feeding, with reduced enteric emissions. These findings, together with the minimal palatability issues encountered at each CaO_2 inclusion rate and CaO_2's capacity to withstand both heat and pressure during incorporation into a feed pellet format, suggest that it may have potential as a tangible alternative to existing ruminant feed additives, with a prospective contribution to supporting global methane mitigation goals, in both intensive and pasture-based production systems.

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Abstract

Direct Laser Writing of Highly Conductive Graphene Patterns via Ultrashort Laser Irradiation of PEEK

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Ultrashort laser can trigger remarkable phenomena in materials due to its extremely short pulse duration, less than a picosecond. This study reports femtosecond direct laser writing (DLW) of highly conductive carbon structures on flexible polyether-ether-ketone (PEEK) exhibiting strong adhesion to PEEK substrate. Two distinctive, conductive regimes categorized as Phase−I, an sp^3−carbon dominated regime, and Phase−II, an sp^2−carbon dominated regime are observed.

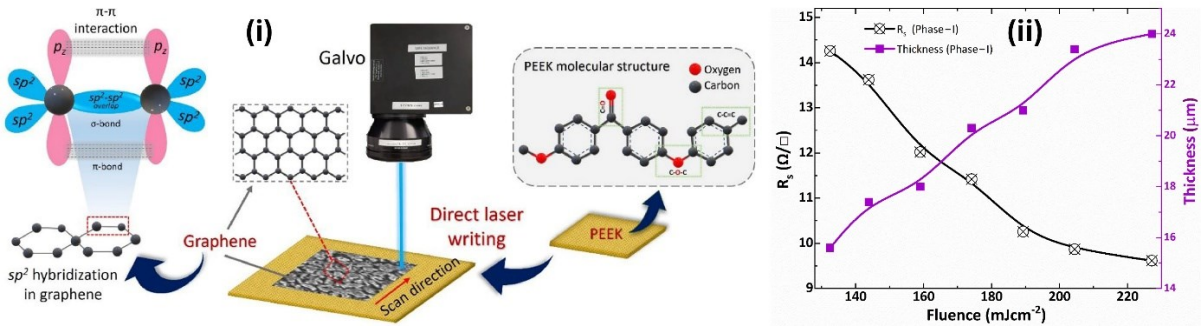

Figure 1. Schematic illustration of DLW process in (i), where (ii) shows variations in sheet resistance (R_s) and SEM-estimated thickness of laser treated PEEK film with applied laser fluences.

INTRODUCTION

The production of low-cost, high-quality graphene on industrial scale is challenging due to complex manufacturing processes. DLW is a non-contact, facile and highly controlled approach with a large scan area, high precision, and higher spatial resolution. The study presents laser writing of robust, highly conductive patterns in flexible PEEK films using femtosecond laser pulses. Ultrashort DLW offers a sustainable manufacturing route to produce highly quality graphene structures on thin, flexible polymers without creating large heat-affected zone, thus enabling their applications in wearable electronics, energy storage devices, electrical and biomedical sensing areas. A femtosecond laser (500 fs, 1030 nm) was used for writing on 50 µm thick PEEK film. Pre− and post −process characterizations such as four−point probe, Hall measurements, XPS, Raman spectroscopy, EDX, SEM, and AFM were performed to investigate LIG characteristics.

RESULTS AND DISCUSSION

Two distinctive, electrically conductive regimes are explored; an sp^3−carbon dominant regime with minor sp^2 contribution (Phase−I) and an sp^2−carbon dominant regime with a small sp^3 contribution (Phase−II) as confirmed from XPS analysis. No characteristic graphene peaks were observed in Raman spectra for Phase−I, however, this phase surprisingly showed higher conductivity compared to Phase−II. In Phase-II, PEEK was transformed into sp^2 graphene in the form of laser induced periodic surface structures (LIPSS). The lowest sheet resistance obtained was 9.60 Ω/Sq. and 11.53 Ω/Sq. corresponding to an electrical conductivity of ~4.33×10^3 S/m and ~4.17×10^3 S/m for Phase −I and Phase−II, respectively. For both phases, PEEK was transformed completely into electrically conductive structures but with a difference in overall chemical composition and nature of carbon bonds for the two phases. The reported low-fluence process is significant for writing of conductive structures on polymers with controlled manipulation of carbon configuration.

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Abstract

Modelling nutrient emissions into waterbodies caused by various land-use

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Changes in land use, driven by urban development, economic growth, and transportation, are placing considerable pressure on the environment. In Ireland, the agriculture, forestry, and other land use (AFOLU) sector accounts for over 40% of the country's greenhouse gas emissions and significantly impacts water quality. Various models, such as SPARROW, SWAT, and MARINA and other nutrient export models, have been developed and used to model the effects of human activities on water quality. In Ireland, The GOBLIN model, has been developed to explore land-use scenarios that align with climate neutrality goals. However, to date these models are not linked and there is a significant gap in relation to validating such models using water quality data within catchments.

This study reviews and summarizes nutrient export coefficients for nitrogen (N) and phosphorus (P) across various land uses based on global literature. These coefficients were adjusted to align with the land-use classifications in the Irish Land Cover Map (2018), ensuring consistency with national land-use definitions. Land types that do not exist in Ireland (e.g., paddy fields, tea plantations) were excluded. Using the compiled coefficients, total nitrogen and phosphorus loads were calculated at the national scale by integrating them with Ireland's land cover data. Additionally, SLAM (Source Load Apportionment Model) export coefficients were adjusted to match the Irish Land Cover Map and applied to calculate nutrient loads, enabling a direct comparison with literature-based estimates.

This research provides a structured methodology for applying export coefficients to Ireland, offering insights into how global estimates can be effectively adapted to national conditions. By leveraging land cover data to refine nutrient load calculations, this study enhances the accuracy of nutrient assessments and supports evidence-based land management strategies, aligning with Ireland's climate neutrality and water quality objectives.

Keywords: land use, nutrient loss modelling, water quality modelling

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Abstract

Getting the balance right: Framework for cost-effective truck fleet decarbonisation using battery and hydrogen fuel cell trucks

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INTRODUCTION

Decarbonisation of heavy-duty trucks is essential to reduce greenhouse gas emissions from the transportation sector. Battery electric trucks (BETs) are seen as the most promising alternative solution to replace the existing diesel-fuelled trucks. However, BETs operational performance is severely impacted when travelling longer distances and carrying heavier loads, making it challenging to completely switch to a BET fleet. Hydrogen fuel cell electric trucks (FCETs) could play a complementary role to BETs and be a viable alternative for longer and heavier trucking operations. While both BETs and FCETs offer their operational benefits, the question for truck fleet operators; whether to completely switch to homogenous fleet of BETs/FCETs or consider mixed fleet comprising both BETs and FCETs remains largely uncertain.

MATERIALS AND METHODS

This study compares the techno-economic and environmental performance of homogenous and mixed fleet of BETs and FCETs to an existing diesel truck fleet. A diesel fleet of 100 trucks was considered for this study comprising four different truck weight classes: 7.5-tonnes, 18-tonnes, 26-tonnes, and 40-tonnes. The performance of truck fleets is evaluated based on three key parameters: total cost of ownership (TCO), well-to-wheel (WtW) greenhouse gas emissions and total cost of carbon abatement (TCA). Energy demand from BETs and FCETs is met by an off-grid energy supply system consisting of wind farm, electrolyser, fuel cell, hydrogen storage tank and lithium-ion battery storage. A mixed integer optimisation problem is formulated to optimally size and operate off grid supply system, trucks and infrastructure such that entire hourly energy demand from trucks are met at minimum system cost.

RESULTS AND DISCUSSION

No single truck type was found to be universally optimal. Most cost-effective choice is strongly impacted by daily driving distance of trucks. Only for short driving distances below 150 km/day for 7.5t trucks and 550 km/day for 40t trucks, homogenous BET fleet proves to be most economical. This is due to higher efficiency, reduced fuel costs, and smaller onboard battery size. Mixed fleet has lowest TCO and TCA for driving distances between 150-400 km/day for 7.5t trucks and 550-800 km/day for 40t trucks. Mixed fleet predominately comprises BETs with FCETs having dominant roles in 26t and 40t weight classes. But as driving distance increases, share of FCETs increases in the fleet composition while BETs decrease. For longer driving distances, above 400 km/day for 7.5t and 800 km/day for 40t trucks, homogenous fleet of FCETs is the most economical solution since mixed fleet now only consists of FCETs. A stationary hybrid energy storage system consisting of both batteries and hydrogen provides higher cost savings than standalone systems (battery/hydrogen). Significant WtW emissions are abated in an off-grid system. Higher carbon tax on diesel fuel is vital to improve BETs and FCETs cost competitiveness.

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Abstract

Residential Building Performance Analysis to Enhance Comfort and Energy Saving: analysis of thermal and air quality parameters

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INTRODUCTION

In Ireland and globally, a key concern is whether energy-efficient buildings truly deliver on their promise of improved indoor environmental quality, enhancing occupant satisfaction and health, while achieving the expected energy savings. Although there has been growing interest in the performance of retrofitted buildings, a post-occupancy evaluation of performance is needed as evidence of improvements. This study evaluates the performance of a home in the west of Ireland based on indoor temperature, humidity, CO2 levels and electricity consumption. The home has a Building Energy Rating (BER) of A2, aligning with stringent energy-efficiency standards. This home is evaluated using data collected throughout the year of 2023. Score 1 is the best performing based on the continuous monitoring of temperature and relative humidity to assess compliance with comfort zone (Temperature: 18-24°C, RH: 40-60%) and an extended acceptable zone (Temperature: 16-26°C, RH: 30-70%). In addition to these scoring, Time of Wetness (TOW) is also calculated to evaluate the risk of mould development, and CO2 concentrations are also analysed. Further, using the Emporia Vue Home Energy Monitor, electricity data for the entire year of 2023 is analysed to assess energy consumption patterns and performance. The findings demonstrate that seasonal fluctuations substantially influence indoor environmental conditions and energy usage, underscoring the importance of adaptive and seasonally responsive climate control strategies for maintaining thermal comfort and energy efficiency. The framework and results of this study can be useful for evaluating building performance, particularly in scenarios where energy savings are contractually guaranteed also ensuring occupant's comfort, health, and well-being.

METHOD

The selected home identified as HC-H036 is a two-storeyed mid-terrace-built type constructed in 2019 with a Building Energy Rating (BER) rating of A2. The total floor area of the home is 146.78 m2, the ground floor area is 80.78 m2, first floor area is 66 m2. The house is fully electric, with both space heating and water heating provided by a heat pump. For this study, two sensors are used and the data from 1st January 2023 to 31st December 2023 is used. The two sensors are: 1. ERS CO2 (for indoor environment conditions) 2.Emporia Vue Home Energy Monitor (For energy monitoring)

RESEARCH IMPACT

This study analyses indoor environmental performance and energy consumption of a home in west of Ireland throughout 2023, revealing seasonal impacts on comfort and energy consumption. Temperature and relative humidity deviated from optimal ranges in summer, while CO_2 levels exceeded thresholds in winter possibly due to limited ventilation. Energy use have peaked in colder months, mainly from the heat pump. These findings underscore the need for improved seasonal ventilation and climate control. Continuous monitoring proves essential for optimising building performance, ensuring energy savings, and supporting occupant comfort and well-being.

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Abstract

Use of waste-derived biochar to improve growth of *Methylomicrobium alcaliphilum* 20Z

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INTRODUCTION

The halotolerant alkaliphilic methanotroph, *Methylomicrobium alcaliphilum* 20Z, can use methane as a carbon source to produce high value products, via aerobic methane oxidation representing a cost-effective solution for methane abatement and climate change mitigation. However, the low solubility of methane in aqueous solutions, and hence low bacterial growth, has prevented commercial scale-up. One potential solution is the use of low-cost adsorbents like biochar to act as a platform for microbial growth.

MATERIALS AND METHODS

We investigated nine waste-derived biochars to determine if they could support the growth of *M. alcaliphilum* 20Z by determining cell dry weights at different biochar concentrations. Scanning Electron Microscopy (SEM) was used to examine biochar surface morphology and to confirm that cell growth was occurring on the biochars. Samples were fractionated, to separate the cells growing suspended in the media, and those bound either tightly or loosely to the biochars. Total DNA was determined to elucidate the bacterial distribution in each fraction compared to a no biochar control.

RESULTS AND DISCUSSION

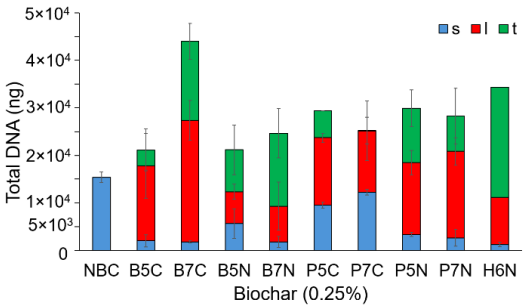

Figure 1: Total DNA (ng) in the three spatial fractions – suspended, loosely attached and tightly adsorbed to biochar (0.25%) compared to a no biochar control (NBC)

The results to date indicate that low concentrations of biochar (0.25%) improves *M. alcaliphilum* 20Z growth under standard growth conditions. Using SEM, bacterial cells were observed to be associated with biochars at 0.25% biochar concentration. The same trend continued with the amount of total DNA being higher in the fractions with cells tightly or loosely bound to the biochars than suspended indicating the bacteria preferred to grow attached to the biochar at 0.25% (Fig.1). This demonstrates the potential for pyrolyzed waste material to be used as low-cost platform to improve the growth of *M. alcaliphilum* 20Z and methane mitigation, hence promoting sustainable circular economy.

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Abstract

Investigating seagrass restoration potential in Irish restored habitats

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INTRODUCTION

As part of the United Nations Decade on Ecosystem Restoration (2021-2030) and the European Union's recently enacted Nature Restoration Law, Nature-based Solutions (NbS) have gained recognition as a viable approach to ensuring the sustainable development of coastal habitats. Of these Nature-based Solutions, seagrass restoration is viewed as a vital mitigation strategy against the adverse effects of climate change.

Seagrass beds in Ireland, largely comprised of Eelgrass (*Zostera marina* L.) and Dwarf Eelgrass (*Zostera* [*Nanozostera*] *noltei* H.), are experiencing multiple anthropogenically induced threats, including ecological degradation, eutrophication, and shifting temperature regimes. Successful restoration would not only ensure the healthy functioning of these habitats but also reestablish the various ecosystem services that their presence provides including carbon sequestration, sediment stabilisation, and improvement of water quality.

This project aims to evaluate the restorative capacity of seagrass meadows in Irish restored habitats. As well as utilising pre-established shoot and seed-based methods, a novel approach incorporating the use of biodegradable mats in shoot transplantations is assessed. Laboratory-based trials evaluating the potential of this innovative approach, as well as the germinative capacity of both *Z. marina* and *Z. noltei* seeds under varying abiotic conditions, are underway. These trials are designed to inform the experimental design of field experiments. On a broader scale, this research will fundamentally contribute to advancing knowledge of seagrass restoration practises in restored habitats and will evaluate its capacity as an effective Nature-based Solution.

This project is funded by the Environmental Protection Agency (EPA).

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Abstract

A web-based life cycle assessment platform for imported timber products

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INTRODUCTION

Under the dual pressure of increasing housing demand and carbon reduction commitments, the greater use of timber has been proposed as a solution for Irish construction. To help promote timber construction in Ireland from a sustainability perspective, this research develops a new web-based platform for life cycle assessment (LCA) for imported timber products, which is currently lacking. By integrating trade data from the UN Comtrade and environmental data from the ECO Portal, this platform supports customised LCA for various imported timber products to a designated country, not only Ireland. During customised LCA, the cradle-to-gate global warming potential (GWP) values are generated and can be visualised in both table and graphical forms and the results and associated metadata can be downloaded in CSV format for further analysis. Under the condition of selecting multiple products, this platform also allows for the comparison between selected products to assist the decision-making process of timber product procurement. Moreover, data quality indicators are provided with both the results and environmental data, including time and geographical representativeness. In the future, the platform will incorporate more LCA databases and encompass more LCA modules related to embodied carbon assessment and domestically manufactured timber products will be supported as well.

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Abstract

Laser Cleaving of Battery Separators

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INTRODUCTION

Widespread uptake of next-generation solid state battery technology requires advances in manufacturing processes. Thin flexible ceramics, commonly used as separators and electrolytes in these batteries, present challenges during laser processing due to their inherent brittleness and unfavourable thermal and optical properties. We describe an alternative laser cutting method which utilizes a low fluence and elongated laser spot to cleave brittle substrates along a defined cleaving path, addressing these challenges.

MATERIALS AND METHODS

The method uses an ultrashort laser source to pattern partially overlapping elliptical recesses on the material surface, with a series of prisms converting the laser spot from circular to elliptical Gaussian beam profiles. By optimizing pulse overlap and fluence, a low-fluence processing window was identified, enabling precise structuring of brittle substrates while eliminating thermal stress and micro-cracking during cooling.

Aligning the beam's long axis with the scanning direction optimizes the overlap between consecutive laser pulses as well as preceding pulses. The material experiences repeated stress cycles in the irradiated area, initiating mechanical fracture. By precisely controlling the laser fluence and elliptical beam dimensions, the stress concentration factor can be adjusted to generate microcracks aligned with the material depth. This allows for only partial material removal by the laser, the remaining material can be easily separated using tensile stress. The cleaved material has exemplary edge quality and produces minimal debris.

RESULTS AND DISCUSSION

The technique is applied to thin flexible yttria stabilized zirconia ceramic and borosilicate glass substrates with thickness in the range 30µm to 150µm. The resulting fractured surface is of higher quality and strength than surfaces cut using full body laser cutting techniques. Furthermore, the low thermal energy input preserves the ceramic material's crystalline phase, preventing phase changes that could compromise product reliability. This process is compatible with roll-to-roll manufacturing, which is essential for achieving the production rates required for economically viable electric vehicle battery manufacturing. Additionally, the optical setup is simple and cost-effective, making it a practical solution for scalable solid-state battery production.

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Abstract

Screening coating materials to prolong the methane inhibition effects of calcium peroxide in cow rumen fluid

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INTRODUCTION

There is an urgent need for the creation and implementation of sustainable solutions to address the impact that we are having on the environment. As outlined in Ireland's Climate Action Plan, we have set a target to reduce greenhouse gas (GHG) emissions by 51% by 2030. Methane emissions from cattle farming as part of our beef and dairy emissions account for 19% of our annual GHG emissions. There is growing interest in the compound calcium peroxide (CaO_2), which is a powerful oxidiser, as a methane mitigation tool. Publications have evidenced its effectiveness in pig slurry, *in vitro* in a rumen simulation technique (RUSITEC), and *in vivo* in pigs and cattle. However, its effectiveness in pasture-based grazing systems in Ireland depends on its controlled release in the rumen.

MATERIALS AND METHODS

The aim of this research is to identify suitable coating materials to target the slow release of CaO_2 in the cow rumen. *In vitro* batch experiments using cow rumen fluid have been carried out to investigate the impact that a variety of coating materials, including sodium alginate, carbohydrates, and gelatine, have on oxidative reduction potential (ORP) and methane production in cow rumen fluid.

RESULTS AND DISCUSSION

Coating CaO_2 can elevate the ORP for multiple hours longer compared to uncoated. Sodium alginate and carbohydrate-based coatings increased methane production *in vitro* potentially due to additional readily available substrate. Gelatine alone does not significantly increase methane production and may be a potential candidate for use as a coating material. Further research will focus on optimising the coatings for commercial applications, contributing to sustainable livestock nutrition and Ireland's sustainability goals.

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Abstract

PRODUCT DEVELOPMET OF A THERMOPLASTIC COMPOSITE PIPELINE (TCP) USED IN OFFSHORE CARBON CAPTURE AND STORAGE (CCS) APPLICATIONS

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INTRODUCTION

The most economic oil & gas transportation methods rely on pipelines [1]. In the case of submarine pipelines, different types (design, materials) of pipelines can be used, depending on the operating depth and the type of product transported, as illustrated in Fig.1 (A). Composite materials have emerged as a competitive lightweight piping option for offshore Carbon Capture and Storage (CCS) applications, such as Enhanced Oil Recovery (EOR), where CO_2 is injected to help oil extraction. CCS consists in capturing CO_2 mainly from Oil & Gas cleaning processes, and transporting it towards secure geologic sites, such as depleted sub-sea oil or gas fields [1]. This project covers a product development from Technology Readiness Level one (TRL 1 – Principal postulated and observed but no experimental proof available), through to TRL 4 ("low fidelity demonstrator"). Within this process, first a market driven material selection was conducted. Next, a scalable cylindrical manufacturing method, Automated Tape Placement (ATP), was used during the manufacturing stage. Lastly, a testing campaign was conducted to test the three individual layers that form the Thermoplastic Composite Pipeline (TCP), as well as the manufactured TCP demonstrator incorporating said three layers bonded together. The three bonded layer system was formed by an unreinforced inner liner layer (used to protect the remaining layers form the product being transported), wrapped via ATP with an intermediate composite layer (responsible for pipe's structural integrity). Finally, an unreinforced cover layer protecting the two previous layers from the external environment was added (see Fig.1 (B) and (C)).

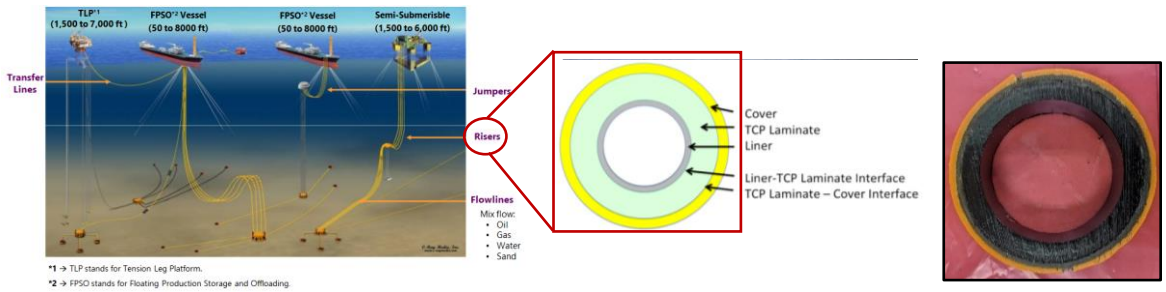
MATERIALS AND METHODS

Using the GRANTA selector software [2], material indices were used to assess the performance of the three layers forming the TCP (see Fig.1 (B) and (C)). A testing campaign was conducted to assess the properties of every layer and, in this way, generate the needed data to assess the safety of each layer separately taking in consideration their specific missions when rendering service offshore bellow see water level.

RESULTS AND DISCUSSION

The final materials combination selected for the TCP demonstrator was HDPE for the inner liner, PP/CF composite for the intermediate layer and PE-100 material for the outer cover layer. A TCP prototype incorporating these materials was manufacture and subsequent mechanical testing confirmed safety according to the specific mission of every installed layer.

FIGURES



(A) (B) (C)

Fig.1: (A) General picture of the different types of submarine flexible pipelines that can be used in offshore applications. (B) Schematic of flexible risers. Layers are bonded to each other. Up – Lateral view [3] *and down – elevation view* [4]. *(C) Manufactured TCP demonstrator.*

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Abstract

Towards a digital twin for fretting in submarine power cables

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INTRODUCTION

Among the various candidate technologies, floating offshore wind turbines (FOWTs) offers a viable pathway to decarbonisation. However, reliability of submarine power cables (SPCs) remains a critical challenge. The present work is focussed on design against fretting wear and fatigue of electrical conductors in SPCs. We propose development of a digital twin framework for fretting in SPC conductors, to identify degradation patterns, optimise design, and extend operational lifespan.

MATERIALS AND METHODS

Global model is developed in Flexcom [1] to simulate the dynamics of FOWT systems and cables. A hierarchy of progressively more localised models is driven by the global model, including (i) simplified SPC sub-element models to assess conductor loading, (ii) detailed multi-wire conductor models for analysing inter-wire contact, and (iii) high-resolution frictional contact models replicating laboratory test setups to compute fretting wear and fatigue damage. Machine learning techniques will be introduced based on data analysis from the global-local modelling workflow. Initial investigations use a cylinder-on-flat configuration, varying key design parameters (e.g., radius, normal load, stroke, bulk stress, friction), simulated using the highly-efficient EASY-FRET (Engineering Analysis System for Fretting) tool, developed at University of Galway, and currently being extended in collaboration with SETU. The research adopts a stepwise approach, starting from localised models and incrementally expanding the training dataset.

RESULTS AND DISCUSSION

This study demonstrates that implementing a lazy-wave configuration in FOWT SPCs significantly reduces fatigue loading and extends service life over traditional catenary designs. We show that (i) neglecting wear effects can lead to significant under- or over-conservative design depending on local contact slip regime, gross versus partial slip, (ii) smaller wire diameters (<6 mm) increased fretting fatigue life but are more sensitive to contact size effects, (iii) minimising cable crossing angle reduces fretting-fatigue. These findings highlight the combined impact of wear, fatigue, and environmental loading on SPC performance, to inform more robust design and maintenance strategies for floating offshore wind systems.

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Abstract

Exploring the Role of ESG Practices in Accelerating Decarbonization in the Construction Industry

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[c] Gunn Lennon Fabrications Ltd, Swords, County Dublin, Ireland.

INTRODUCTION

The construction industry is crucial to global sustainability, contributing around one-third of carbon emissions, resource utilisation, and 40% of global energy consumption. Hence, this study assesses the progress of the Irish construction companies towards adopting Environmental, Social, and Governance (ESG) practices, in alignment with EU Corporate Sustainability Reporting Directives, ISO IWA 48 ESG targets, Paris Agreement, EU Green Deal, UN Sustainable Development Goals (SDGs), and Ireland's 2050 carbon-neutrality goals. The research focuses on selected 50 Irish construction companies, categorised under micro, small and medium (SMEs), and large enterprises. As illustrated in **Figure 1**, the results highlight strengths in environmental practices, with 90% of companies adopting circular economy models, significant progress in biodiversity conservation (68%) and energy efficiency (68%). However, advanced measures such as material substitution and R&D investments remain underdeveloped, with 18% and 20% of companies adopting those respectively. Governance practices, including stakeholder engagement and regulatory compliance, are strong (96% and 100% adoption respectively), but gaps exist in sustainability monitoring (34% adoption) and internal control systems (28% adoption). On the social front, companies show strong commitments to workplace health, safety and employee engagement (96% and 88% adoption respectively). However, the attention to human rights across the value chain is limited (24%). Large enterprises lead in comprehensive ESG integration, leveraging more resources, while SMEs excel in pollution control and biodiversity conservation. Micro enterprises show basic ESG efforts but face resource limitations. The research findings underscore the need for targeted policy interventions, financial support and capacity-building initiatives, particularly for SMEs and micro enterprises. Strengthening governance, improving sustainability tracking, and fostering industry collaboration are key to achieving Ireland's decarbonisation objectives and supporting the EU Green Deal. This study highlights the construction sector's potential to drive transformative change towards a sustainable future.

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Abstract

A development of a guidance document to mitigate overheating risks in Irish dwellings

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[2]Construct Innovate, University of Galway, Galway
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Introduction:
As the climate is changing around the globe, the warmer weather conditions can negatively affect the health, comfort and wellbeing of building occupants. New and retrofitted buildings are designed with better insulation and airtightness of their envelope, which in some cases, may lead to indoor overheating risks. Therefore, it is crucial to evaluate strategies to prevent the overheating so that residential buildings can better withstand the future climate conditions.

Objective:
This study aims to (i) investigate the potential risks of overheating in Irish dwellings, (ii) identify the assessment methods for quantifying the risk of overheating and (iii) propose solutions to mitigate overheating, including design solutions and active and passive cooling methods. This study will reach those objectives by reviewing relevant literature, building regulations and best practice in the design and operation of buildings, in order to develop a guidance document on residential building overheating to be referenced in the Technical Guidance Documents Part L of the Irish Building Regulations.

Methodology:
A systematic literature review is being conducted using search strings in reliable academic sources like Scopus and web of science. The search has focused on case studies in Ireland, Britain, France, Germany, Belgium and Netherlands, which have similar climatic conditions and residential building construction types as Ireland. Furthermore, the technical guides and building regulations are also being reviewed to identify potential solutions for preventing overheating.

Discussion:

The literature review so far has highlighted that it is crucial to limit unwanted solar gains and remove excess indoor heat by passive and occasionally active methods. Next the work will focus on compiling practical methods to reduce overheating in houses and assessment tools for estimating building performance, with a focus on thermal comfort. This will lead to the development of the guide.

Key words: Overheating risks, houses, assessment methods, prevent indoor overheating

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Abstract

ATTITUDES AND BEHAVIOURS TOWARDS INDOOR AIR QUALITY AND VENTILATION IN IRISH ENERGY-EFFICIENT HOMES (BE-VENT)

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2. School of Natural Sciences & Ryan Institute, University of Galway

INTRODUCTION

Europe's carbon neutrality goals drive building energy retrofits, yet increased air tightness risks compromising indoor air quality (IAQ) without adequate engagement with ventilation – a critical determinant of occupant health and wellbeing. This study investigates occupant knowledge, attitudes, and behaviours (KAB) around ventilation systems in Irish energy-efficient homes (new/retrofitted) to design interventions balancing health and energy efficiency.

MATERIALS AND METHODS

A nationwide cross-sectional survey of energy-efficient dwellings occupant assessed demographics, dwelling/ventilation characteristics, IAQ knowledge, and ventilation behaviours. Statistical analysis included chi square which examined pollutant knowledge disparities, latent class analysis (LCA) which segmented occupants by ventilation priorities, while correlation analysis and Kruskal-Wallis tests evaluated IAQ satisfaction drivers and information-source impacts.

RESULTS AND DISCUSSION

A chi-square test revealed significant disparities in pollutant knowledge: 75.9% of low-knowledge and 74.1% of medium-knowledge participants identified carbon monoxide as the primary health threat, versus to 53.2% of high-knowledge groups. The high-knowledge group recognised broader risks ($\chi^2(14)= 67.31$, $p < 0.001$, Cramer's V=0.26). LCA identified three occupant groups: Comprehensive Endorsers (24.1%), Selective Skeptics (18.2%), Balanced Responders (57.7%). Across all groups, health and comfort outweighed energy and financial savings as ventilation motivators. Indoor environmental quality satisfaction correlated strongly with odour (r =.69), air quality (r =.73) and temperature (r =.40; all $p < .001$), advocating holistic IAQ management and communication. No signed differences emerged in perceived utility of information sources (professional/manuals/social networks), suggesting universal gaps in clarity ($p > .05$).

CONCLUSION

Baseline KAB data reveals critical gaps in IAQ risk awareness, particularly among low-knowledge groups. Interventions must integrate targeted pollutant education, tailored health-energy messaging, and holistic IAQ metrics to ensure Ireland's energy efficiency mandates deliver both climate and public health benefits. Findings will guide behavioural interventions to ensure healthier, sustainable dwellings without sacrificing energy efficiency.

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Interoperable Data Spaces: Harnessing Building Blocks with Actionable Design Principles

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[1]Data Science Institute, Insight Centre for Data Analytics

ABSTRACT

The European Commission actively supports cross-sectoral interoperable, secure and sovereign seamless data exchange. To ensure interoperability and deliver effective services to citizens and businesses, a clear set of guiding principles is essential. The proposed set of DPs (DPs) guide data space participants by translating high-level data space design requirements into actionable features, ensuring alignment with interoperability, trust, covering legal aspects and compliance goals with objectives. This work highlight's role of data space DPs in building trust-worthy, scalable, compliant with EU regulations and standards-aligned dataspace ecosystems.

INTRODUCTION

Realising interoperable data spaces is bit challenging, which requires clear guidelines for an effective design and implementation. This work begins by gathering data space requirements from existing best practices across initiatives like Gaia-X, IDSA, etc. and by performing desk research on available DPs. All these findings are then translated into set of Pillar-specific and Cross-pillar actionable DPs using Design Science Research (DSR) methodology. Furthermore, these proposed principles are then evaluated through an iterative validation process by involving experts from thematic group by ensuring their applicability, reusability, and alignment with key interoperability, governance, and compliance objectives as shown in Fig. 1.

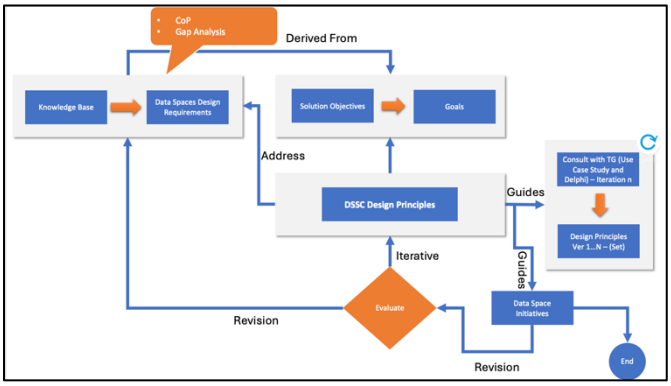

Figure 1: Validating DPs - Workflow

MATERIALS AND METHODS

The data space DPs are derived through a structured analysis of functional and semantic requirements gathered from aforementioned key initiatives. Using knowledgebase for existing DPs and extracted list of meta-requirements, by applying DSR approach, they were translated into DPs as shown in Fig. 2. Each of principle was then evaluated through a three-stage iterative validation process, where they were evaluated against goals and objectives, validated against the requirments, and finally their pilot applicability was checked through expert groups.

Figure 2: Mappings for the Problems, Meta-requirements and DPs

RESULTS AND DISCUSSION

The proposed DPs effectively address key data space requirements such as interoperability, governance, and semantic alignment. This work offers a robust, DSR-based approach for guiding interoperable data spaces development aligned with existing data space building block.

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Abstract

A novel approach to undertake a socio-economic impact assessment of a major urban regeneration project

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Abstract

Urban regeneration investments, particularly those involving multi-million-euro allocations, require diverse evaluation methodologies to comprehensively assess their impacts. This paper aims to evaluate the effects of a substantial urban regeneration investment in a city characterized by significant deprivation. Utilizing a hybrid, downscaled multi-regional input-output (MRIO) analysis alongside impact analysis, this study examines the economic, environmental, and social impacts of the project. The results indicate that the project generated 1,676.43 jobs during the construction phase and 2,400 jobs in the long-term phase. However, the employment opportunities created did not substantially benefit deprived areas, primarily due to a mismatch between the skill sets required for the jobs and those available within the local population. This study highlights the necessity for supplementary training and upskilling initiatives to effectively target these communities. Future research may focus on refining the model from an environmental perspective, incorporating more robust methodologies for carbon pricing and cost-benefit analysis.

Key Words: Impact Analysis, Input-Output model, Regeneration, Deprivation, Social impact, Environmental impact

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Abstract

AUTO-FLOATING FILAMENTOUS MICROALGAE FOR AQUACULTURE TAILWATER TREATMENT AND RESOURCE RECOVERY

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INTRODUCTION

Aquaculture expansion presents increasing environmental pressures through the discharge of nitrogen- and phosphorus-rich effluents. Microalgae-based wastewater treatment offers a sustainable solution due to their high nutrient uptake capacity and potential for biomass valorisation. However, efficient harvesting remains a major bottleneck for real-world application.

MATERIALS AND METHODS

This research focuses on the development of auto-floating filamentous microalgae that can passively separate from treated water. Laboratory-scale cultivation in simulated aquaculture tailwater was conducted using photobioreactors. Key parameters including nutrient removal rates, biomass productivity, and auto-floating efficiency were measured. Biochemical composition of harvested biomass was analysed to assess potential for use in aquafeed and bioproduct development.

RESULTS AND DISCUSSION

The selected microalgae strains exhibited strong auto-floating behaviour, achieving >85% nitrate and >90% phosphate removal. The biomass contained high protein content (up to 38%) and showed potential for extracting omega-3 fatty acids and beta-glucans. The passive floating characteristic significantly reduced the energy required for biomass harvesting. These findings demonstrate that the integrated system can contribute to a circular bioeconomy in aquaculture by coupling wastewater treatment with high-value product recovery.

Ollscoil na Gaillimhe University of Galway
Coláiste na hEolaíochta & na hInnealtóireachta College of Science & Engineering

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Abstract

Nanocomposite sensors for health monitoring of composite structures

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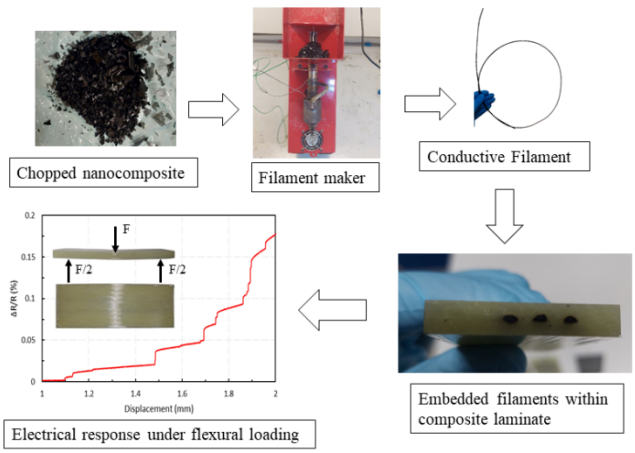
Abstract

The emergence of new technologies in composite laminate manufacturing and inspection can lead to advances in the wind energy industry. Unidirectional (UD)-Glass fibre reinforced epoxy composite laminate is widely using for manufacturing of wind turbine blades as they can tolerate high fatigue loads. One of the important subjects in wind turbine blade is periodic repair and maintenance. Delamination and crack propagation are important issues which often occurs within the composite laminate. In this study Structural health monitoring by using a developed thermoplastic piezoresistive sensor was carried out to evaluate damage extension within the UD-Glass fibre epoxy composite laminate. The thermoplastic sensor contains thermoplastic elium and carbon nanotube materials. It has prepared by material extrusion filament technique. The electrical resistance of a sensitive filament assessed through cyclic loading. The prepared material in the filament shape was embedded in the intermediate layer of UD glass fibre-epoxy composite. To evaluate damage propagation, flexural and electrical tests were carried out on the prepared smart composite laminate simultaneously. 3D point flexural bending test was conducted for mechanical test and relative resistance change was recorded through Wheatstone bridge circuit. Sharpe increase in the electrical resistance output indicated that the smart composite laminate is sensitive to damage extension under flexural test. In this study, the electromechanical evaluation on the composite laminate was an indication for potential application of this technique for structural health monitoring of large composite structure such as wind turbine blade.



Graphical abstract

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Abstract

ENRICHMENT OF AEROBIC METHANE OXIDISING MICROBIAL COMMUNITIES CAPABLE OF COLONISING BIOCHAR.

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INTRODUCTION

Methanotrophic bacteria use methane as a substrate for the production of a range of high value compounds through aerobic methane oxidation. Type I methanotrophs utilise the Ribulose Monophosphate Pathway to produce compounds like ectoine, an osmoprotectant that strengthens the bacterial cell membrane preventing osmotic lysis in high salinity environments. A major limitation is methane's solubility in water, which decreases with increasing temperature and salinity. Biochar, the product from pyrolyzed carbon-based materials, is one potential solution for this. It has the potential to trap methane molecules in its pores making it more readily available to bacteria within the media. The interaction between aerobic methane oxidising bacteria and biochar is not well studied however. This study aims to enrich methanotrophic microbial communities and evaluate how the inclusion of biochar influences community structure and colonization dynamics.

METHODOLOGICAL APPROACH AND PROGRESS

Water and sand were collected from Lettermullen, Galway, activated sludge was collected from the Tuam Wastewater Treatment Plant and soil was collected from Devlin South, Mayo. Enrichments were set up with a nitrate mineral salts media to selectively grow type 1 methanotrophs, with a 1:10 liquid-to-gas headspace. Biochar was added to half of the vials which were then inoculated with the relevant samples, and a headspace of 20 % methane was introduced. Incubation was at 15°C, shaking at 150rpm. When methane levels dropped to 5%, or when pmoA gene copy numbers approached those of 16S rRNA (determined via qPCR), aliquots of media (from vials without biochar) or biochar (from biochar vials) were transferred to fresh medium. Quantification and diversity of the microbial community are being assessed using qPCR and sequencing, respectively, of the 16S rRNA, *pmoA*, and *ectC* genes. This experimental investigation is ongoing, and future work will include investigation of the enriched methanotrophic community to produce ectoine under varying environmental conditions.

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Abstract

Non-Ablative Surface Modification of SiO_2/Si Substrates Using Ultrashort Laser Pulses: Formation of Conical Nanostructures Below the Ablation Threshold

Hamza Qayyum, Nazar Farid and Gerard M. O'Connor

NCLA Laser Laboratory, Physics, School of Natural Sciences, University of Galway, Ireland

Ultrashort laser pulses can modify materials, enabling the creation of micro- and nanostructures. These processes, occurring both above and below the ablation threshold, are strongly influenced by the energy distribution and often result in surface modifications such as micro bumps and microcraters. However, thermal effects are not the sole mechanisms responsible for melt-like states that facilitate targeted microforming of material surfaces. Material restructuring can also occur within a few hundred femtoseconds—before electronic energy fully converts into thermal energy. This timescale is shorter than the material's relaxation time, leading to what is known as non-ablative surface modification.

This study investigates the use of non-ablative surface modification to alter SiO2/Si substrate surfaces. Samples were processed with an ultrashort pulsed laser (515 nm wavelength, 500 fs pulse duration) to explore the correlation between laser processing parameters and resulting surface topography changes. Below the damage and ablation thresholds, unique conical nanostructures were observed at the irradiated spots, with heights reaching up to 300 nm. The formation and height of these nanostructures were influenced by laser power and the number of laser pulses. No nanostructures were observed when the laser power was below 80 mJ/cm2. However, when the power was increased beyond 80 mJ/cm2, up to 300 mJ/cm2, a systematic increase in the height of the nanostructures was observed. At powers exceeding 300 mJ/cm2, a microcrater formed at the irradiated area instead of an outgrown conical nanostructure. This study underscores the significance of non-ablative surface modification, demonstrating the feasibility of laser writing on SiO_2/Si surfaces without damaging the substrate, using ultrashort pulsed laser radiation. This non-ablative surface modification demonstrates a great potential to be used for fabrication of controlled nanostructures which can be further used in biomedical and optoelectronic applications.

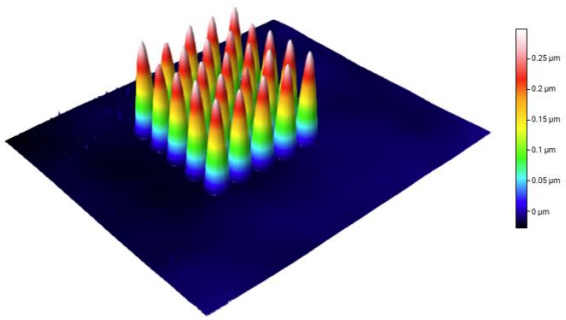

Figure 1: 3DWLI image of the laser generated surface structures

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Abstract

Developing a MegaWatt Scale Array of Vertical-Axis Wind Turbines (VAWTs) on a Single Floating Platform

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2. ERI, MaREI Research, University College Cork, P43 C573 Cork, Ireland;
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INTRODUCTION

Wind energy technology is advancing into deeper waters to take advantage of the abundant wind resources available at sea. While Horizontal Axis Wind Turbines (HAWTs) have historically dominated the wind energy sector, it may be premature to conclude that this technology is the most effective option for generating energy in deep-water environments. Vertical Axis Wind Turbines (VAWTs) could provide a more suitable alternative for harnessing energy in such locations. The MEGA4Wind project is an SEAI-funded collaboration between the University of Galway, the University College Cork and Emerald Energies, focusing on the development of a megawatt-scale array of VAWTs on a single floating platform.

METHODS

DeepWindDemo serves as a precursor to the MEGA4Wind project. This project involved the development of a 10 kW VAWT, which consists of two turbines, each with three blades, all mounted on a single platform. In addition, a separate blade has been constructed for testing at the University of Galway's Structural Testing Lab. This blade will undergo various static loading conditions. Finite Element simulations of the blade will be verified against the lab testing. The insights gained from this testing and an evaluation of the manufacturing methods will inform the design of the scaled-up MEGA4Wind blade.

An external provider utilised Ansys Fluent to conduct 2-D simulations of various configurations for two- and three-turbine arrays in order to identify the most efficient arrangement. Based on the findings from this study, the optimised configuration and scale of the final turbine are being determined. Ansys AQWA will be employed to perform 3-D simulations of the final design. A small-scale model of the final design will be 3D printed and tested in a meter-wide wave tank at the University of Galway. Additionally, a larger-scale version of the final design will be constructed and tested at the National Ocean Test Facility to validate the results from the small-scale test and the Ansys AQWA analysis.

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Abstract

Evaluating Energy Absorption Capacity in Airtight Membranes for Sustainable Construction

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1. INTRODUCTION

Mechanical performance evaluation of airtight membranes involves tensile and tear tests to measure resistance to stretching and crack propagation. However, these methods do not capture a material's capacity to absorb and dissipate mechanical energy. This study incorporates energy absorption capacity (EAC) as an additional metric to assess membrane durability and deformation characteristics. Also, the evaluation framework aims to better align material selection with the mechanical demands of building envelope applications. This approach supports the development of more durable and sustainable membrane solutions for modern construction.

2. MATERIALS AND METHODS

Four building membranes were tested to assess their contribution to building durability through controlled vapor permeability and airtightness. All specimens were evaluated according to international standards (I.S. EN 12311-1:2000, BS EN 13859-1:2014, and I.S. EN 12310-1:2000) to ensure reliable results. Figure 1 illustrates the experimental procedures for tensile and tear testing.

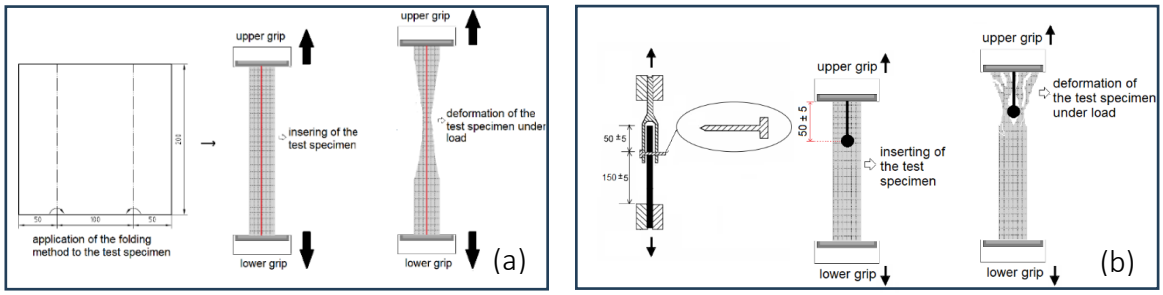

Figure 1. Experimental setup (a)Tensile test, (b)Tear test

3. RESULTS AND DISCUSSION

Eco membranes generally exhibited higher tensile performance on the maximum forces. However, non-eco membranes showed higher tensile energy absorption, suggesting better performance to dissipate energy under load. In tear testing, non-eco membranes significantly outperformed eco variants in both maximum force and energy absorption, highlighting their enhanced toughness against tearing. These findings highlight that eco membranes provide greater tensile strength, while non-eco membranes offer better energy absorption and tear resistance. Overall, material selection should balance strength and durability depending on performance priorities in construction applications.

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Abstract

From Regulation to Consumption: Exploring the Energy Implications of Effluent Discharge Limit Stringency in Wastewater Treatment Plants

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3. Civil, Structural and Environmental Engineering, School of Engineering, University College Cork

INTRODUCTION

Wastewater treatment plants (WWTPs) are essential for safeguarding water resources in the face of increasing water scarcity and climate-related challenges [1]. While stricter effluent discharge regulations have led to improved water quality[2], they also require energy-intensive technologies, contributing to higher electricity demand and greenhouse gas (GHG) emissions[3] . The water sector currently accounts for 2–3% of global electricity consumption [4] , with WWTPs alone consuming 1–4% in the U.S. [5], 1% in the EU [6], and 0.35%-0.67% in China[7]. This growing energy burden highlights a critical trade-off between effluent stringency, energy consumption, and GHG emissions.

MATERIALS AND METHODS

While existing research has extensively evaluated how key influencing factors, including plant scale, influent characteristics, operational loading rates, reginal and seasonal variability affect energy consumption in WWTPs, the connection between these factors and effluent discharge regulation-particularly the influence of regulatory stringency-has not been fully explored. Discharge regulations are generally established using conservative assumptions to ensure the protection of receiving waters under worst-case conditions, such as low assimilative capacity or limited flow. However, if it were possible to vary the discharge regulations seasonally, taking into account varying assimilative capacity, then there may be an opportunity to enable WWTPs to sufficiently protect the receiving water whilst also minimising the energy requirement.

RESULTS AND DISCUSSION

To address this knowledge gap, this study examines the relationship between discharge regulations and energy consumption in WWTPs. It further explores how modifying discharge limits—particularly through seasonal variation—may influence WWTP energy performance and identify opportunities to mitigate GHG emissions. The research will analyze available Irish WWTP energy data to evaluate the impact of variable regulations on energy usage under different scenarios. In the final phase, the study will apply life cycle assessment (LCA) methods to assess the trade-offs between stricter effluent regulations and energy consumption.

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Abstract

Racking tests of CLT panels manufactured from C16-grade Irish timber

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2. Department of Building and Civil Engineering, Atlantic Technological University & Construct Innovate

INTRODUCTION

Due to the increase in focus towards sustainable construction materials, cross-laminated timber (CLT) has emerged as an excellent choice due to its high strength-to-width ratio and light weight. CLT panels in Europe are manufactured primarily using C24-grade timber, with a small proportion of C16-grade timber in the internal layers. However, Irish timber is typically graded as C16. There is limited information on the racking strength and stiffness of CLT panels manufactured entirely using C16-grade timber, and this study aims to examine this. These racking tests will inform the design of a multi-storey modular building using C16-grade Irish timber, which is a part of the Modular Mass Timber Building for the Circular Economy or MODCONS project.

MATERIALS AND METHODS

2.4 m x 1.2 m CLT panels have been manufactured as per EN 16351. Commercially available Rothoblaas TTF200 angle brackets and WHT440 hold-downs are used to connect the wall panel to the floor panel in combination with 5 mm diameter LBS screws of 50 mm length in a fully-fastened configuration. The racking test is performed as per EN 594, and the displacements are recorded using linear variable displacement transducers (LVDTs), as shown in Figure 1.

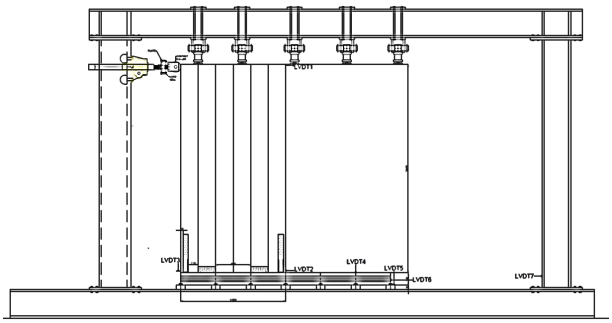

Figure 1: Racking test layout of 2.4 m x 1.2 m CLT panel

RESULTS AND DISCUSSION

The racking displacement of the panel is calculated as the difference between the horizontal displacement at LVDT 1 and the horizontal displacement at LVDT 2. The vertical displacement at LVDT 3 gives the uplift of the panel. The racking strength of the panel is the maximum load attained during the test (F_{max}). The racking stiffness (R) is calculated as shown.

$$R = \frac{F_{40} - F_{10}}{v_{40} - v_{10}} \quad (1)$$

Where F_{10} and F_{40} = are the loads corresponding to 10% and 40% of F_{max} and v_{10} and v_{40} = are the displacements corresponding to 10% and 40% of F_{max}, that is the slope of the line between 10% and 40% of F_{max}.

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Abstract

Dynamics of N_2O Emissions in a Partial Nitrification SBR under Intermittent Aeration

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1. Department of Civil Engineering, College of Science and Engineering

INTRODUCTION

Nitrous oxide (N_2O), a potent greenhouse gas, is frequently emitted as a by-product—especially under intermittent aeration in sequencing batch reactors (SBRs) during partial nitrification (PN) process. This study aims to investigate the dynamics of N_2O emissions in typical SBR cycles under intermittent aeration, and identify the biological factors driving its fluctuation.

MATERIALS AND METHODS

A lab-scale SBR (1.8 L) was operated. Water-soluble inorganic nitrogen (NH_4^+-N, NO_2^--N and NO_3^--N) as well as N2O-N were measured in long-term running and typical cycles. DNA and RNA samples were collected at key time points (Sequencing results are not yet available).

RESULTS AND DISCUSSION

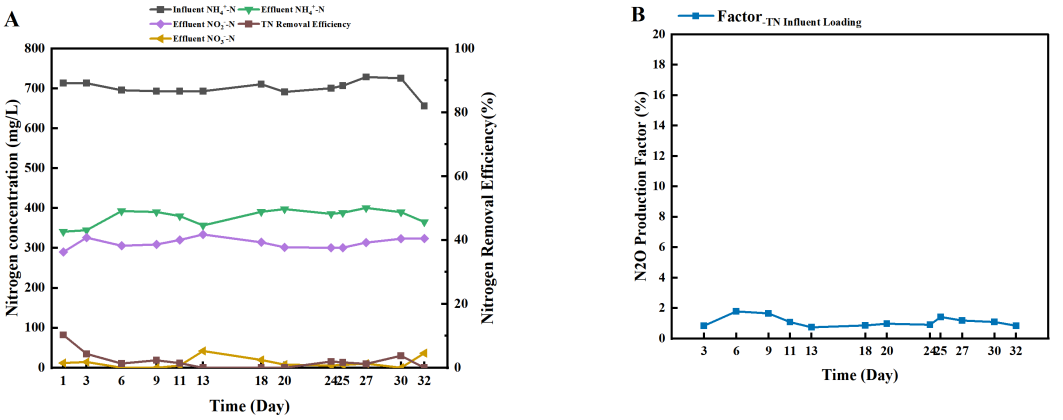

Figure 1. Long-term performance (A: Inorganic nitrogen changes; B: N_2O production factors)

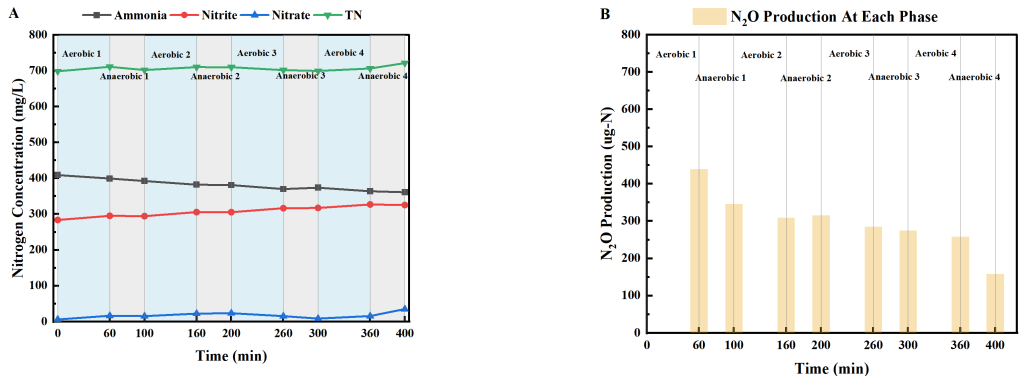

Figure 2. Cycle experiment (A: Inorganic nitrogen changes; B: N_2O production)

N_2O emission was primarily observed during aerobic phases, with the first aeration stage contributing the most. Emissions declined over time, indicating substrate availability and microbial activity play key roles in N_2O production.

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Abstract

Stakeholder Perceptions and Dynamics in Ireland's Dairy Sector: Mapping the Path to Sustainable Food Systems

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2. School of Computer Science
3. School of Political Science & Sociology

INTRODUCTION

Food systems face complex challenges rooted in human agency. While technological innovation has dominated solution spaces, meaningful transformation relies more on the perceptions, values, and interactions of diverse actors—consumers, institutions, policymakers, investors, and suppliers—within systems shaped by social, cultural, and knowledge-based factors.

Ireland's Food Vision 2030 was globally recognised at the 2021 UN Food Systems Summit as a leading national strategy. This study explored perceptions of sustainability in Ireland's dairy sector, focusing on trust, relationships, and the dynamics of conflict and collaboration. The industry operates within a closely interconnected network of farmers, processors, policymakers, and the public. However, increasing regulatory and environmental pressures, coupled with critical public narratives, have strained relationships and challenged efforts toward collective action.

MATERIALS AND METHODS

A mixed-methods approach was employed to investigate the social and relational dynamics underpinning trust and leadership. Following stakeholder identification, 17 in-depth interviews were conducted via video conferencing and an online survey. The study examined perspectives on sustainability, trust, conflict, knowledge exchange, power dynamics, and shared values.

RESULTS AND DISCUSSION

The findings reveal a wide range of stakeholder perspectives on sustainability and identify both significant barriers to trust and promising avenues for fostering collaboration and shared leadership within the dairy sector. This research contributes to academic and policy dialogues by offering practical insights to enhance stakeholder engagement and strengthen sectoral resilience.

Participants demonstrated a strong awareness of sustainability's multiple dimensions, particularly environmental concerns such as carbon emissions, water quality, and biodiversity. However, they also emphasised the interplay between ecological goals, economic viability, and social well-being. Many expressed frustration with shifting regulatory demands, inadequate communication, and the financial strain of compliance, noting that environmental priorities often eclipse economic and social considerations, potentially undermining the sector's long-term stability.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Investigation of the Thermal Degradation Pathways of Novel Brominated Flame Retardants

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INTRODUCTION

Brominated flame retardants (BFRs) are extensively used in expanded (EPS) and extruded polystyrene (XPS) foam insulation to improve fire resistance. However, these compounds undergo complex thermal degradation, potentially producing highly toxic by-products such as polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs). With the anticipated rise in bromine-rich construction waste—over 10,000 tons annually by 2035 in China—thermal treatment remains the dominant disposal method. Yet, the thermal behaviors of emerging BFRs like TBBPA-DBMPE and brominated SBS (Br-SBS) are still poorly understood. Studying their degradation mechanisms is essential for predicting toxic emissions and improving waste management strategies.

MATERIALS AND METHODS

EPS and XPS foams were collected from China. Thermal behavior was studied via TG-DSC; Py-GC–MS identified decomposition products. Molecular transformations were modeled using DFT. Geometry optimization used B3LYP-D3/6-311G(d,p); single-point energies were computed at M06-2X-D3/6-311G(d,p).

RESULTS AND DISCUSSION

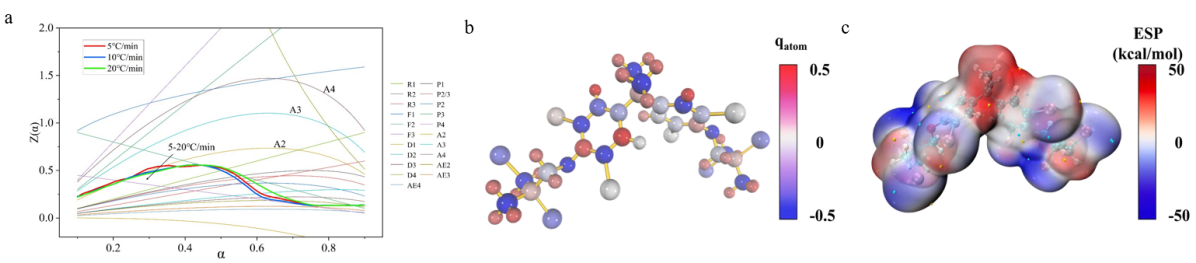

Fig. 1 Kinetic fitting results, atomic charges (c) and surface electrostatic potential (d) of TBBPA- DBMPE

TBBPA-DBMPE showed a multi-step degradation profile. At low conversion (α = 0.1–0.4), decomposition followed an Avrami-Erofeev A2 model, indicating a nucleation-growth mechanism, mainly involving debromination and molecular rearrangement. At high conversion (α = 0.7–0.9), AE2/AE3 models were more applicable, reflecting char formation and diffusion-limited reactions. DFT analysis indicated high electron density on aromatic rings and electron-deficient bridging carbons, suggesting preferential cleavage sites. Br-SBS exhibited similar transformation patterns with distinct product profiles and thermal thresholds.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Enabling Commercial Building Retrofit

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Retrofitting is a growing area within the construction industry aimed at maximising energy efficiency in buildings, thereby decreasing energy costs and greenhouse gas emissions while ensuring user comfort. However, retrofitting has primarily focused on residential buildings in Ireland, neglecting the significant potential of commercial buildings such as offices, retail spaces, and leisure facilities.

Enhancements like improved insulation, modern heating systems, and facilities such as showers and changing rooms can encourage sustainable commuting and healthier lifestyles among employees. These improvements contribute to reduced carbon footprints and potentially increase workplace productivity, helping to justify the investment in retrofitting through lower energy bills and shorter payback periods.

With 90% of today's buildings projected to still be in use by 2050, retrofitting is essential for achieving Net Zero targets. Addressing the inefficiency of Ireland's commercial building stock presents a tremendous opportunity to reduce emissions while aiding in the pursuit of climate targets.

Understanding behavioural drivers and potential barriers to retrofit for SMEs allows the assembly of tailored solutions to further promote renovation within the commercial sector. This paper aims to centralise information regarding the financial, regulatory and ESG drivers and barriers, and viewpoints of various stakeholders, along with an analysis of past renovations and recommendations of technological advancements to produce a tool for developers in the retrofit journey.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

AQU3D: Advanced Automated Data Collection for Quality Control in 3D Concrete Printing

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The AQUA3D project aims to revolutionize 3D concrete printing (3DCP) by introducing an automated, sensor-based data collection system that enhances quality control and precision in real-time manner. At the core of this system is the Raspberry Pi Single-Board Computer (SBC), which serves as the central processing unit, collecting and transmitting environmental and process data. Through seamless integration with platforms like Azure IoT Hub and Microsoft Power BI, AQUA3D enables real-time data visualization and analytics, providing stakeholders with actionable insights throughout the printing process. Harcourt Technologies Ltd (HTL), as the funder and collaborator on the AQUA3D project utilizes the COBOD BOD2 3D construction printer (Fig. 1), known for its precision and efficiency in on-site concrete printing.

Figure 1: COBOD BOD2 at HTL

The system is designed to monitor and analyse a range of environmental and material parameters that influence the quality and reliability of the 3DCP process. These include temperature, humidity, pressure, layer height, and moisture content. AQUA3D's functionality is rooted in non-contact sensor technologies that ensure accuracy without disrupting the ongoing print. This setup enables early detection of anomalies, such as improper curing or material degradation, which can impact final output.

Furthermore, AQUA3D integrates machine learning capabilities through the Raspberry Pi AI-Hat, allowing the system to adaptively respond to changing print conditions. High-resolution imaging via the Raspberry Pi Camera Module supports visual inspections.

All collected data is integrated into a centralized, cloud-connected database and displayed through a user-friendly web-based dashboard. This remote monitoring capability empowers project teams and stakeholders to make informed, timely decisions, improving resource management and quality assurance.

With its modular architecture and intelligent design, AQUA3D offers a scalable, data-driven solution to modernize and optimize 3DCP. By minimizing human intervention, enhancing sustainability, and improving operational efficiency, it paves the way for a smarter future in automated construction technologies.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

A Communication Toolkit for Enabling Commercial Building Retrofitting Among SMEs in Ireland

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INTRODUCTION

The commercial building sector represents a significant opportunity for energy efficiency improvements in Ireland, yet small and medium-sized enterprises (SMEs) remain notably underrepresented in building retrofitting initiatives despite their collective environmental impact. The ENACT project addresses this gap by investigating the behavioural drivers in broader context that influence SME decision-making regarding energy retrofits and developing targeted communication strategies to overcome adoption barriers.

METHODOLOGY

Identifying the behavioural drivers for building retrofitting among small and medium business is vital for policy makers to streamline the policies accordingly. This research employs mixed method approach to identify these behavioural drivers. Series of workshops and interviews were carried out with business owners, services providers and government department staff to understand these drivers deeply. These inputs from the SMEs and other stakeholders then will be analysed and categorised under 13 broader topics to understand more about this topic. During final stage of the project, a communication toolkit will be designed targeting the SME sector by equipped with the required information and decision-making tools that help their decision on retrofitting.

IMPACT

This project targets a range of audiences, with business owners being the primary focus. However, other key stakeholders such as policymakers, retrofit consultants, and service providers can also benefit significantly from the project's outcomes

RESULT AND DISCUSSION

17 SMEs were engaged during the first phase of the workshop series. 43 behavioural drivers were identified in the first phase of the survey carried out among SMEs and further classified them under 13 broader topics. On the other hand, after finalising the findings of the project, those deliverables are disseminated through a dedicated web-based communication toolkit that enriched with case studies, decision making tools and training sessions that support for the wide range of SMEs across the country.

The ENACT project contributes to accelerating commercial building retrofitting by addressing the specific behavioural and informational barriers faced by Irish SMEs. By translating complex technical and financial information into accessible, context-specific guidance, the communication toolkit empowers smaller businesses to make informed decisions about energy efficiency improvements. This approach not only supports national climate objectives but also enhances the competitiveness and sustainability of a SME sector of the Irish economy.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Exploring the Role of ESG Practices in Accelerating Decarbonization in the Construction Industry

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Introduction

The building and construction sector plays a vital role in meeting sustainability goals. However, it is also a major source of global carbon emissions (approx. 37%) and energy consumption (36%). In response to the EU Corporate Sustainability Reporting Directive (CSRD), ISO IWA 48, the Paris Agreement, the EU Green Deal, and Ireland's Climate Action Plan, this study evaluates the extent of Environmental, Social and Governance (ESG) practice adoption within the Irish construction industry to support Ireland's 2050 carbon neutrality target.

Materials and Methods

Fifty Irish construction companies were sampled across micro, small, medium and large enterprises. A mixed-methods approach combined desktop reviews of ESG reports and structured surveys. Assessment used benchmark indicators from ISO IWA 48, CSRD, and the EU and Irish policy. Performance was evaluated across environmental (e.g. circularity, energy, biodiversity), social (e.g. workplace safety, employee engagement, human rights), and governance (e.g., compliance, stakeholder engagement, internal monitoring) dimensions.

Results and Discussion

The analysis, as illustrated in **Figure 1,** showed that 90% of firms engaged in circular economy practices, while biodiversity and energy efficiency measures were adopted by 68%. However, advanced environmental strategies like material substitution (18%) and green R&D (20%) were underutilized. Governance performance was strong in regulatory compliance (100%) and stakeholder engagement (96%), but weak in monitoring (34%) and internal controls (28%). Socially, health and safety (96%) and employee engagement (88%) were widely practiced, while human rights due diligence was low (24%). This study revealed that larger firms showed greater ESG integration, while SMEs outperformed in biodiversity and pollution control. Micro-enterprises displayed basic ESG efforts, limited by resources.

The findings highlighted the need for targeted support, especially for SMEs, improved ESG data systems, and enhanced governance to align with Ireland's sustainability goals.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Non-equilibrium dynamics and interaction characteristics via femtosecond Pulsed Laser annealing of ultra-thin metal films

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INTRODUCTION

The process of modifying material properties using ultrashort laser pulses has the ability to measure the non-equilibrium dynamics at femtosecond time resolution. It has shown that there is improvement in electrical conductivity of low temperature synthesized 2D semiconductor thin-film ultra-short pulsed laser annealing (PLA). This process makes use of a solid-state diffusion process, with single pulses of Femtosecond(fs) laser energy. The approach depends on several factors and incident fluence is most prominent among them and it is significantly lower than those typically required for the onset of damage or ablation. The main aspect of the interaction for ultrashort pulsed irradiation at these low fluence regimes is the generation of a non-equilibrium between nonthermal electrons and cold lattice. The Two-Temperature model that agrees with the hot electron dynamics and transferring thermal energy via phonons to the lattice should modified accordingly. The temperature of electrons is in the range of thousands of Kelvins and follows a non-thermal distribution for few femtoseconds and the relaxation time of electrons with non-thermal electrons and Phonons collectively characterize the electron dynamics and equilibrates thereafter. While the ejection of electrons happens, we estimate the probability by photoelectric and thermionic emission for such ultra-thin materials since the microscopic non-thermodynamic pathway of the electronic transition upon femtosecond laser-excitation is still under debate.

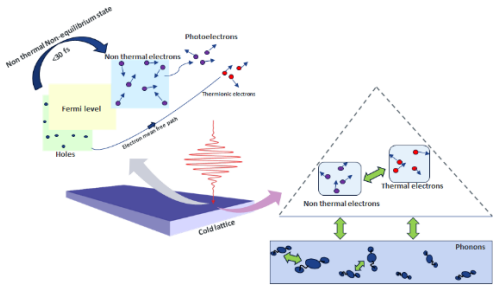

Figure 1: Non-equilibrium dynamics of electron at femtosecond range

The ultimate ambition of the project is to unravel the issues behind the carrier dynamics of TMD materials and invent solutions that lead to integrated circuit (IC) technology 3D integration issues. 2D TMD growth is currently not at the single crystal level: grain dimensions larger than 10 microns have been demonstrated, but wafer-scale defect-free single-crystalline films are hardly obtained. A sophisticated method of approach towards the integration issues can only be resolved using a state-of-the-art process with minimal thermal budget as well as Back End Of Line BEOL compatible. Low fluence Pulsed Laser Annealing (PLA) using femto second single pulses seems to have a huge potential but rarely investigated.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Nitrate chemodenitrification by iron sulfides to ammonium under anoxic conditions and transformation mechanism

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2. School of Energy and Power Engineering, Beihang University
3. School of Civil Engineering, Hefei University of Technology
4. School of Physics, Trinity College Dublin

INTRODUCTION

Nitrate contamination in groundwater poses significant environmental and health risks. Traditional biological denitrification processes can be limited under certain conditions. This study investigates the potential of iron sulfides to chemically reduce nitrate to ammonium under anoxic conditions, offering an alternative pathway for nitrate remediation.

MATERIALS AND METHODS

Batch experiments were conducted under anoxic conditions to assess three common iron sulfides (FeS, FeS_2 and pyrrhotite) reactivity with nitrate. Nitrate and ammonium concentrations were monitored over time using ion chromatography. Solid-phase analyses were performed using X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS) to elucidate reaction mechanisms.

RESULTS AND DISCUSSION

The study found that FeS exhibited the highest reactivity, converting nitrate to ammonium efficiently. This reactivity is attributed to the high density of sulfur vacancies on FeS, which enabled rapid electron release and enhanced surface reactivity. Experimental evidence and density functional theory (DFT) calculations revealed that surface-bound Fe(II) was the primary active site responsible for nitrate reduction and FeS possessing sulfur vacancies exhibited the specific adsorption of O atoms within the nitrate molecule and promoted intrinsic activity for H_{ads} formation through water dissociation, thus leading to a heightened selectivity in ammonium formation. This selectivity suggests a promising route for converting nitrate, traditionally viewed as a pollutant, into ammonium, which has potential reuse value as a nitrogen-based fertilizer or fuel. Beyond the practical implications for wastewater treatment, these findings deepen the understanding of iron sulfide reactivity in geochemical processes and nitrogen cycling. The insights also extend to prebiotic Earth scenarios, where Fe–S systems may have contributed to early biochemical transformations.

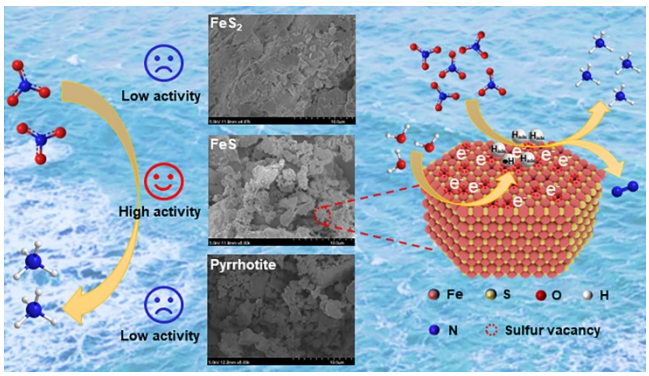

Figure 1: Nitrate chemodenitrification by iron sulfides to ammonium and transformation mechanism.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Nuclear Dynamics During Seed Priming

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INTRODUCTION

Seed priming is a widely adopted strategy in modern agriculture due to its beneficial effects on germination speed, uniform seedling establishment, and improved tolerance to early environmental stress. Seed priming involves controlled imbibition to activate seed metabolism, followed by a timed dehydration step prior to radicle emergence. Although the physiological outcomes of seed priming are well-documented, the underlying molecular mechanisms, particularly those contributing to its long-lasting effects, remain poorly understood. We hypothesize that the persistence of seed priming effects arises from the establishment of an epigenetic memory that is localized in specific cell types of the seedling. This epigenetic memory may play a critical role in modulating gene expression patterns that support enhanced vigor and stress resilience post-germination.

MATERIALS AND METHODS

To investigate this hypothesis, our research combines transcriptomic and epigenomic approaches to identify key regulators of seed priming. As a first approach, we performed bulk RNA sequencing (RNA-seq) on *Arabidopsis thaliana* primed and unprimed seedlings to identify differentially expressed genes associated with primed seeds. This analysis allowed us to pinpoint a set of candidate genes potentially involved in mediating the priming response. Moving forward, we aim to achieve higher spatial resolution by applying single-nuclei multiomic profiling, including single-nuclei RNA-seq and Assay for Transposase-Accessible Chromatin with sequencing (ATAC-seq).

PERSPECTIVES

This approach will enable us to map both transcriptional and chromatin accessibility changes across diverse cell types within primed seedlings, providing insights into how epigenetic memory is established and maintained in a cell-type specific manner. By integrating these datasets, we seek to uncover the molecular and cellular mechanisms that underpin the enduring effects of seed priming, ultimately contributing to the development of more resilient crop varieties through targeted priming strategies.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Method Development for Extracting Microplastics from High Organic Matter Matrices

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2. Civil Engineering, University of Galway, Ireland.

INTRODUCTION

Animal manure is widely used as an organic fertilizer; however, recent studies have identified the presence of microplastics (MPs) in animal manure, which could contribute to soil pollution. Research on microplastics in manure is still in its early stages, and no standardized method for organic digestion and extraction has been established. The digestion process for extracting MPs from organic materials typically takes 24 to 48 hours. However, this process can be optimized by adjusting variables such as reagents, concentrations, time, and temperature.

This study aims to reduce MPs extraction time from high-organic matrices, evaluate the effect of agitation speed at optimum temperature to remove organic matter.

MATERIALS AND METHODS

The manure samples were oven-dried for 48 hours at 50°C. Five grams of the dried manure was placed into an Erlenmeyer flask and incubated in a shaker at 40°C and 120 rpm, with the addition of varying concentrations of H_2O_2 (10, 20, 40, and 100 ml) for 24 hours. After 6 hours, additional H_2O_2 were added to the samples with lower initial concentrations to bring them up to 100 ml. After 24 hours, the samples were filtered and centrifuged at 4500 rpm for 30 minutes. The filter papers were then oven-dried at 50°C overnight and weighed to calculate the removal of organic matter.

RESULTS AND DISCUSSION

Preliminary results showed significant organic matter reduction (30–78%) at 40 °C with varying agitation speeds (Fig. 1). The highest removal (78%) occurred with sequential H_2O_2 addition at 120 rpm, while 100 ml H_2O_2 at 140 rpm also enhanced digestion. However, replicates at 140 rpm showed reduced efficiency (30%). Despite variability, sufficient breakdown was achieved to facilitate MP release for density separation. Future work will assess MP recovery using $ZnCl_2$-based density separation techniques.

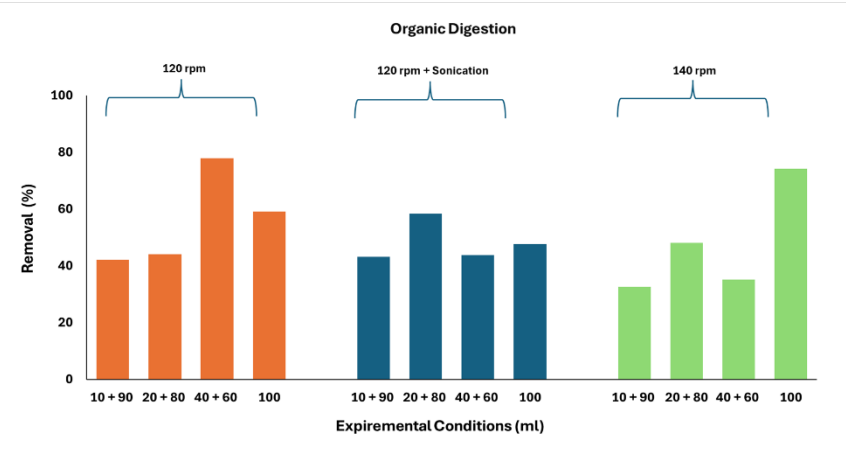

Fig. 1: Preliminary results of organic matter removal under different tested conditions (The histogram on x-axis shows the concentration of H_2O_2)

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Abstract

Development of water quality model for evaluating the peatland rehabilitation measures in Ireland

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There is increasingly demanding effort across Europe to restore degraded peatlands through rewetting techniques. While the measures of restoration by rewetting can effectively encourage the growth of peat-forming mosses, there have been concerns about peatland water quality problems due to the interaction between raised water table level and the release of nutrients such as ammonium (NH_4^+), nitrate (NO_3^-) and phosphate (PO_4^{3-}), which may pose a significant risk to water quality in receiving water bodies.

To date, there is no peatland-specific water quality model. To address this knowledge gap, the objective of this study was to develop a 2D water quality model for peatlands, considering advection-dispersion solute transport, decomposition of organic matter and related biochemical processes that affect the concentration of nutrients.

The solutions to the system of governing partial differential equations were implemented by using the finite volume method (FVM). While the overall solver was based on an explicit scheme, e.g. by using the Euler's forward method, a second-order central differencing scheme was applied to discretise the dispersion term. In order to make the solver stable, the advection term was discretised using the second-order upwind total variation diminishing (TVD) method. The model was verified by comparing the numerical modelling results of a 1D benchmark problem with related analytical solutions, getting a correlation of $R^2 > 0.99$. The 2D version of the water quality model is currently being developed and will be coupled with a hydrological model that was previously developed in this PhD project to predict the effect of peatland rewetting measures (such as blocking drains and/or creating ponds) on water quality on some selected bog sites in Ireland. The model will be calibrated by water quality data (NH_4^+ and NO_3^-) being measured currently.

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Abstract

A focus group study of sustainable food perceptions and practices among adult residents of County Galway, Ireland

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INTRODUCTION

There is growing consensus that societal buy-in and bottom-up societal change must accompany other forms of innovation if sustainable food systems are to be achieved[1-3]. Despite their power to drive change as consumers and the electorate, little is known about what citizens in Ireland perceive as sustainable in food practice, and what they find affordable, feasible, and culturally acceptable in adopting healthier, more sustainable food practices. In this mixed-methods study of residents in County Galway, we explore individuals' perceptions of and experiences with food sustainability, as well as what they are prepared to do to help achieve sustainable food systems.

MATERIALS AND METHODS Eight focus group sessions were held both in Galway City and online for a total of 30 participants. Focus group topics included: perception of sustainable/unsustainable food systems and participants' roles within; engagement with food environment; what participants are prepared to do to make food practices more sustainable; and what tools, supports, or changes could help participants be more sustainable. Thematic analysis is underway to generate the major themes of focus group discussions. A survey (n=82) was used as a recruiting tool and survey analysis is underway to supplement focus group data with demographic and quantitative data on perceptions of food sustainability and engagement with the food environment.

RESULTS AND DISCUSSION Analysis is ongoing. Preliminary results suggest perceived sustainability of locally sourced diets and community-driven food systems and feelings of isolation and disempowerment in sustainable food action. Expected significance includes identifying key beliefs and perceptions about sustainable food practices in Galway, informing sustainable food policy, and laying groundwork for co-creation of tools and supports that could be implemented in food environments to encourage sustainable food practices.

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Abstract

FLUSH WITH CONSEQUENCES: HYGIENE PRODUCTS, MICROPLASTICS, AND THE URBAN WATER CYCLE

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INTRODUCTION

Wet wipes and sanitary towels, commonly disposed of via lavatory flushing, are an underestimated source of microplastic pollution in aquatic environments. This study examines the role of these products in contributing white microplastic (MP) fibres to marine sediments, with a focus on areas downstream of wastewater treatment plants (WWTPs) in Ireland. Sediment samples collected near the Mutton Island WWTP revealed concentrations of up to 6,083 MP fibres per kilogram, with 91% identified as white fibres likely originating from personal hygiene products.

Material analysis showed that many wipes and sanitary towels contain synthetic polymers such as polyethylene terephthalate (PET), polypropylene (PP), or mixed cellulose blends. Notably, 50% of products labelled as "flushable" still contained persistent synthetic fibres. The findings suggest that these products bypass or survive wastewater treatment processes, especially during combined sewer overflow events triggered by heavy rainfall, leading to their release into the marine environment.

Given the direct link between everyday hygiene products, environmental contamination and the potential of microplastics to act as vectors for pathogens and chemical contaminants, the present work raises concerns and supports the development of sustainable solutions and innovations to protect both ecosystem and human health. The study calls for improved public awareness, clearer product labelling, and innovations in urban wastewater management to reduce plastic fibre release at the source.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Evaluating Embodied Carbon of Deep Retrofit Homes in Ireland

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INTRODUCTION

Existing buildings in Europe contribute nearly 40% of the overall energy usage and represent about 36% of the energy-related greenhouse gas emissions. Thus, European governments set energy retrofit targets for existing buildings. Moreover, the EU has recently projected to transition from net-zero energy buildings to zero-carbon buildings by 2030, including embodied and operational carbon emissions. The study evaluates the embodied carbon (EC) emissions linked to materials used for deep retrofitted homes in Ireland.

MATERIALS AND METHODS

The research develops a methodology for evaluating the EC of deep retrofit homes and applies it to 10 real case studies. The developed method follows the EU standard EN 15978 and adopts the EU Level(s) indicator 1.2 - Life cycle Global Warming Potential as a framework. The methodology uses a constant database of materials' (A1-A3) carbon emissions in Ireland, which combines data from Cambridge Architectural Research, Circular Ecology, EPDs from cement manufacturers in Ireland, and data from the UK Inventory of Carbon and Energy (ICE) database for other materials. A hotspot material analysis was undertaken and focused on the top 5 contributors for each case study.

RESULTS AND DISCUSSION

The findings show that the EC average of the deep retrofit homes in Ireland is 347 $kgCO_2e/m^2$ (Fig. 1). This average represents a benchmark for current market practice and a starting point for developing EC reduction targets for upcoming projects. In total, 16 materials were the most impactful (e.g. in-situ reinforced concrete, mortar, steel sections, concrete blocks, aluminium, windows/doors, EPS insulation, plasterboard, and granite). Particular focus should be given to the principal contributors: concrete, cement, steel, windows, and insulation, to find solutions for reducing their impacts. Ultimately, the study is a guide for the retrofitting specialists to evaluate and compare the EC of their upcoming projects with the developed benchmark.

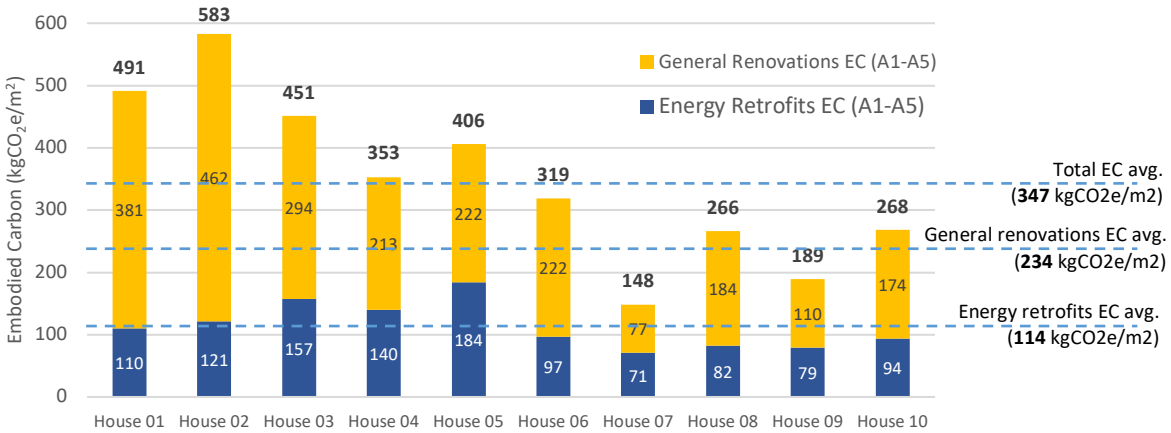

Figure 1 Embodied carbon evaluations for 10 deep retrofit homes in Ireland

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Development and 3D Printing of Three-Dimensional Reinforcement from Waste Composites for Concrete Structures (3DREDO)

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INTRODUCTION

Cementitious materials are widely used in the construction industry. However, their inherently low ductility often necessitates reinforcement with steel rebars, which introduces challenges such as corrosion. Polymer-based reinforcements immune to corrosion have been introduced as alternatives to steel. Cementitious composites reinforced with traditional polymeric materials typically demand a higher reinforcement ratio to achieve adequate performance. Three-Dimensional (3D) printing, as a revelatory technology enable the creation of polymer-reinforced structures with tailored properties. This innovation significantly reduces the required reinforcement ratio while simultaneously enhancing the mechanical performance of cementitious composites. The 3DREDO project addresses the low ductility of cementitious materials by innovatively using waste polymers and composites to 3D print customized reinforcements that strengthen concrete components. By repurposing industrial and domestic plastic waste into specialized filaments for material extrusion 3D printing, the project focuses on improving the mechanical performance of reinforced parts as well as advancing the sustainability in construction industry. A variety of composite filaments containing recycled polymers and varying fiber contents were fabricated and optimized formulation was selected considering filament's superior mechanical properties as well as printability. Different lattice structures were fabricated through 3D printing, incorporating a range of design parameters including cell size and density. The configurations which offered the highest ductility, fracture performance, and overall mechanical strength of cementitious components were identified. A key innovation of this research focuses on 3D printing reinforcements with minimal or no support structures, contrasting with conventional methods that often rely on additional supports. This approach achieves high performance characteristics through simplified geometry, leading to streamlined production, reduced material waste, and greater operational efficiency. By shedding light on these considerations, the project presents a corrosion-resistant, eco-conscious alternative to traditional reinforcement, offering a transformative solution that aligns engineering innovation with global sustainability goals.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

UBP5 MODULATES CHROMATIN STATE, NUCLEAR MORPHOLOGY, AND HORMONAL BALANCE TO CONTROL SEED GERMINATION IN ARABIDOPSIS

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INTRODUCTION

Seed germination, a main key agricultural trait, is a tightly regulated developmental transition that ensures plant growth begins only under favourable conditions. This process is orchestrated by hormones: abscisic acid (ABA), which inhibits germination, and gibberellins (GA), which promote it. However, how plants integrate these hormonal signals with chromatin-based gene regulation remains poorly understood. UBP5 is the main deubiquitinase of H2A in the plant. The ubiquitination of H2A (H2Aub) is an epigenetic mark associated with gene repression and involved in plant development. However, the role of UBP5 activity during seed germination had not been investigated. In this study, we explore how UBP5 coordinates gene expression, hormone biosynthesis, and nuclear architecture to control germination.

METHODS

We used Arabidopsis thaliana wild-type (Col-0 ecotype), UBP5 mutant (ubp5), and UBP5-GFP overexpression lines to assess germination behaviour under ABA and GA treatments. Germination rates were measured over 12 days. Levels of ABA and GA were quantified in dry and imbibed seeds using liquid chromatography–tandem mass spectrometry (LC-MS/MS). Gene expression was analysed by RNA sequencing (RNA-seq) and quantitative PCR. Nuclear structure in seed embryos was visualized using DAPI (a DNA-binding dye) and 3D structural imaging. Ongoing experiments include chromatin immunoprecipitation sequencing (ChIP-seq) to identify genomic regions enriched in H2Aub, and flow cytometry to assess DNA content and cell cycle progression.

RESULTS

ubp5 mutants exhibited a strong germination delay that was partially rescued by GA application. Hormone quantification revealed elevated ABA and reduced GA_1 levels in imbibed/germinating ubp5 seeds compared to Col-0. Transcriptomic profiling confirmed upregulation of ABA biosynthesis genes (e.g., NCED6) and repression of GA biosynthesis genes (e.g., GA20ox1) in ubp5. Microscopy showed abnormal nuclear shape and size in ubp5, which were restored in the UBP5-GFP overexpression lines. These results suggest that UBP5 is a key player during the control of seed germination orchestrating chromatin structure, regulating hormone levels, and ensuring proper nuclear remodelling during seed germination.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Multi-scale Modeling of Through-Thickness Microstructure Gradients in TMCP Rolled X100 Steel for Offshore Wind Turbine Support Structures

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INTRODUCTION

The offshore wind industry is advancing rapidly, necessitating progress in the materials and manufacturing processes used for support structures. Multi-scale simulation of deformation behavior can optimise manufacturing process parameters by capturing the effects of microstructural modifications on the final mechanical properties. This study develops multi-scale modeling of the thermo-mechanical control process (TMCP) rolling at 900˚C to quantify the strain variations through thickness of X100 steel sheet and the resulting microstructure gradients. This enables improved design of wind-turbine support structures to reduced cost and improve energy efficiency.

MATERIALS AND METHODS

Initially, ABAQUS simulated the macroscale plane-strain rolling, with the input properties of experimental stress-strain data under plane-strain compression of X100 at different rates, to calculate the variations in normal and shear strain and their rates in depth. This data was then inserted to a nonlocal micro-scale crystal plasticity fast Fourier transform (CPFFT) representative volume element (CPRVE) using plane-strain compression to model the rolling process. CPFFT method used the synthesized initial austenitic microstructure of X100 at 900 ˚C, containing equiaxed grains with high-angle grain boundaries and uniform mechanical properties in depth before rolling.

RESULTS AND DISCUSSION

The developed model quantified the contributions of plastic deformation gradient with different normal strain, shear strain, and their rates on the evolutions in crystal morphologies, dislocation accumulation, and grain texture at different depths. Sheet regions nearer to the surface had higher overall microstructure variations under more severe deformation trends. Normal strain had relatively higher lattice rotation and stronger <111>//loading direction (LD) than shear strain, both of which increased with their evolution rates .

College of Science and Engineering, Inaugural Research and Innovation Day 2025

Abstract

Design and Analysis of the Full-Scale Helical-Bladed Offshore Vertical Axis Wind Turbine

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INTRODUCTION

Helical-bladed vertical axis wind turbines (VAWTs) offer smoother torque output and better structural performance than straight-bladed designs, making them suitable for offshore wind energy applications. One of the main challenges in these systems is ensuring the strength and stability of the blade-to-strut connection under combined aerodynamic and centrifugal loads. Additionally, minimizing blade deflection without increasing turbine weight is a key design goal. This study focuses on improving the structural design of a medium-scale helical-bladed VAWT by optimizing the strut geometry and validating the blade-strut connection.

MATERIALS AND METHODS

A T-bolt configuration was selected for connecting the blade to the strut. Finite Element Analysis was used to evaluate the mechanical behavior of the joint. Different failure modes were considered, including bolt shear, bearing failure, net-tension, and fastener pull-through. Modal analysis was also conducted to identify the turbine's natural frequencies and to guide the number and positioning of struts.

To optimize the strut geometry, a parametric study was carried out focusing on strut thickness and width. These parameters were chosen to reduce blade deflection while keeping the added weight to a minimum. Two experimental setups were designed: (1) testing the strut-blade connection under realistic loads, and (2) full-scale blade testing to measure structural deflection and dynamic response.

RESULTS AND DISCUSSION

FEA results showed that the optimized T-bolt joint design achieved a high safety factor against all investigated failure modes. Modal analysis helped to avoid resonance and informed the design of the strut layout. The parametric study revealed that increasing strut thickness and width improved stiffness but added weight, highlighting the importance of a balanced design.

The planned experimental tests are expected to confirm the computational findings by observing failure mechanisms and measuring the natural frequencies and deflection of the system. These results will contribute to validating a reliable and lightweight turbine structure that meets the performance demands of offshore environments.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Structural and Electrical Tuning of Site-selective on Chip Components by Ultrashort Lasers

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Transition-metal-dichalcogenides (TMDs) two-dimensional (2D) semiconductor materials are of significant interest to modern, smart, flexible technology due to their exceptional properties such as high mobility, good mechanical strength, and high surface to volume ratios. Although 2D growth methods such as chemical vapor deposition (CVD), molecular-beam epitaxy (MBE), and atomic layer deposition (ALD) are capable of high-quality growth and control over the number of atomic layers at high temperature, the non-selectivity of a desired area during such thermal processing is a key issue that can easily damage the surrounding devices or components on a chip. Therefore, a process with precise control and low thermal budget is highly needed to control the desirable change in the electrical and mechanical properties.

We propose a non-thermal ultrashort laser process for selective crystallization of 2D material thin films without melting or generating excessive heat to nearby components on a chip. The proposed method is highly effective in tuning the electrical and structural properties of the deposited thin film layers in a precise and controlled manner.

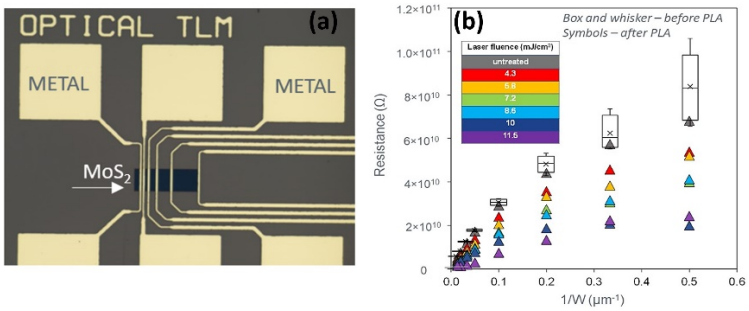

Figure 1. L-TLM test structure in (a), where (b) shows vvariation in resistance with reciprocal of width (1/W) for MoS_2 thin films before and after laser annealing at different fluences.

In this work, we used MoS_2 thin films (from mono layers to few layers) fabricated at low temperature by CVD and ALD methods on Si and other heat sensitive flexible substrates. Laser fluence of a femtosecond laser (500 fs) source, well below the damage threshold of MoS_2, and with higher spatial pulse overlapping, is used in annealing the MoS_2 thin films. We demonstrated that ultrashort pulsed laser scanning not only converts the amorphous MoS_2 layers into crystalline phase but also improves the degree of crystallization of partially crystalized films. Crystallization was occurred by solid-state diffusion process at temperatures lower than the melting temperature of respective thin films. In addition to crystallization, laser annealing process also helps to improve the contact resistance and surface adhesion with the underlying silica layer. The proposed low fluence method, based on the non-thermal annealing process is capable of enhancement in electrical and mechanical properties in a selective manner. It demonstrates a great potential for sustainable manufacturing route for scalable thin film processing industry for their wide range applications in electronics and miniaturized industry.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Noble metal-free-based MCOF designed for CO_2 conversion: electrocatalytic and photocatalytic approaches

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INTRODUCTION

Excessive fossil fuel consumption is leading to escalating concerns regarding climate change and the intensifying greenhouse effect. To address this, it is imperative to reduce the dependence on pollutant fuels, substituting them with cleaner, more sustainable alternatives. Electrocatalysis and photocatalysis can be utilised to produce value-added chemicals using pollutants such as CO_2 as feedstock materials.[1]

Although many different types of functional catalysts have been synthesized for energy conversion systems, limitations have arisen due to energy-intensive reactions, insufficient active sites and large energy band gaps, among others.[2] Porous materials such as metal-organic frameworks (MOFs) have been noted for their potential for catalysis due to their good conductivity, high surface area and porosity. However, their low stability resulting from the coordination bonding linking the frameworks has hindered their application for CO_2 reduction. These problems could be addressed by bonding the metal complexes of the MOF with stable covalent organic framework (COF) backbones, bringing together the advantageous properties of both materials into a new porous material, a metal covalent organic framework (MCOF).[3]

$Ru(bpy)_3$ and $Ru(tpy)_2$ metalloligands incorporated into frameworks have shown promising results for electrocatalytic and light-driven reactions, encouraging future advancements focused on the replacement of the noble metal centre with earth-abundant alternatives.[4,5] $Fe(typ)_2$-based metalloligands have been proposed as replacement candidates due to their reported catalytic efficiencies for CO_2 electro- and photoreduction, in addition to their abundant nature.[6]

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College of Science and Engineering, Research and Innovation Day 2025

Abstract

SEAGRASS RESTORATION FOR CLIMATE RESILIENCE: EVIDENCE FROM IRELAND AND THE CLIMAREST PROJECT

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Seagrasses are marine angiosperms that form extensive coastal meadows across the planet, providing essential ecosystem services such as carbon sequestration, nutrient cycling, sediment stabilization, and a critical habitat for marine biodiversity. Despite their ecological value, seagrass meadows are among the most threatened ecosystems worldwide, experiencing ongoing decline due to a combination of natural and anthropogenic pressures, including coastal development, eutrophication, and climate change.

Given their role in supporting biodiversity and enhancing climate resilience, restoring seagrass habitats is increasingly recognized as a key nature-based solution for climate change mitigation. Within this context, the EU-funded CLIMAREST project focuses on the restoration and monitoring of Atlantic coastal ecosystems, with a particular emphasis on seagrass meadows. As part of this initiative, our research explores small-scale restoration of *Zostera marina* and *Nanozostera noltei* in three estuaries along the Irish coast, selected based on ecological criteria and stakeholder input to serve as both donor and recipient sites.

Preliminary results after one year indicate promising outcomes: transplant survival rates exceeded 100% for *Z. marina* using shoot methods (with and without ballast) in shallow subtidal zones, and for *N. noltei* using sediment plug-core transplantation in intertidal areas. However, similar restoration efforts in other demonstration sites using identical techniques failed, underscoring the critical role of site-specific environmental factors in determining restoration success.

Our study aims to refine restoration strategies by identifying optimal sites and techniques, while also assessing their impact on ecosystem services. By integrating field experimentation with targeted monitoring, CLIMAREST contributes to the development of effective, scalable approaches to seagrass restoration, supporting coastal resilience in the face of accelerating environmental change.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Phase-Field Method as a Predictive Tool for Microstructure Simulation in TMCP and Welding

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INTRODUCTION

The phase-field method is a computational tool for simulating microstructural evolution by introducing continuous order parameters to distinguish between different phases. It is well-suited for modelling complex phase transformations and grain evolution under thermal-mechanical conditions as found in TMCP and welding. Within the TRANSFORRM (The tailored manufacturing for safe, sustainable offshore wind turbine support structure materials) project, phase-field modelling plays a central role in establishing a multi-scale framework that links composition, processing, microstructure, and performance. This enables predictive, manufacturing-informed design of advanced HSLA steels and welded components with improved strength and fatigue resistance.

MATERIALS AND METHODS

This study focuses on simulating the microstructural evolution during the cooling stage of the TMCP process using a phase-field approach. A phase-field model is developed to describe the austenite-to-ferrite transformation under varying cooling rates. The influence of prior plastic deformation introduced during rolling is incorporated through stored energy and orientation-dependent nucleation kinetics. By adjusting thermal gradients and strain history, the model predicts the resulting ferrite grain morphology and texture distribution. The generated microstructure is then imported into a finite element model to evaluate the constitutive behaviour of a representative volume element, enabling the exploration of processing–property relationships through virtual thermal process tuning.

RESULTS AND DISCUSSION

In this work, a MATLAB-based phase-field model has been developed to simulate austenite-to-ferrite transformation under both isothermal and continuous cooling conditions. The model captures key features of phase transformation kinetics and microstructure evolution. Coupling with ABAQUS finite element simulations is currently under development, and preliminary results have demonstrated strong potential for integrated processing–microstructure–property analysis.

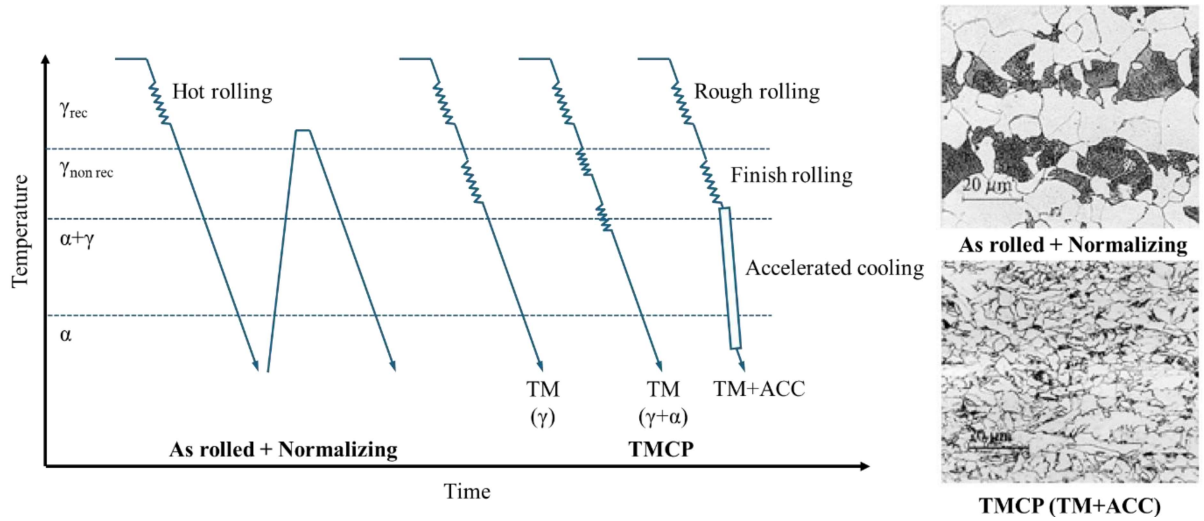

Figure 1: Schematic representation of conventional processing and thermomechanical controlled processing (TMCP) paths and the resulting microstructures (P. Fluess et al. 2008).

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Resilient classrooms for the future – Exploring lean and agile techniques for sustainable and healthy learning environments

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Introduction

Classroom indoor climate refers to the indoor air quality (IAQ) and thermal environment component of the classroom's indoor environment. The indoor climate of a classroom affects student comfort and learning. Factors such as climate, building elements, HVAC system, and occupants and occupant behaviour has an intimate impact on classroom indoor climate. Classrooms need to be designed to face challenges to their indoor climate from these factors and continue functioning in an energy efficient manner. This would mean more conducive learning environments and less disruptions to teaching.

Methodology

To model these design principles for a classroom, a building performance simulation model was created for an existing classroom in Galway city in DesignBuilder. The model was calibrated based on indoor air temperature (IAT) for thermal comfort assessments and CO2 concentration level for indoor air quality (IAQ) assessments. We used Fanger comfort assessment method for comfort calculations during winter and ASHRAE 55 adaptive comfort model for simulations during summer.

Results and discussion

Air source heat pump (ASHP) and different window options including Double, Triple, Thermochromic, and Electrochromic windows were used in simulations for thermal comfort improvement and heat recovery ventilation (HRV) is used in simulations for IAQ improvement. Total number of 224 scenarios were defined including challenged occupancy state when the classroom is not fully occupied (10 students + 1 teacher) and normal occupancy state when the classroom is fully occupied (20 students + 1 teacher). Combination of ASHP with different window options could keep comfort level in acceptable ranges during winter and summer times in both challenged (e.g. pandemics) and normal occupancy states as well as future weather scenarios (overheating risk assessment). Both TC and EC windows showed significant potential in improving percentages of times comfort falls within acceptable ranges in future scenarios during summer.

College of Science and Engineering, Research and Innovation Day 2025

Abstract

Towards Assessing Cycleway Pavement Surface Roughness Using an Action Camera with IMU and GPS

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ABSTRACT

This work introduces an autonomous and cost-effective method for assessing cycleway pavement roughness, using an action camera equipped with high-resolution sensors including an Inertial Measurement Unit (IMU) and a Global Positioning System (GPS). The methodology (flowchart shown in figure 1) utilizes simplified quarter car model for bicycles, without manual intervention, to calculate International Roughness Index (IRI) for cycleway surface quality evaluation. It utilizes our novel approach to determine stable section from which average acceleration orientation vector is computed. For analysis we propose a corrected-roughness index (CRI), which is a quantized version of IRI. Experiments conducted on asphalt cycleways in Ireland revealed strong correlations between vehicle vibration and surface roughness. Results further demonstrate the consistency of the proposed model across different bikes through comparative analysis. Observations indicate bias in vibration data, influenced by different tire sizes and the mechanical features of the bicycles.

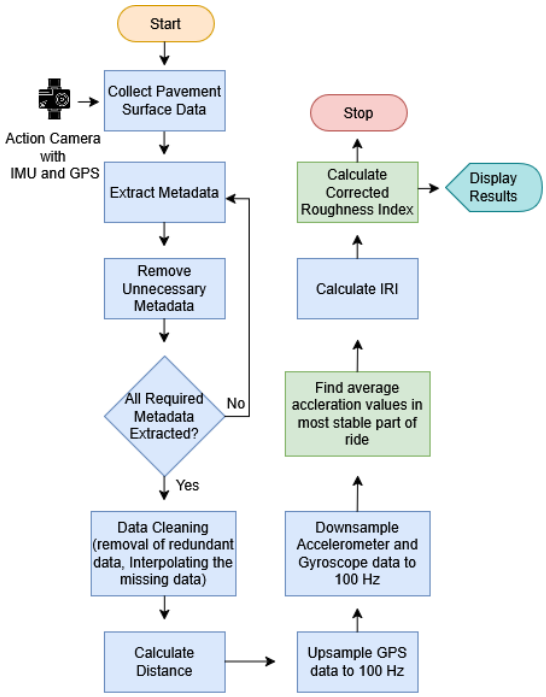

Figure 1: Shows flowchart of methodology

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