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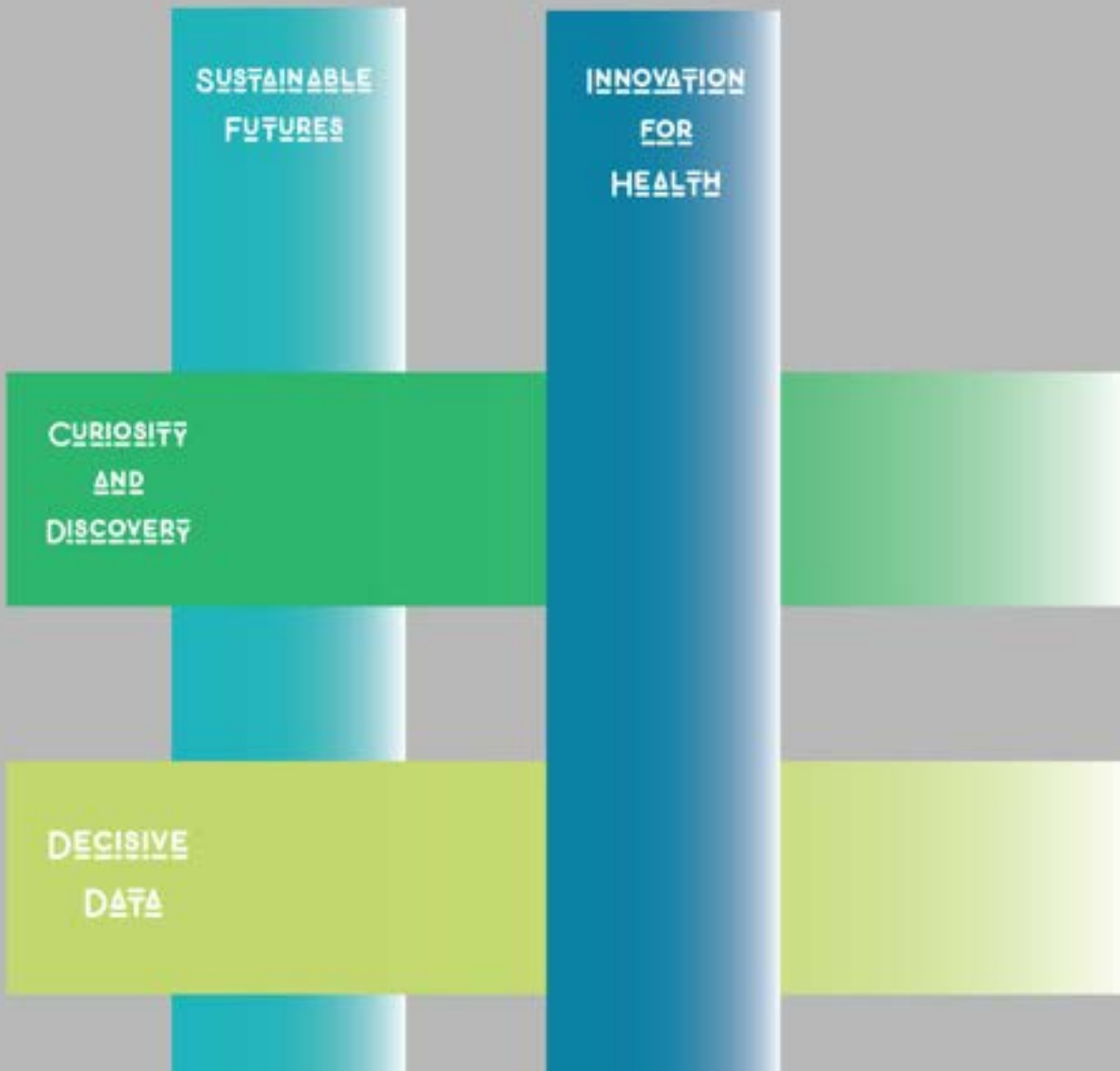
RESEARCH AND INNOVATION DAY 2023

- ABSTRACTS -



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Tidal GES: Tidal Energy – A transition to affordable and clean energy that can achieve Good Environmental Status

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INTRODUCTION

The 'TIDAL-GES' project at the University of Galway is focusing on enabling tidal energy to become part of the solution to securing transition to affordable and clean energy that also enhances the health and resilience of communities, wildlife, and the environment. The project will engage with multiple stakeholders – including the people living in the coastal communities - to unlock the potential benefits for them in our drive to decarbonise the economy. Part of the University of Galway Global Challenges Programme, the project will bring together a multi-disciplinary team of researchers from the school of engineering, the school of natural science and the school of business and economics to tackle challenges facing the widespread uptake of tidal energy.

MATERIALS AND METHODS

The Tidal-GES project has several key objectives: use global ocean data and high-resolution coastal models to better understand the potential impacts of climate change on tidal energy resources, develop a monitoring system for wildlife in the vicinity of tidal energy devices and assess the impact of tidal energy devices on benthic species, capture the socioeconomic impact of tidal energy developments on key stakeholders and provide an effective structure for enhancing participation by key stakeholders, develop a new methodology for predicting remaining fatigue life and residual strength of tidal turbines' blades periodically until their end-of-life to ensure structural integrity.

Figure 1: Image of the Schottel tidal turbine.

EXPECTED IMPACT

Successful completion of the project will de-risk tidal energy production by developing new engineering tools for the tidal industry, understanding the influence tidal devices have on their local environment and engaging with stakeholders to avoid conflict. This, in turn, will allow tidal energy to fulfil its potential as part of the transition to clean renewable energy.

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SPOTBlade-WP5: Strategies for erosion and fouling Protection of Offshore Turbine Blade

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INTRODUCTION

In today's world, green energy sources are playing a crucial role in powering communities and industry, and one of the most reliable sources of renewable energies is wind energy. In recent years, the installation of wind turbines spread widely has grown. Lowering maintenance costs and improving operational efficiency are two significant challenges the wind industry faces. One of the leading causes of damage to wind turbine blades is the erosion caused by the repeated impact of water droplets (as shown in Figure 1). To reduce the costs of maintenance, this is crucial to have a precise estimation of wind turbine leading edge lifetime. SPOTBLADE Work Package 5 focuses on modelling the erosion in leading edges to estimate the lifetime.

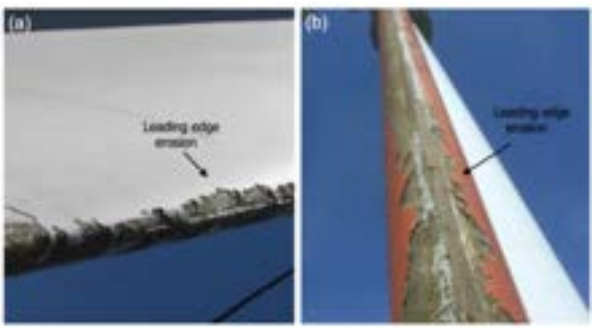

Figure 1: Leading edge erosion damage on two blades [Verma et al., 2020]

MATERIALS AND METHODS

The main goal of research within SPOTBLADE Work Package 5 is to provide a series of strategies that leads to predicting the wind turbine's lifetime, which could help reduce the annual energy production loss and maintenance costs. The objectives that lead to this goal could be considered as:

- To develop a new numerical model to evaluate the lifetime of the leading-edge coating.
- To consider the Irish weather to predict the lifetime of a coating, based on the local climate.
- To study the mechanism of erosion in the leading edge to better understand the nature of this phenomenon.

This research will use different commercial finite element method software, such as ANSYS, and validate the accuracy of models developed using experimental data. This project is supported and funded by SEAI through their RDD Funding Programme.

RESULTS AND DISCUSSION

The main output from this research will be a better understanding of the erosion damage mechanism in wind turbine blades' leading edge, along with better prediction of the lifetime of the leading-edge coating base on Irish weather. This will reduce the maintenance and repair cost of wind turbines.

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University of Galway State of the Art Building Envelope Test Facility

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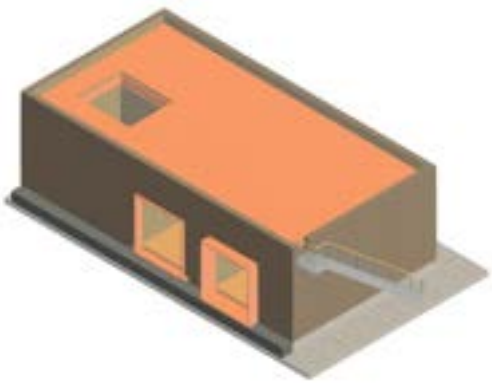
INTRODUCTION

University of Galway is partner of the H2020 METABUILDING LABS project. METABUILDING LABS strives to unleash the innovation potential of the SMEs in the construction sector by lowering the entry barriers to test innovative solutions in a network of testing facilities in RTOs and Living Labs in 10 countries, including the Alice Perry Engineering building. METABUILDING LABS proposes a new and affordable model of building envelope testbeds (O3 Building Envelope Testbench, O3BET) that can be adapted to the SME's needs and innovation landscape conditions. University of Galway has committed to building and operating an O3BET testbed.

MATERIALS AND METHODS

The testbed is specifically targeted to SMEs innovation path requirements to test the installation and performance of façade solutions in full scale real conditions. The testbed is designed for the specific market of SMEs developing complex, innovative, adaptive, dynamic envelope systems, for which they expect short and efficient testing providing feedback on installation, functionality and performance in a short, low-cost test



RESEARCH IMPACT

The O3BET testbed will increase the testing capabilities of University of Galway for stakeholders across the construction sector both nationally and internationally. Furthermore, the testbed will enhance the research and development of building envelope systems capabilities at the University of Galway and can be for used for cross-disciplinary research across multiple schools in areas such as structural, mechanical and energy performance monitoring, in addition to assessing indoor environment, health, comfort and wellbeing of building occupants.

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Exploring the effects of Solar Wind on Pulsars using the LOFAR telescope

Sai Chaitanya Susarla

Pulsars are rapidly rotating neutron stars mainly visible as pulsating radio sources. Their rotation is so reliable that it can be used as a highly-precise clock-like signal. By studying this clock signal, via their emitted radio pulses, pulsars can be used to probe a number of effects, such as interstellar weather like the Solar Wind. The Solar Wind (SW) is a highly magnetized stream of plasma out of the Sun due to the pressure of the hot solar corona. The free electrons in the SW induce noise in the pulsar signals that can be measured to gain a deeper understanding of the heliospheric magnetic field and the Solar corona. The ecliptic pulsar whose line-of-sight (LoS) comes close to the sun are best used to track the variations in the electron content of the SW. This is quantified by a parameter known as the Dispersion Measure (DM). Variations in DMs have strong, inverse dependencies on the observing frequency which makes LOFAR, that covers frequencies below 240 MHz, one of the best-suited instruments to measure the effects of the SW. We have obtained data from 7 LOFAR stations which have been observed in the frequency range 110-190 MHz band at a weekly cadence for the past 10 years.

The effect of SW is starkly observed in the DM variations once every year when the pulsar's LoS is closest to the sun. We measure the effect of SW by calculating the electron density at 1 AU (ne_sw). In this talk I will describe my solar wind modeling using the Enterprise pulsar timing software which employs a Bayesian MCMC approach to additionally estimate the value of various other noise parameters. The value of these SW noise parameters can be highly covariant with those of the pulsar (Red Noise) and of the interstellar medium DM noise. I will describe the difficulties in disentangling these intermingled effects using the regular-cadence of these ecliptic pulsars and the low frequency observations. I will show how these problems can be solved and how it is theoretically possible to get the true value of ne_sw that is several times more precise than previous measurements. These will, in turn, help us to model and understand this ever changing noise process and get us closer to the discovery of nano-hertz gravitational waves.

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Contrasting water soluble pesticide applications in mineral soils to predict the influence of surface runoff to watercourses

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INTRODUCTION

Herbicides, such as MCPA and clopyralid, are used for the control of weeds. Following land application, there is a risk of their transmission to surface waters via runoff. Split herbicide applications (i.e., two half doses with a six-week gap, versus one full dose) retain effectiveness, may reduce adverse environmental impacts, but no study has investigated this. This study aimed to quantify the impact of split applications of MCPA and clopyralid on losses in surface runoff.

MATERIALS AND METHODS

Intact grassed soil sods were extracted from a medium intensity dry stock farm and packed into 15 flumes ($1m \times 0.23m \times 0.05m$), facilitating triplicate treatment and controls. On day one, MCPA and clopyralid were applied to the grass surface at one full dose (1350 g MCPA/ha; 200g clopyralid/ha) or one half dose (675 g MCPA/ha; 100 g clopyralid/ha. The second half dose was applied to the relevant flumes after 42 days. At 2, 7 and 21 days following each herbicide application, flumes were subjected to controlled laboratory rainfall simulations at an intensity of 11 mm/hr (average rainfall intensity in Ireland), at a slope of 6 degrees, and the herbicides in the captured run off were quantified.

RESULTS AND DISCUSSION

The flow weighted mean concentrations of MCPA and clopyralid were highest immediately after the initial application and decreased in subsequent rainfall events. Both herbicides, for both full and split-dose applications, were below the limit of detection (0.45 µg/l for MCPA and 1 µg/l for clopyralid) at 44 days. For the full dose applications, the concentrations in the runoff were more than double that of the half-dose application (Figure 1), and no herbicides were detected following the second split application. These results indicate that the environmental impacts of MCPA and clopyralid may be reduced by splitting herbicide applications.

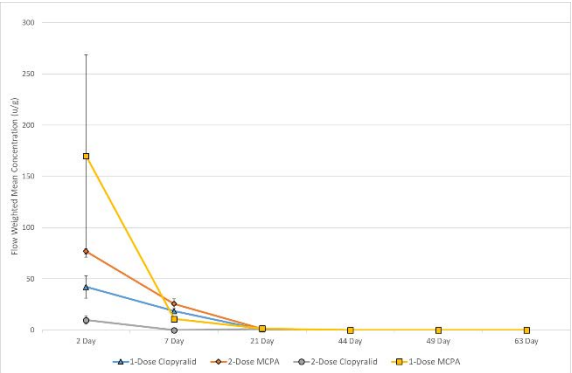

Figure 1. Flow weighted concentrations of surface runoff (ug/l) detecting MCPA and clopyralid in high clay mineral soil for 63 days, graphed with standard deviation error bars. Pesticide applications coincide with days 2 and 42.

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Optimal Sizing of Behind-the-Meter Battery Energy Storage Systems Under Optimal Battery Operation: A Case Study in Ireland

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INTRODUCTION

This study proposes an optimization tool to optimally size behind-the-meter (BTM) batteries for households, Fig. 1. A Genetic Algorithm (GA) incorporating optimal battery control schemes from a multi-objective mixed-integer linear programming (MOMILP) is used to minimize battery degradation and save costs. The proposed model is assessed through various scenarios, taking into account different metering and billing systems and operational constraints. Compared to a case without optimization, the tool can save households 4.5% on annual costs by keeping battery degradation to a minimum of 2.1% per year. This study provides insight into the economic impacts of implementing BTM devices and the potential benefits of optimization.

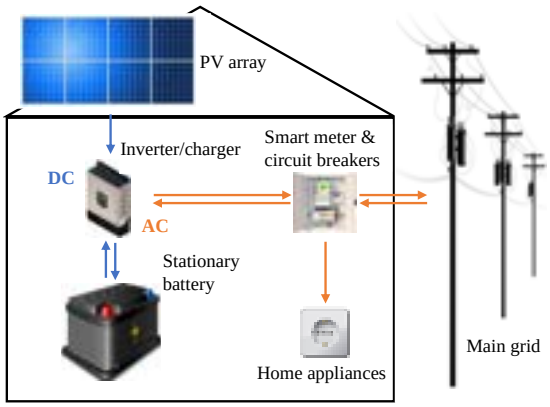

Figure 1. *Illustration of the system under study.*

MATERIALS AND METHODS

1) An optimization tool is designed to capture the bidirectional impacts between the sizing and scheduling problems to optimally size home batteries under optimal operational control schemes.
2) The scheduling problem is formulated as a MOMILP and is solved using the ε-constraint scalarization method to obtain all Pareto efficient solutions, from which the best compromise solution is selected using a Euclidean distance-based method.
3) A comprehensive techno-economic analysis is provided to investigate the impacts of deterministic factors on the optimization problem, and the presented model is assessed by analysing its performance in a set of simulation scenarios.

RESULTS AND DISCUSSION

According to the results, the optimization tool reduces the overall cost by 4.5% for households, compared to a case with no optimization applied. Batteries are still expensive technologies, necessitating the consideration of degradation control in their optimization. However, with relaxed operational constraints, annual savings totalled more than €179, but it increases the degradation rate by 7%. This demonstrates how lower battery costs can increase the profitability of BTM resources, as well as people's willingness to purchase and install such resources.

ATP Pipeline: Market driven materials selection and characterization of Thermoplastic Composite Pipelines (TCP) used for offshore and subsea applications

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INTRODUCTION

The most economic oil & gas transportation method rely on pipelines. In the case of submarine pipelines, different types of pipelines can be used depending on the operating depth and the type of product transported, as illustrated in Fig.1 – A. Thermoplastic composites have emerged as a competitive lightweight piping option for applications such as off-shore Carbon Capture and Storage (CCS). Therefore, Thermoplastic Composite Pipelines (TCP) are a recyclable option employed in such application where three bonded layers are normally present i.e. polymer liner, intermediate composite laminate (responsible for pipe's structural integrity) and polymer cover (see Fig.1 – B). In particular, 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.

(A) (B)

Fig.1: (A) Different types of submarine flexible pipelines used in offshore applications. (B) Schematic of flexible risers. Layers are bonded to each other.

MATERIALS AND METHODS

This project uses materials selection methodology capable of down-selecting cost-effective material candidates for flexible TCPs compatible with CCS offshore applications. A scalable cylindrical composite structure manufacturing methods such as Automated Tape Placement (ATP) was used to manufacture a demonstrator.

A market driven materials selection methodology employed GRANTA selector software to evaluate material indices (MIs) to assess the cost-effective performance of intermediate TCP laminate (see Fig.1 – B). After manufacturing a TCP demonstrator, mechanical and physical-chemical testing was conducted to obtain material performance.

RESULTS AND DISCUSSION

Carbon fibre reinforced polypropylene (CF/PP) material was down-selected as a potential cost-effective candidate. After ATP manufacturing applying enough heat to surpass the previously obtained melting temperature, subsequent material consolidation was checked via volume fraction and density testing. Lastly, additional mechanical characterization was conducted to assess material performance and therefore, cost-effectiveness in offshore and subsea applications.

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I-ASIDE: Towards the global interpretability of image models through the lens of axiomatic spectral importance decomposition

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INTRODUCTION

Global interpretability summarizes the decision dynamics of neural networks en masse in contrast to instance-wise local interpretability. Local interpretability has achieved great success in image models, yet global interpretability virtually remains unexplored for image models. To this end, we present I-ASIDE a model-agnostic method to quantify the decision dynamics of image models from the perspective of robust decisions versus non-robust decisions. Unlike prior works, I-ASIDE directly quantifies model explainability and enables a large number of impactful applications across multiple research domains.

METHODS

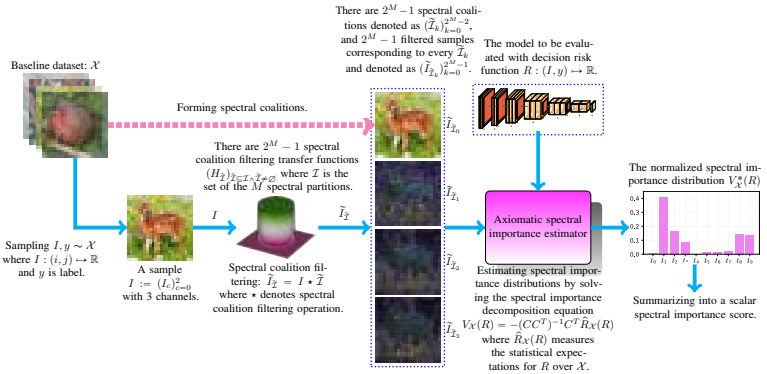

Figure 1: The overview of axiomatic spectral importance decomposition for image models.

APPLICATION SHOWCASES

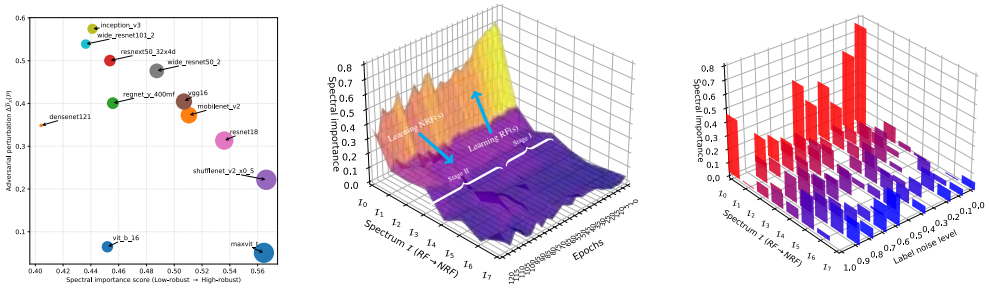

Figure 2: We showcase three impactful applications in deep learning research: (1) Understanding adversarial perturbations, (2) investigating training dynamics and (3) demystifying how models respond to various noise levels in supervision signals.

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Designing multi-user social spaces in Virtual Reality for People living with Dementia

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INTRODUCTION

Dementia is a cognitive condition that leads to a gradual decline in mental faculties over time (WHO, 2020). This can impact the daily activities of people who live with dementia. According to the World Health Organisation, around 55 million people are living with dementia (WHO, 2020). The provision of opportunities for people with dementia to interact socially, can help reduce isolation and agitation (Ballard et al., 2018).

Virtual Reality (VR) is increasingly being used to re-create traditional treatments such as reminiscence technology and music therapy. VR has been acknowledged as a feasible technology to provide non-pharmacological dementia care (Flynn et al., 2003) with positive responses from people living with dementia after using this technology.

VR has also been used to provide social interaction through applications like VR Chat and RecRoom. Multi-user spaces in VR allow participants to interact in a computer-generated world in a manner similar to real-world interaction. Contrary to a real-world setting, the VR space/environment is not bound by the limitations of reality. Currently, there is a paucity of research on design methods and design considerations regarding a multi-user environment for people with dementia.

This paper details the design techniques and their application in the development of a multi-user VR space for people with dementia. It also highlights the implementation of a system to record game data for the purpose of measuring the interactions of a person with dementia with the VR environment and with other participants.

MATERIALS AND METHODS

The design of the multi-user VR space followed a user-centred approach where the targeted audience (i.e. people living with dementia) were directly involved in the development process; which in itself was multidisciplinary in nature and involved collaborations between a Game Designer and an Occupational Therapist. Using an Action Research approach, all changes made to the multi-user VR space were verified by the participant's families.

The multi-user VR space was developed using Unity 3D and Photon PUN networking. Virtual Avatars were created using MakeHuman and ReadyPlayerMe. These avatars were designed to facilitate social interaction among participants.

A series of experiments was established to measure user engagement and interaction within the VR multi-user space. A multi-pronged data collection approach was adopted, comprising; game data to measure the participant's movements and interactions, recordings of audio and video to add context to the data and a questionnaire to measure the participant's attitudes to VR.

RESULTS AND DISCUSSION

In order to address the research question "What is the best approach in the design of an activity based multi-user VR space to support the social interaction of people living with dementia (PLWD)", a multi-user VR social space was developed consisting of five levels. Each level had corresponding activities including; a cinema, music hall, 360 video room, a greenhouse and a tent containing different games. This VR application, entitled "Multi-user VR space for PLWD" is being evaluated as part of another study which identifies suitable VR design choices for people with dementia.

The Social Presence in Gaming Questionnaire (SPGQ) (De Kort et al., 2007) is used to measure social interaction within each of the three activity levels in order to assess the efficacy of the Multi-user VR space for PLWD to support social interaction. In validating the effectiveness of measuring social interaction within VR using this questionnaire, people who do not have dementia will initially be tested.

The results of both experiments will provide further steps to designing a refined social space for people with dementia.

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Leveraging Adversarial Autoencoders for Generative Probabilistic Novelty Detection

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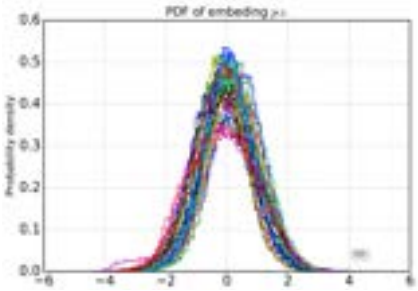
INTRODUCTION: The challenge of novelty detection involves determining whether a new data point can be classified as an inlier or an outlier, given that the available training data only represents the inlier distribution [1]. Contemporary methods mainly utilize deep encoder-decoder network structures to calculate a reconstruction error, which is then employed to derive a novelty score or to train a one-class classifier[2].Our approach also employs an innovative network of this nature, but we incorporate a probabilistic perspective to assess the likelihood of a sample originating from the inlier distribution and reconstructing the outlier distribution.

METHODOLOGY: This research presents a methodology that combines generative probabilistic modelling with adversarial autoencoders for effective anomaly detection. The main aim of this approach is to enhance novelty detection by improving the quality of inlier reconstruction while simultaneously reducing it for outlier reconstruction. generative probabilistic framework based on adversarial autoencoders (AAEs) is proposed to address the problem of anomaly detection. The framework consists of two main components: an autoencoder and a discriminator. The autoencoder is responsible for learning the underlying structure of normal data, while the discriminator evaluates the quality of generated data samples, ensuring they resemble the true data distribution.

RESULTS AND DISCUSSION: Some initial results are shown in Fig. 1. the model is trained to recognise class “7” from the MNIST dataset, which has 70,000 handwritten digits from 0 to 9. Rows 1 and 2 show inputs and their reconstructions for the inlier class "7”. Rows 3 and 4 show inputs and reconstructions for class “0”, which is an outlier. Reconstructions of the outlier class poor, which indicates its novelty.



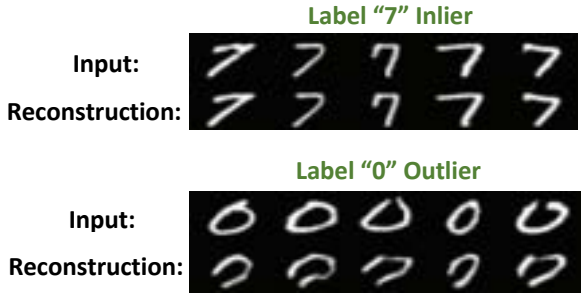


Figure 1: Probability density function of embedding (Left) and reconstructions (Right) for an autoencoder network trained on MNIST class "7" as the inlier and tested on “7” and “0”.

Acknowledgement:

This research is conducted with the financial support of Science Foundation Ireland under Grant number 18/CRT/6223, partnered with Valeo.

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A Comparative Analysis of Data Synthesis Techniques to Improve Classification Accuracy of Raman Spectroscopy Data

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Centre for Research Training in Artificial Intelligence (CRT-AI)

INTRODUCTION

Raman spectra are examples of high dimensional data that can often be limited in the number of samples. This is a primary concern when developing Deep Learning frameworks for tasks such as chemical species identification, quantification, and diagnostics. Open-source data is difficult to obtain and often sparse, furthermore, the collection and curating of new spectra requires expertise and resources.

METHODOLOGY

Deep generative modelling utilises Deep Learning architectures to approximate high dimensional distributions and aim to generate realistic synthetic data. The evaluation of the data, and the performance of the deep models, is usually conducted on a per-task basis and provides no indication of an increase to robustness, or generalisation, on a wider scale. In this study, we compare the benefits and limitations of a standard statistical approach to data synthesis (*weighted blending*) with a popular deep generative model, the *Variational Autoencoder*. Two binary data sets are divided into three folds to simulate small, limited samples. Synthetic data distributions are created per fold using the two methods and are then augmented into the training of two Deep Learning algorithms, a *Convolutional Neural Network,* and a *Fully Connected Neural Network*. The goal of this study is to observe the trends in learning as synthetic data is continually augmented to the training data in increasing batches.

RESULTS

To determine the impact of each synthetic method, the discrete *Fréchet* distance is implemented to measure the distance between the source and synthetic distributions along with standard Machine Learning evaluation metrics such as accuracy and F1-score. We demonstrate that both methods yield improved results when sample sizes are small, but their influence converges at larger scales.

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Regional Mapping of Peatland Boundaries using Airborne Radiometric Data and Supervised Machine Learning

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INTRODUCTION

Historically, peatlands have acted as globally important carbon sequestration habitats via the storage of organic material. Drained peatlands emit this carbon as CO2 via decomposition of the stored organic material. National climate action plans require a knowledge of peatland spatial distribution across large geographic areas.

Globally, peatland maps are created in a variety of ways including optical satellite remote sensing or traditional mapping techniques. However, remote sensing cannot detect peatlands under landcover such as forest or grassland. Traditional maps are often created from sparse in-situ data which rarely measure peatland boundaries.

MATERIALS AND METHODS

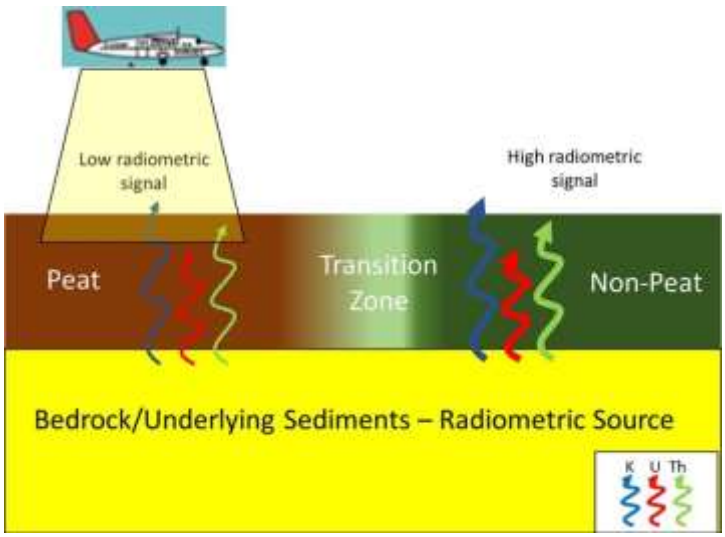

Figure 1: Diagram of Airborne Radiometric data for identifying Peat and Non-Peat Soils

Modern airborne geophysical datasets offer a potential means to update national and local scale peatlands maps. Radiometrics (Figure 1), a geophysical method that measures radiation emitted from geological materials, is particularly suited to peatland studies. Peat is a mostly organic material and so is, generally, not a source of radiation. Peat is also saturated and water acts to scatter the emitted gamma rays. These effects combined means that peatlands act as a blanket to any source of radiation from below and show as "low" radiometric signal in the landscape.

Satellite Remote sensing and airborne geophysical datasets, and their relationship to the subsurface, are often complex. Modern Machine Learning methods can play a role in analysing such multi-variate data.

RESULTS AND DISCUSSION

In Ireland, the Tellus survey, acquired by the Geological Survey, Ireland (GSI) aims to acquire airborne radiometric data, consistently across the country. This study uses Tellus airborne radiometric data in combination with machine learning classification, to identify peatlands under modified landcover, and to update the boundaries of peatland maps. The methodology is robust and can be applied in all areas where these data exist. The results may update national and international inventories of peatlands geographic distribution and inform European policy.

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Modelling the infection spread dynamics of Mpox

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2. School of Computer Science, University of Galway, Ireland.
3. Technology University, Dublin, Ireland.
4. University of Limerick, Ireland.

INTRODUCTION

Mpox is a viral disease that is like smallpox. It is primarily transmitted to humans from animals. The virus can also spread from person to person through respiratory or direct contact with infected bodily fluids. Although Mpox is not a sexually transmitted infection, the recent outbreak outside of Africa has shown that the majority of transmission occurs through sexual contact between men-who-have-sex-with-men (MSM). In this paper, a model to study the spread of Mpox in an artificially simulated society is presented.

MATERIALS AND METHODS

Agent-based models (ABMs) are an important tool in order to understand the dynamics of disease spread in a population. Two ABMs are presented in this paper, simulate the spread of Mpox in an artificial population. The parameters for contact formation and dissolution are drawn fromNatsal-3 dataset (National Survey of Sexual Attitudes and Lifestyles). Presented ABMs are based on the principles of classic compartmental Susceptible-Exposed-Infected-Recovered (SEIR) model and complexity is further added to them to break the assumptions of homogeneous mixing and populations. The first ABM is based on an heterogeneous population, consisting of people from two self-identified genders (male and female) and various sexual preferences (homosexual, bi-sexual and heterosexuals). The second ABM is a subset of the first ABM, that focuses on the relevant MSM population, which is at high-risk of Mpox. We report a set of experiments modelling varying scenarios by varying initial infected cases, imported cases, super-spreader events and vaccination strategies.

RESULTS AND DISCUSSION

Our analysis concludes that Mpox infection reaches locally stable disease-free equilibrium in the absence of concurrent sexual partnerships. The findings also indicate that vaccination strategies focused on vaccinating high-risk group can help reduce the disease transmission. The effective reproduction number is significantly reduced in scenarios where a random sample of the high-risk population is vaccinated, compared to scenarios where a random sample from the entire population is vaccinated or when no one is vaccinated.

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UPFRONT CO2e emissions of buildings in Ireland

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2. MaREI Centre for Marine, Climate and Energy, Ryan Institute, University of Galway, University Road, Galway, Ireland.
3. ERBE Centre for Doctoral Training, University of Galway, University Road, Galway, Ireland.
4. Construct Innovate, University of Galway, University Road, Galway, Ireland.
5. Irish Green Building Council, 19 Mountjoy Square East, Dublin 1, Dublin, Ireland.

INTRODUCTION

The Irish Government has set out the aim of achieving a fully decarbonised economy by 2050. Within that time frame, building infrastructure will be required to accommodate the expected population increase, including at least half a million new homes and home retrofits. Despite this vision, there is currently limited, publicly available, comparable and representative high quality data for benchmarking the embodied environmental impacts of buildings constructed in Ireland. This lack of data can be partially explained by the fact that there is no standardised LCA based approach/criteria as part of the public procurement process in Ireland.

MATERIALS AND METHODS

The Irish Green Building Council and University of Galway have developed a LCA methodology/tool for the life cycle assessment of buildings. The purpose of this tool is to carry out a life cycle assessment (LCA) of commercial/non-commercial developments using a standardised method in line with the EU Level(s) Framework indicator 1.2 and the ISO standard EN15978. The use of this standardised approach will enable direct comparisons both against benchmarks and between projects.

RESULTS AND IMPACT

The methodology is currently being applied to a student accommodation development. Preliminary results for the embodied carbon emissions of the student accommodation development are shown in Figure 1. The current embodied carbon emissions footprint is calculated to be 750 kgCO2e/m². As part of the SEAI funded UPFRONT CO2e project and Laudes Foundation funded INDICATE project, the developed methodology will be applied to up to 50 case study buildings to benchmark the embodied carbon associated with current construction practices. Overall this study will assist in:

- Benchmarking life cycle environmental impacts associated with the construction of new building and renovation infrastructure in Ireland by 2040.
- Developing pathways to mitigating the embodied environmental impact of future building construction based on standardised LCA approach, market analysis and stakeholder engagement.

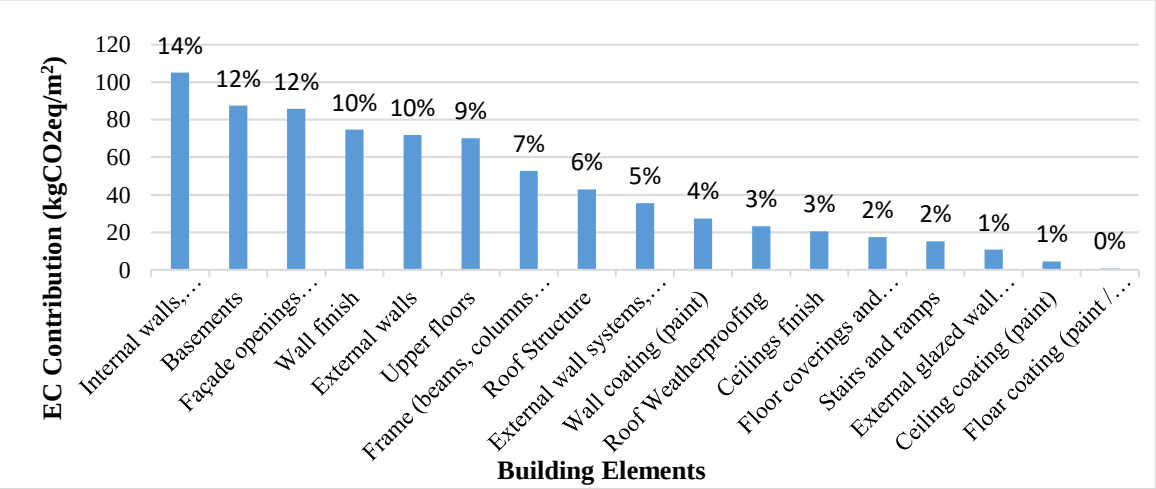

Figure 1: Embodied carbon contribution by building element of student accommodation building

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Exploring an OTA Model Update Process for TinyML-Based RTOS Systems (Collaborating on the implementation of this with external partners)

Eoin Jordan

This paper presents a novel model update process for TinyML-based Real-Time Operating Systems (RTOS) that eliminates the need for downloading and verifying large update packages. The proposed process changes the minimal parameters for the ML model through a patch update and reference change to the memory allocated to the model parameters, ensuring the integrity and safety of the system. This approach is compared to traditional full firmware OTA, and a detailed overview of the process is provided, including the various steps involved. Finally, the paper provides a comparison between traditional full firmware OTA and this method.

Publish my findings and contribute to the emerging area.

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ChildGAN – A Dataset of Synthetic Children for Data Privacy in Smart-Toy Platforms

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1. Center for Computational, Cognitive and Connected Imaging (C3I)

INTRODUCTION: In this work, a pair of StyleGAN2 networks are fine-tuned for generating synthetic boys and girls facial data. ChildGAN performs smooth domain transfer using transfer learning and provides photo-realistic, high-quality facial data samples (1024 x 1024 pixels resolution). A large-scale dataset is rendered with various facial transformations: facial expressions, age progression, eye blink effects, head pose, skin and hair color variations, and variable lighting conditions. The dataset comprises 300,000 distinct data samples derived from a base set of 10,000 boys and 10,000 girls. The motivation behind this research is to provide training datasets for computer vision models to be deployed on an Edge-AI platform for smart-toys. As it would be impractical to collect data from such a large population of real children this data-synthesis approach allows us to introduce much broader variation and diversity into the training dataset than would otherwise be feasible.

MATERIALS AND METHODS: The dataset is based on a fine-tuning of the StyleGAN2 model using a seed dataset of several thousand images. These seed images are derived primarily from adult image generated by StyleGAN which as then transformed into an equivalent child image using a selection of algorithms and publicly available imaging apps. The seed data samples are manually checked for quality, realism and diversity. Fine tuning with seed data samples retains the diversity of the original StyleGAN model, but generates child-like facial data samples.

As a primary test we have generated 10,000 facial data samples each of boys and girls. This dataset is made publicly available for other researchers to explore and use in their research and experiments. The uniqueness and characteristics of the rendered facial features are validated by running different computer vision application tests which include CNN-based child gender classifier, face localization and facial landmarks detection test, identity similarity evaluation using ArcFace, and lastly running eye detection and eye aspect ratio tests.

The results demonstrate that synthetic child facial data of high quality offers an alternative to the cost and complexity of collecting a large-scale dataset from real children. A small sample of the synthetic child face samples is shown in Fig 1.

Fig 1: Photorealistic child data samples generated using ChildGAN with example smart image transformations

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Manipulation of purine homeostasis to exploit and Achilles heel in MRSA beta-lactam resistance

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2. Section of Molecular Microbiology and Medical Research Council Centre for Molecular Bacteriology and Infection, Imperial College London, London, UK.
3. The Florey Institute, School of Bioscience, University of Sheffield, Sheffield, UK.

INTRODUCTION: The clinical burden of infections caused by antimicrobial resistant (AMR) pathogens is a leading threat to public health. Finding new ways to overcome antibiotic resistance and maintain the usefulness of current antibiotics is an important part of the response the AMR crisis. Predominantly, the safest and most effective class of antibiotics are β-lactams, which no longer work against methicillin-resistant *Staphylococcus aureus* (MRSA).

MATERIALS AND METHODS: Exogenous guanosine, xanthosine, adenosine and inosine were used in determining MRSA β-lactam susceptibility using broth microdilution, and disk diffusion assays. Mutations that interfere with *de novo* purine synthesis (*pur* operon), transport (NupG, PbuG, PbuX) and the salvage pathway (DeoD2, Hpt) were introduced and their MICs were checked against β-lactam antibiotics. Suppressor mutants resistant to oxacillin/guanosine combinations were raised, and whole genome sequencing (WGS) analysis performed to identify mutations. The cell size of strains exposed to purine/ β-lactam combinations were measured using Confocal Microscopy and ImageJ analysis. The levels of c-di-AMP were determined using ELISAs. PBP2a expression was determined with western blotting.

RESULTS AND DISCUSSION: Our data revealed the therapeutic potential of purine nucleosides, as β-lactam adjuvants. We showed that the purine nucleosides guanosine and xanthosine have potent activity as adjuvants that can resensitize MRSA to β-lactam antibiotics (Fig.1). Mechanistically, exposure of MRSA to these nucleosides significantly reduced the levels of c-di-AMP, which is required for β-lactam resistance. Drugs derived from nucleotides are widely used in the treatment of cancer and viral infections highlighting the clinical potential of using purine nucleosides to restore or enhance the therapeutic effectiveness of β-lactams against MRSA and potentially other AMR pathogens.

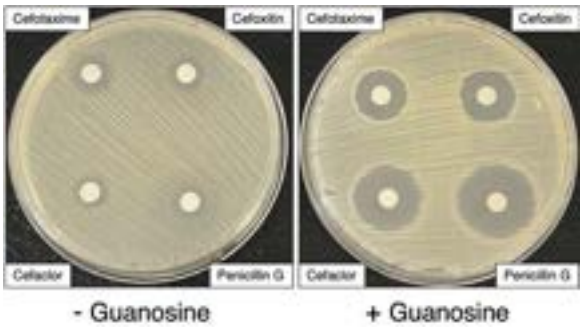

Figure 1: Exposure of MRSA to guanosine enhances MRSA killing by β-lactam antibiotics.

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Protein – Calixarene Crystal Engineering

Mockler, N.M[1], Ramberg, K.O[1], Raston, C.L[2] , Crowley, P.B[1]

[1]School of Biological and Chemical Sciences, University of Galway, Galway.
[2]Flinders University, Bedford Park, Adelaide, Australia

Small molecule crystallographers use *supramolecular synthons* to design new crystalline materials.[1] A similar method may be applied in protein crystal engineering, with scope to construct functional protein-based materials. Macrocycles such as calixarenes are useful mediators of protein assembly.[2-5] Crystalline protein-based frameworks may be engineered via the combination of protein – macrocycle and macrocycle – macrocycle *synthons* from a library of structures.[2] Previously, dimers of phosphonato-calix[6]arene (**pclx$_6$**) mediated two different assemblies of cytochrome *c* (cytc).[3,4] *Ralstonia solanacearum lectin* (RSL) forms at least 4 crystalline frameworks with sulfonato-calix[8]arene (**sclx$_8$**).[5,6] A porous framework, in space group *I*23, is mediated by dimers of **sclx$_8$**, which 'glue' RSL molecules together by binding at two distinct sites on the protein surface (Figure 1).[5] Now, an RSL - **pclx$_6$** crystalline framework in space group *H*32 has been generated, in which the dimeric **pclx$_6$** replaces **sclx$_8$** at these sites (Figure 1). In each of the RSL frameworks, the solvent exposed N-terminus is disordered. An RSL mutant with an extended dicationic N-terminus (MK-RSL) was designed to direct macrocycle binding to this accessible site. Such controlled calixarene binding would allow for encapsulation of a usually disordered region as well as production of a new RSL-based crystalline framework. Here, a crystal structure of MK-RSL in complex with **pclx$_6$** is reported, with the calixarene 'freezing' the designed N-terminal site and mediating a porous framework (Figure 1).

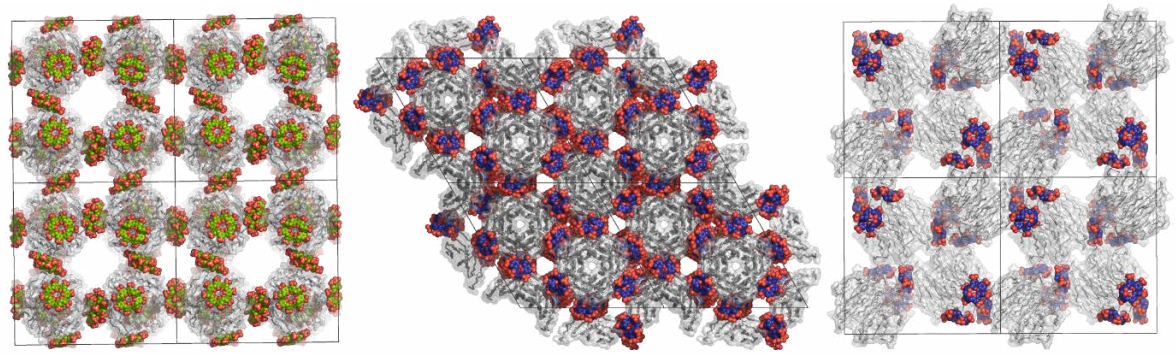

Figure 1: RSL – **sclx$_8$**, RSL – **pclx$_6$** and MK-RSL – **pclx$_6$** frameworks discussed in this work.

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AN *IN VITRO* INVESTIGATION INTO THE MECHANISMS UNDERLYING ACTUATION-MEDIATED FOREIGN BODY RESPONSE MODULATION

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2. Institute of Medical Engineering and Science (IMES), Massachusetts Institute of Technology, Cambridge, MA, USA
3. Anatomy and Regenerative Medicine Institute (REMEDI), School of Medicine, College of Medicine, Nursing, and Health Sciences, University of Galway

INTRODUCTION

Medical implant longevity is hindered by the foreign body response (FBR), and resultant deposition of a collagen-rich fibrotic capsule (FC) around the implant. This is detrimental for therapy-delivery devices as the FC impedes molecular exchange. We previously reported that intermittent pneumatic actuation (IA) of an implanted reservoir significantly reduced FC thickness in a 14-day rat model[1], and significantly improved therapy delivery in an 8-week mouse model[2]. Here we describe an *in vitro* platform used to elucidate the precise cell signalling pathways IA mediated FBR modulation.

MATERIALS AND METHODS

Human myofibroblast cell line WPMY-1 were seeded onto actuatable reservoirs and cultured for 14 days *in vitro.* Each reservoir incorporated a thermoplastic polyurethane (TPU) hemisphere (Ø=7.2 mm), with a central catheter to prove pressurised air input. The reservoirs were connected to a pneumatic actuation system, and an IA regime of 1 Hz actuation for 5 minutes every 12 hours was applied at output pressures of 27 and 68.9 kPa. WPMY-1 metabolic activity, proliferation, TGF-β1 production, and soluble collagen production were quantified. Analytical and computational models of the tissue-interfacing membranes and surrounding fluid were designed to quantify the radial strain and the fluid velocity profile at the device interface during IA.

RESULTS

Exposure to IA did not affect WPMY-1 metabolic activity or proliferation (*not shown*). IA exposure for 9 and 14 days induced a significant reduction in both TGF-β1 (Fig. 1a) and collagen (Fig. 1b) production in the 68.9 kPa actuation group compared to static controls. Modelling predicts mean radial strains of 3.6/6.7% (Fig.1c), and maximum average fluid velocities of 2.62/3.18mm/s (Fig. 1d) during IA at 27.5/68.9 kPa respectively.

DISCUSSION

IA is a promising approach to modulating the FBR[1,2], but the mechanisms are not well understood. Here, we correlate cellular responses to strain and fluid velocity profiles to better understand the relationship between mechanical loading and fibrotic pathways, and identify that IA can modulate TGF-β1 and collagen production.

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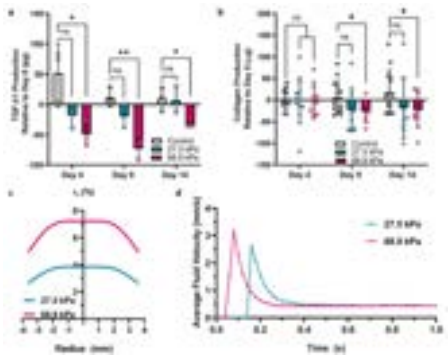

Fig. 1: a. TGF-β1 production by WPMY-1 cells **b.** Collagen production by WPMY-1 cells **c.** Radial Strain profile during IA at 27.5 and 68.9 kPa **d.** Fluid velocity profile surrounding reservoir during IA at 27.5 and 68.9 kPa

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Isolation and Characterisation of Mesenchymal Stem Cell Apoptotic Bodies

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INTRODUCTION

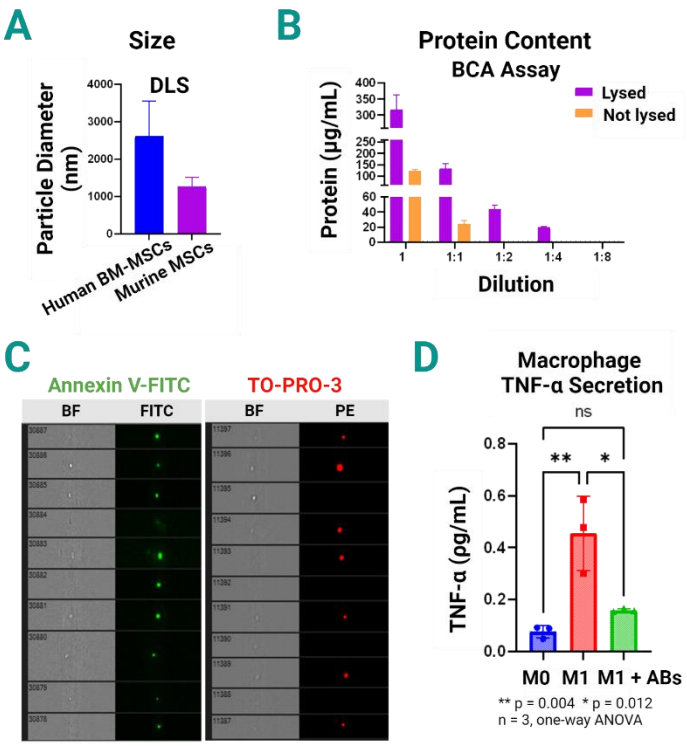
The concept of mediating tissue regeneration using Mesenchymal Stem Cells (MSCs) was primarily based on the early hypothesis that MSCs would engraft and differentiate, to replace damaged tissue. However, analysis of MSC engraftment rates provided evidence that transplanted MSCs are transient and are subjected to apoptosis. MSC viability and regenerative capabilities are also inversely related. Hence, it is hypothesized that regeneration is mediated via MSC apoptotic bodies. This project aims to isolate and characterise MSC apoptotic bodies.

MATERIALS AND METHODS

Apoptosis was induced in the D1 ORL UVA murine MSC cell line and human bone marrow-derived MSCs via UV irradiation. Apoptotic bodies were isolated from the conditioned media via differentiation centrifugation. Apoptotic bodies were characterised using Dynamic Light Scattering (DLS), the Pierce™ BCA Protein Assay Kit, and flow cytometry for marker analysis. ELISA was used to measure TNF-α secretion from RAW 264.7 M1 macrophages post-treatment with MSC apoptotic bodies.

RESULTS AND DISCUSSION

MSC apoptotic bodies isolated are between 1 µm and 4 µm in diameter (Fig. 1A), and can be quantified by protein content (Fig. 1B). The Amnis ImageStream flow cytometer can be used to detect markers (Fig. 1C). MSC apoptotic bodies show potential to modulate inflammation *in vitro* (Fig. ID).



A Protein content of apoptotic bodies isolated from D1 MSCs. **B** DLS analysis of MSC apoptotic body diameter. **C** Imaging flow cytometry of MSC apoptotic body markers. **D** TNF-α secretion from RAW 264.7 macrophages post-treatment with MSC apoptotic bodies.

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DIRECT IN-SITU EVALUATION OF STRESS IN MUSCLE

Destrade, M.

School of Mathematical and Statistical Sciences, University of Galway

INTRODUCTION

It is challenging to probe noninvasively local mechanical stresses in situ, particularly when the material properties are unknown. We propose an acoustoelastic imaging–based method to infer the local stresses in soft materials by measuring the speeds of shear waves induced by custom-programmed acoustic radiation force.

MATERIALS AND METHODS

We establish a mathematical relationship between the wave speeds of shear waves and the stress levels, which is independent of the material parameters. Then, we use an ultrasound transducer to excite and track the shear waves remotely inside an isotropic hydrogel and a skeletal muscle.

RESULTS AND DISCUSSION

We demonstrate the application of the method by measuring accurately first, uniaxial and bending stresses in the hydrogel and second, passive uniaxial stress in the skeletal muscle. We emphasize that these measurements were all done without the knowledge of the constitutive parameters of the materials. The experiments indicate that our method will find broad applications, ranging from health monitoring of soft structures and machines to diagnosing diseases that alter stresses in soft tissues.

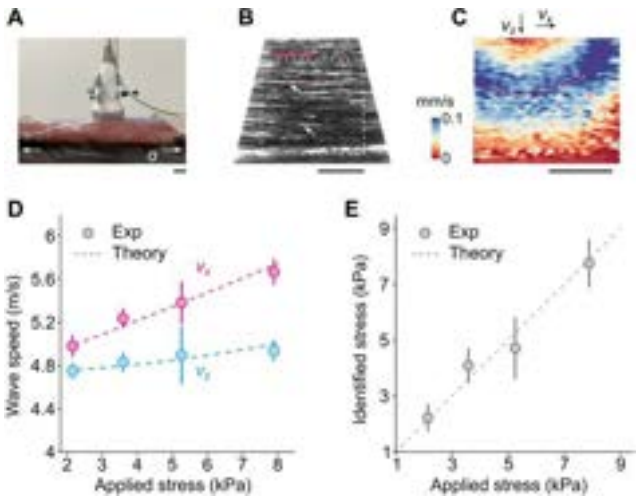

Figure 1: Acoustoelastic stress imaging of a skeletal muscle.

Zhang Z, Li GY, Jiang Y, Zheng Y, Gower AL, Destrade M, Cao Y. Noninvasive measurement of local stress inside soft materials with programmed shear waves. *Science Advances* (2023) **9**:eadd4082

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Co-culture with HepG2 spheroids spurs *in vitro* growth and development of the infective stages of the helminth pathogen *Fasciola hepatica*

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3. School of Medicine, Pharmacology and Therapeutics

INTRODUCTION

The helminth (worm) parasite *Fasciola hepatica* is a significant cause of livestock and human morbidity worldwide. Part of the difficulty in developing new chemotherapeutics and vaccines for the control of this disease (Fasciolosis) lies in our inability to culture and propagate worms outside their living hosts. Several laboratories maintain *F. hepatica* short-term in simple media, but these are usually for the purpose of collecting excretory/secretory (E/S) products containing molecules important in parasite host interaction, rather than for short- or long-term biological studies.

MATERIALS AND METHODS

Here we show that the first stage in the infective cycle of the parasite, the newly excysted juvenile (NEJ), exhibit significant growth and development in vitro when co-cultured with spheroids (cell aggregates) derived from HepG2 cells, a human non-tumorigenic liver cell line with high proliferation rates and epithelial-like morphology. We investigated parasite development using antibody probes against two major NEJ proteolytic enzymes, FhCL1 and FhCL3, and by scanning electron microscopy (SEM).

RESULTS AND DISCUSSION

Juvenile infective parasites grown in the presence of HepG2 spheroids exhibit not only a rapid increase in size (length and width) but also extensive development of the gut caecum, musculature, and surface sensory system (Fig.1). Parasites were observed regularly interacting with the spheroids, sometimes invading the tissue, and moving between or tangentially to them indicating the importance of tactile stimuli. There was also evidence of parasites 'grazing' on the peripheral cells of the spheroids. We propose that the methodology developed here mimics *in vivo* parasite host liver interactions, greatly improving our ability to investigate and understand *F. hepatica*-host biology. This methodology will greatly enhance our prospects for the future development of new parasite control methods, such as vaccines and anthelmintic drugs, without using live hosts and in compliance with the 3Rs (the Replacement, Reduction and Refinement of animals in research).

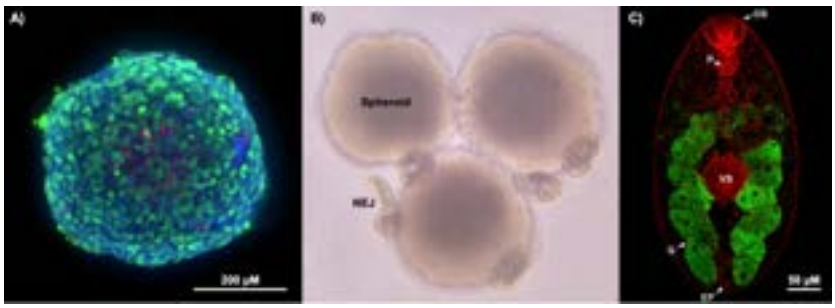

Figure 1: Co-culture of *Fasciola hepatica* newly excysted juveniles (NEJ) with HepG2 spheroids promotes survival, growth and development *in vitro*. A) A 13-day-old spheroid prior to parasite co-culture displays a healthy exterior (green) and anoxic core (red), with individual nuclei shown in blue. B) Spheroids are plated in triplet and are co-cultured with five NEJ per well for a period of 21 days, with spheroids replaced every seven days. C) A seven day old NEJ exhibits increased expression and secretion of the gut-associated proteolytic enzyme FhCL1 (green) and well developed musculature (red). OS; oral sucker, VS; ventral sucker, G; gut, EP; excretory pore.

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PTBP1 enforces ATR-CHK1 signalling determining the potency of CDC7 inhibitors

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INTRODUCTION

CDC7 kinase is crucial for the initiation of DNA replication and is important for replication stress responses. Several ATP-competitive CDC7 inhibitors (CDC7is) are being developed as possible cancer therapeutics. CDC7 inhibition causes a dose-dependent delay in S-phase progression and mild activation of the S-phase checkpoint pathway which further limits origin firing. In these circumstances, ATR activity is dependent on the ETAA1 activating subunit.

METHODOLOGY

To identify the genes that modulate the cellular responses to CDC7is we have established CRISPR/Cas9 genome-wide loss-of-function screen capability. Our workflow utilizes a breast-derived cell line expressing Cas9 (MCF10A^{EditR}) and a pooled library consisting of 155.000 sgRNAs targeting ~19,000 protein encoding genes on lentiviral vector.

RESULTS AND DISCUSSION

In a pilot screen, together with ETAA1 we identified the Polypyrimidine Tract Binding Protein 1 (PTBP1) as a top hit. PTBP1 binds RNA and is involved in mRNA stabilization, translation, and alternative splicing.

We have generated cell lines in which PTBP1 protein level is either partially or highly reduced. PTBP1-deficient cells are more efficient at synthesising DNA and have a higher proliferation rate when challenged with CDC7is. We found that upon treatment with CDC7is, or with genotoxic agents, PTBP1-deficient cells only partially activate the ATR-CHK1 checkpoint, which correlates with deficient RPA chromatin binding and genomic instability. PTBP1 deficiency noticeably affects the expression and splicing of many genes. Intriguingly, we show that an exon skipping event in the DNA repair factor RAD51AP1 contributes to this checkpoint deficiency in PTBP1-deficient cells.

Altogether, these results reveal a new level of S-phase regulation and identify PTBP1 as a key factor in the replication stress response and the response to CDC7is.

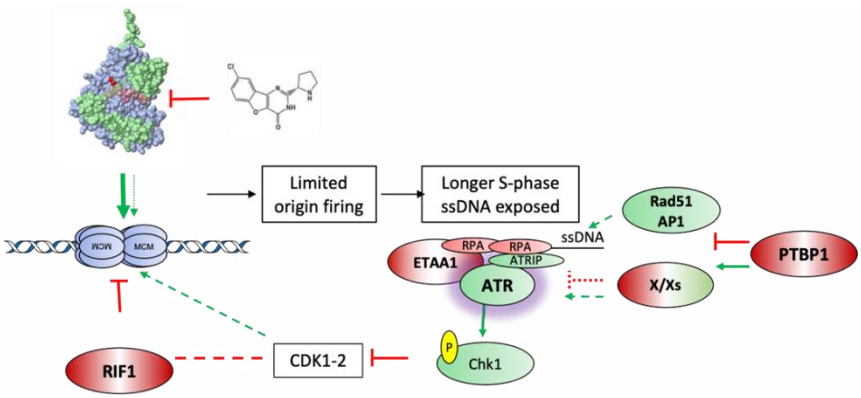

Figure 1: Roles of ETAA1, PTBP1 and RAD51AP1 in restraining DNA replication upon CDC7is.

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Laser Functionalisation of Flexible Polymer- Carbon Composites for Medical Sensing

Patricia Scully, Raul Biswas, Chiara Mischo

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INTRODUCTION: New carbons, such as graphene, create novel electronics at an ultra-compact scale, replacing metals, silicon and semiconductors, but are disadvantaged by complex and toxic manufacturing methods, requiring process liquids/gases, clean rooms and controlled atmospheres. This project creates flexible polymers, for sensing spatial variations in temperature, moisture and strain for smart polymer skins or smart dressings are required for wound healing, or contaminated or damaged surfaces in structural health monitoring.

METHOD: A single step direct laser writing (DLW) process will structure the solid carbon material in 3D to tune the composite conductivity, functionalization and sensitivity to strain, temperature and moisture, by dynamic computer control of the laser beam.

A low cost, portable and rugged ultrafast laser inscribes electrically conducting subsurface carbon tracks inside the polymer, without multiple processing steps involving controlled atmospheres, clean room conditions or hazardous liquids. The 3D DLW process inside polymers, eliminates pre or post processing, enabling laser inscription of carbon inside coatings, and en-capsulants without surface damage, removing the need for expensive multiple-step manufacturing. It inscribes enclosed subsurface tracks formed from a 3D interconnected nano-porous graphitic carbon network, with digitally controlled laser parameters defining porosity, and thus percolation threshold to tune conductivity.

Thus, multifunctional polymer-carbon composites that are sensitive to strain, temperature, will be generated, tuned by the spatial position, conductivity, and porosity of the laser induced carbon inside the polymer substrate.

RESULTS: This project demonstrates flexible polymer sensors as medical devices ranging from smart skin, implants to wearable sensors, measuring conductivity, strain, temperature, charge and moisture (smart catheter, wound monitor, smart skin, electronic tattoo).

Cost effective inscription and process scale-up are defined by digital control of a laser beam. This enables fast, scalable, green, roll-to-roll manufacturing; providing massive scale-up in speed and volume; reduced manufacturing costs, and increased range of new devices enabled by DLW processes.

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Implantable Sensor for AAA Surveillance for Post-EVAR Follow-Up: Challenges of Sensor Design and Characterisation

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An abdominal aortic aneurysm (AAA) is a dilation of the aorta artery larger than its normal diameter (> 3 cm). This disease affects the abdominal portion of the aorta artery, which gradually weakens and expands outward due to the force of the blood pressure. Endovascular aneurysm repair (EVAR) is a minimally invasive treatment option that involves the placement of a graft in the aneurysmal portion of the aorta artery. This graft creates a new pathway for blood flow, minimising the risk of artery rupture. This treatment requires multiple follow-ups with medical imaging, which is expensive, time-consuming, and resource-demanding for healthcare systems. An alternative solution is the use of wireless implantable sensors to monitor the growth of the aneurysm. The design of these sensors can be complex and challenging. The sensor design process involves accounting for geometric constraints of the sensor and constraints of the target application, as summarised and schematised in Figure 1. In this ongoing work, a novel sensor design is proposed. The proposed sensor is composed of a Z-shaped inductor, similar to a stent ring. Moreover, the proposed design will easily fit into a catheter to be deployed into the aneurysm in order to keep the EVAR procedure as minimally invasive as possible. Additionally, the geometry of the proposed sensor will allow it to expand or contract following aneurysm growth after deployment. In this study, the electrical parameters of the proposed sensor have been evaluated both numerically and experimentally. Those electrical parameters were investigated considering different possible geometries related to a Z-shaped configuration, such as the number and height of the struts. The results show that this novel sensor configuration meets the discussed geometric constraints of the target application. However, the optimisation of the sensor and the determination of the working frequency of the sensor must be evaluated.

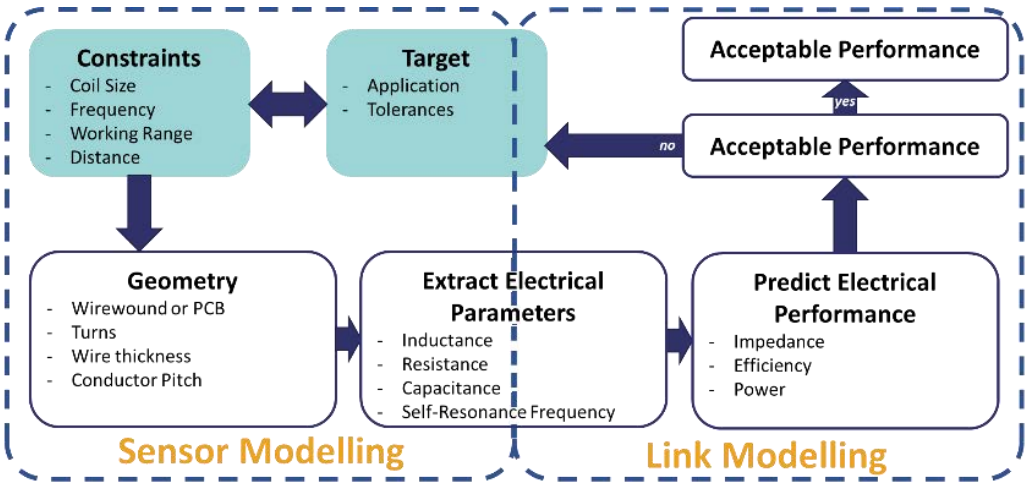

Figure 1. The sensor design modelling process.

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Vision Transformer-based Depth Estimation for Autonomous Vehicles

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INTRODUCTION

Accurately estimating the distance between the camera and different objects is a critical task known as depth estimation (DE). The accuracy of DE is critical for a wide range of autonomous driving tasks, such as object detection, lane detection, and collision avoidance. A camera-based DE approach using self-supervised learning is important and beneficial for autonomous vehicles as it provides a cost-effective and efficient way to estimate depth information, without the need for additional sensors or substantial amounts of labelled data.

MATERIALS AND METHODS

As a first step, we analysed the applicability of Dense Prediction Transformer (DPT)[1] for autonomous vehicles (AV). This is a Vision Transformer (ViT) based supervised DE technique, requiring data labelled with depth annotations for each pixel. This algorithm can take different resolution images as input, and it progressively combines them to generate a high-resolution depth map as output. The algorithm consists of an encoder-decoder network, but the fundamental building blocks of the network are the ViTs. Images are converted into feature-based tokens with the help of a pretrained ResNet-50 and fed to ViTs. The output of the decoder ViT is the depth map of an input image.

RESULTS AND DISCUSSION

Figure.1 shows results produced by DPT on a sample test image[2]. Our future aim is to enhance the model by incorporating temporal information (e.g. utilizing KITTI dataset) to generate the depth estimates in a partially supervised or self-supervised manner, which will reduce or eliminate the need for labelled data for training.

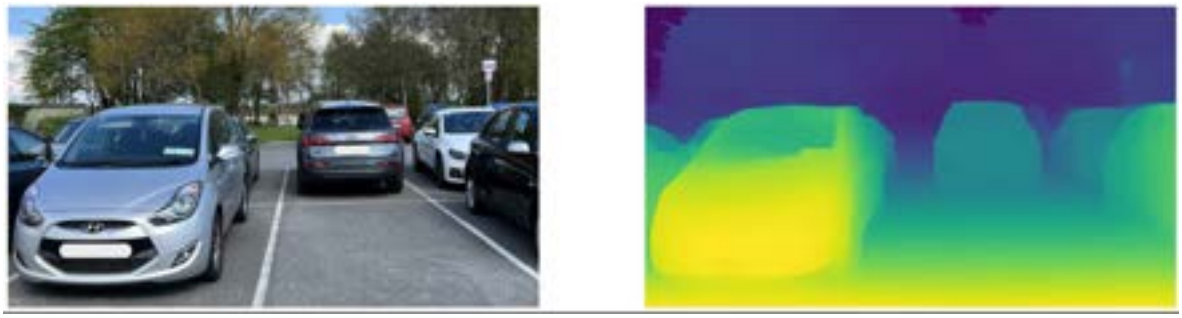

Figure 1: Left is original image and right is estimate depth with yellow being closet and black being furthest

ACKNOWLEDGEMENT This research is funded by Science Foundation Ireland under Grant number 18/CRT/6223. It is in partnership with VALEO.

[1] Ranftl, René, Alexey Bochkovskiy, and Vladlen Koltun. "Vision transformers for dense prediction." Proceedings of the IEEE/CVF International Conference on Computer Vision. 2021.
[2] Test images taken by us in Computer Science building parking, University of Galway.

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Integration of anaerobic co-digestion into a sustainable livestock farming system

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INTRODUCTION

Anaerobic digestion (AD) is an effective approach to reduce greenhouse gas (GHG) emissions from slurry management while producing biogas and digestate. In Ireland, pasture-based beef systems could provide slurry and grass silage for AD. However, there is little information about how AD could be sustainably integrated into a beef farm. This study aimed to assess different farmland area proportions dedicated to growing grass for AD in terms of feedstock provision, GHG emissions and nutrient flow.

MATERIALS AND METHODS

The Grange Dairy Beef Systems Model (GDBSM) was implemented, which includes economic and GHG emissions submodels from a pasture-based beef production system (Kearney *et al*., 2022). Economic and GHG parameters from AD were included in the model. A 40 GWh biogas plant was implemented, this being considered as representative of a commercial scale. Three farm scenarios (total area of 50 ha) were assessed in terms of their farm activity: 100% Livestock (50 ha for livestock only), 50% AD (25 ha for AD silage, 25 ha for livestock) and 100% AD (50 ha for AD silage only). Red clover and perennial ryegrass (RC/PRG) sward were selected for AD silage as they do not require nitrogen inputs and therefore support the aim of renewable energy production. Hence, digestate was returned only to the livestock area.

RESULTS AND DISCUSSION

Results showed that based on the feedstock produced per farm, a total number of 123 farms would be necessary to meet the feedstock demand (Table 1). The greatest share of GHG emissions in the 100% Livestock and 50% AD were associated with the livestock system (enteric fermentation, excreta at pasture, etc.) (Table 2). The 100% AD had the least total emissions as there was no livestock component within these farms. Although, proportionally contributing much less to total GHG emissions, AD silage production was the second largest source of emissions in the 100% AD and 50% AD scenario, mainly due to the inorganic phosphorous and potassium fertilizers applied.

Table 1

Total number of farm systems needed to supply the annual demand of a 40 GWh biogas plant.

Farm scenario	Total silage supplied [%]	Total slurry supplied [%]	Number of farms needed
100% AD	50%	0%	9
50% AD	50%	9%	18
100% Livestock	0%	91%	96
Total	100%	100%	123

Table 2

GHG emissions per farm scenario.

Emissions per process	g $CO_{2\ eq}$ $farm^{-1}$ $year^{-1}$ / % of total emissions					
	100% Livestock		50% AD		100% AD	
AD silage production [a]	0	0%	7,442,827	3%	14,885,654	82%
AD silage transport [a]	0	0%	1,606,156	1%	3,212,311	18%
Slurry transport [b]	658,182	0.2%	329,091	0.1%	0	0%
Livestock system [c]	420,238,963	98.3%	211,536,560	94.4%	0	0%
Digestate application [d]	6,547,192	1.5%	3,273,596	1.5%	0	0%
Total g $CO_{2\ eq}$ $farm^{-1}$	427,444,337	100%	224,188,230	100%	18,097,966	100%
Total g $CO_{2\ eq}$ ha^{-1}	8,548,887		4,483,765		361,959	
% compared to baseline farm [e]	-7.8%		-51.6%		-96%	

[a] Silage produced for anaerobic digestion (AD).
[b] Slurry produced on the farm goes for AD.
[c] Emissions associated with slurry storage and spreading were excluded.
[d] Digestate applied to the livestock silage area.
[e] Conventional livestock farm with slurry management on-farm (9,269,572 g $CO_{2\ eq}$ ha^{-1} $year^{-1}$).

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Driving Climate Action

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There are 2 major climate-action barriers this research tackles, the first: consumers do not know what climate-actions to take confused by the: (i) financial cost, (ii) personal effort, and (iii) emissions reduction benefits of a whole series of competing climate-actions. Our busy lifestyles increase the dissonance. The second climate barrier is that communities are significantly isolated and there are relatively few trusted solutions in which they can invest. Our Spark Change research (here) utilised climate-action drivers to transfer climate-actions from lighthouse to follower communities building trust, knowledge, feedback, confidence, agency and action.

This research seeks to build a webtoolkit (Fig. 1) to drive co-creation and climate-action further. This will include a range of tools, case studies and a sharing platform to support decarbonized communities tangibly reduce their carbon footprint by 2050. There are supports to set up a decarbonisation committee and formal procedures including the development of a decarbonisation plan for the community. Necessary also are supports to engage the individuals and the community to measure the carbon intensity of a myriad of competing climate-actions. Susequent to measurement we provide supports for local campaigns on reinterpretation, dialogue and reflection on low carbon behaviours, practices and actions. As learning by doing and norm activation are powerful drivers of action our toolkit also hosts stories and case studies of climate-action both at the individual and community scales. The climate change challenges needing community action are diverse and we build a support within our toolkit for diverse climate-action issues such as erosion, flooding, economics, biodiversity and peatlands remediation.

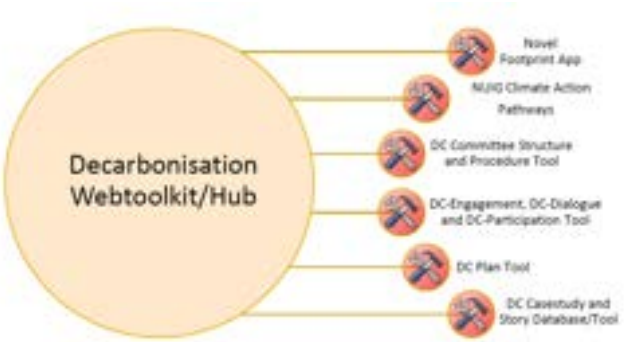

Figure 1: Decarbonisation Webtoolkit

This is a research partnership with: twelve academics; five Decarbonising communities, their five local authorities and their climate action regional office, four volunteer Ireland branches, and Energy Cooperatives Ireland. To find out more click here.

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Investigation into potential use of coconut-based activated carbon as an adsorbent for herbicides

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Herbicides are synthetic chemical substances used to control undesired plants, also known as weeds. However, extensive and inefficient use of herbicides has led to contamination of soils and waterways. In recent years, the production of novel activated carbons, derived from renewable, low-cost materials, including coconut, have been widely researched as adsorbents for herbicides in batch adsorption studies. An alternative approach to water treatment facilities, which sometimes incorporate powdered or granulated activated carbon (GAC) filters to remove herbicides, could be the development of a system to support herbicide remediation at the source, i.e., in the field.

The aim of this study was to design and assess the efficiency of two configurations of low cost, coconut-based activated carbon (CAC) intervention systems capable of herbicide removal from waterways (Fig. 1).

The herbicides, 2,4-D, clopyralid, fluroxypyr, MCPA and triclopyr, were detected at all three sites, with many detections being above the maximum allowable concentration (MAC) of 100 ng.l^{-1}. Results show that both configurations were successful in adsorbing herbicides from the streams, with reductions in herbicide concentrations to below the MAC in the majority of cases. Both intervention configurations adsorbed herbicides from the waterways most efficiently when the water flow in the waterways was slow, the interventions spanned the width of the waterway, and the depth of water present in the waterway was lower than the depth of the interventions, ensuring that the water cannot easily bypass above or around the interventions. The pipe configuration, however, was better at herbicide removal than the bag configuration. This investigation into the use of a CAC-based adsorption system for herbicide removal at source shows its excellent potential.

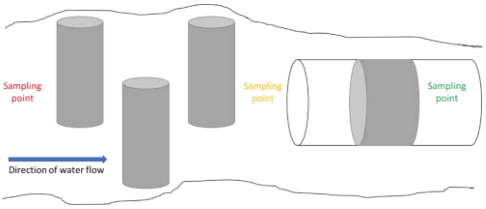

Fig. 1. Schematic of different configurations of the intervention positioned in the stream.

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The emerging field of AgroGeophysics – Its role in sustainable agriculture.

Eve Daly

Soil is a vital non-renewable resource with the capacity to deliver food production, nutrient retention and cycling, carbon storage, filtration of water and a habitat for biodiversity. Global food demand is expected to increase by 100% by 2050. Agriculture also has the dual and environmental sustainability. This results in the need to use less water and fertilizer. Key to achieving these goals is improving the understanding of processes and interactions governing the soil–plant–atmosphere continuum of agricultural ecosystems.

Increasingly, geophysics is used to provide a multidimensional suite of tools to image the near subsurface, and monitor fluid dynamics (from root water uptake to water table monitoring) and biogeochemical processes (e.g., water, and carbon cycles) across multiple spatial scales noninvasively. High-resolution two- and three-dimensional mapping and monitoring provides extensive options to tackle the inherent heterogeneity and complex dynamics of soil and cropping systems especially when integrated with Earth Observation data.

The HY-RES research group at the University College Galway is applying machine learning to develop new tools to update national peatland extent maps and find peat soils under grass and forest cover using the Tellus Airborne Geophysical Radiometric dataset. This has implications for the estimation of carbon emission factors of peat soils and the management of climate emission targets wherever radiometric data is available. Future works includes testing the effectiveness of UAV radiometrics in monitoring the rewetting of peatlands for the first time. Other projects in the HY-RES group include applying field-based electrical methods to monitor soil compaction due to cattle grazing patterns as compacted soils have larger greenhouse gas emissions, and generating high resolution soil moisture maps from satellite data. This work will have impact in improving farm drainage management therefore improving the efficiency of grazing and crop management practices.

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Rule-Based Multi-Agent System for Autonomous P2P Energy Trading in Dairy Farming

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INTRODUCTION

The pressure for farm businesses to improve energy efficiency has led to the increased use of renewables as the primary energy source, replacing fossil fuels. This study aims to decrease dairy farms' dependence on the electricity grid by allowing them to sell excess renewable generation in a Peer-to-Peer market. The objective is to enable farms to reduce electricity costs, lower carbon footprint and reduce energy demand during peak hours. The dynamic and self-interested nature of the farm community makes this challenging. A simulation model named ***M**ulti-**A**gent **P**eer-to-Peer **D**airy Farm **E**nergy **S**imulator (MAPDES)* has been developed to address this issue. It utilizes a rule-based approach, load and battery management system, multi-agent systems, and distributed peer-to-peer energy trading. An auctioneer acts as a price advisor for the dairy farm community. The results obtained demonstrate significant cost savings for farms and decreased demand for utility grids during peak hours.

METHODOLOGY

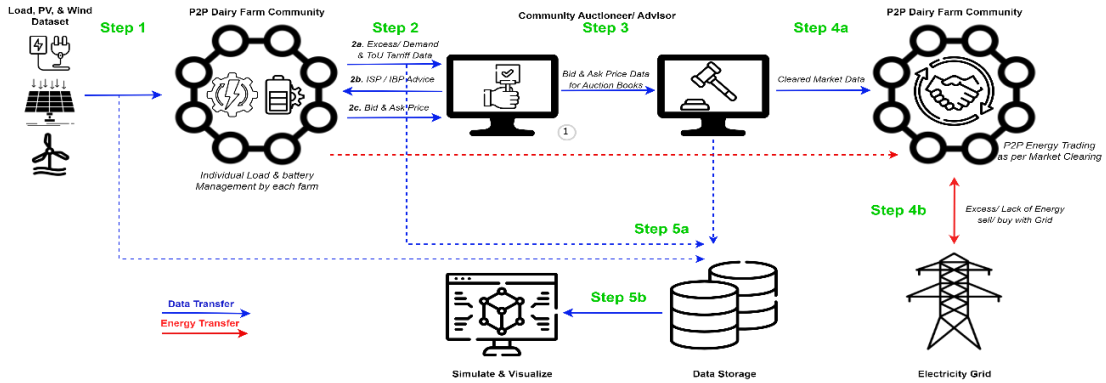

Figure 1 Simulation Development & Working Methodology of RBEIRE-I

RESULTS AND DISCUSSION

Figure 2a, 2b Energy Purchased and Sold by Farms (P2P vs Non-P2P)

P2P energy trading & market clearing results in a notable decrease in energy costs, with the community paying ~27% less for energy compared to farms that don't use P2P approach. Moreover, during peak hours, dependence on the grid is reduced by ~24%.

Emerging Pollutants in our Environment: the What, the Where, and the Why Do We Care

Martin Sharkey

Synthetic chemicals are an intrinsic part of our everyday lives, permeating virtually every sector: synthetic polymers used to make clothes and plastic products; water-repelling surfactants for food packaging and clothing; flame retardants in furniture, electronics, and building materials; antibiotics and antiparasitics for treating humans and animals; and pharmaceuticals such as sunscreen agents and ultraviolet filters. Unbeknownst to us all they are produced en-masse, used in a multitude of applications, and eventually disposed of into our environment.

So many novel chemicals are created and produced that reliable research on their environmental and human health hazards is, by comparison, in its infancy. For the vast majority of these chemicals, we do not know how much is entering the environment and in what form; we do not know how bioavailable and bioaccumulative they are in the food chain; and we do not know the health effects of over-exposure to them. These potential “emerging pollutants” are an under-investigated and potentially toxic deficiency in environmental pollution research.

High volumes of fundamental discovery research is therefore sorely needed to fill this knowledge gap and begin the process of identifying the hazardous substances from the crowd of otherwise useful synthetic chemical: quantifying how much is in the environment during or following its use, and determining how best to protect human health and the environment.

Our research within the School of Natural Sciences over the last 10 years has been to investigate hazardous and potentially hazardous emerging pollutants in the Irish environment: collecting exposure data, identifying high-risk environmental uptake pathways, and developing solutions for remediation. We have thus far identified significant levels of emerging pollutants such as flame retardants and surfactants in indoor and outdoor environments as a result of the use of everyday objects, insufficient waste management systems, and likely leading to human exposure through various pathways.

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Multimodal Machine Translation

Ali Hatami

Supervisors: Paul Buitelaar, Mihael Arcan

Machine Translation task is a subfield of Natural Language Processing (NLP) that translates a text from a source language into a target one. In recent years, neural network-based models have been widely used in translation tasks. Neural Machine Translation (NMT) represents an incredible improvement in the quality of translation, but they use parallel text corpora as the only source of training.

Recently many studies in machine translation have been increasingly focusing on using visual and textual content to improve the quality of translation. Although the text-only NMT model considers contextual information, word sense disambiguation is still an open challenge for NMT. Textual context does not always provide sufficient information for word sense disambiguation. Due to this, visual information can enrich text-only NMT models by adding extra information to disambiguate the input words and provide correct translations on the target side.

Multimodal Machine Translation (MMT), a subarea of NMT has been introduced to use visual information extracted from other modalities such as images or videos to improve the translation quality. Similar to other multimodal NLP tasks, MMT endeavours to utilise the model's ability by taking visual context as an additional input to better understand and translate the input text. The idea behind MMT is to incorporate visual information to perform word sense disambiguation in the input text.

Despite the importance of using visual context, visual resources such as images and videos contain a lot of noisy information. This useless information cannot improve the performance of the baseline model and in some cases, it even drops the translation quality. So the recent studies on MMT focus more on finding a suitable approach to reduce the negative effects of noisy visual information and enrich the translation model with the related visual information. To overcome this challenge, current work focuses on decreasing the noisy impact of using visual information by finding related visual information. After extracting visual information such as objects and the relations between them, the next step is how to find relative visual information to the source text. This related information can be used in the multimodal setting to improve the performance of the output translation.

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The TAPAS Project: Tracking adaptation progress in agriculture and food security using an AI-powered satellite remote sensing platform

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2. School of Natural Sciences, Ryan Institute

TAPAS is a technology platform that uses AI to identify, quantify and track climate change-induced biomass anomalies by analysing both archival and real time earth observation (EO) data. Advanced statistical models, machine learning models and deep learning models have been developed to identify crop cultivation patterns in the Senegal River Valley (SRV) where rice is the predominant crop type. Over the past ten years in particular, the SRV has been the target of a number of large-scale multi-million dollar investments in programmes that aim to stabilise and expand rice production both to mitigate climate change-related pressures and to support food security strategies in response to population growth. One of the main goals of the TAPAS project is to use EO platforms and data sets, coupled with state of the art AI analysis and models, to track multi-annual crop cultivation patterns, particularly where there have been funded interventions, in order to accurately assess the impacts of these interventions and optimise future intervention capacity.

Data sources for this work include various derived indices from the MODIS instruments on the NASA Terra satellites and data products from the ESA Sentinel-1 and Sentinel-2 satellites. Time series of the Normalised Difference Vegetative Index (NDVI) from MODIS were used for the initial statistical analyses. Enhanced Vegetative Index (EVI), Normalised Difference Yellow Index (NDYI) and Synthetic Aperture Radar Polarimetry (SAR) data products from Sentinel-1 and Sentinel-2 were added to subsequent analyses to provide both better spatial resolution and to enable the detection of phenological stages of crop development. Short Wave Infrared (SWIR) images were used for segmentation of the study areas to more clearly identify cultivated crop regions. Machine learning models using random forest and support vector machine classifiers were developed and refined to create dynamic yearly crop masks. Data extracted from Google Earth Engine (GEE) based on these crop masks were then analysed using a Convolutional Neural Network (CNN) model to identity cropping intensity patterns.

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A Support Centre for Developing and Deploying Sustainable Data Spaces

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INTRODUCTION

A data space provides a clear structure (from the perspectives of business, legal and governance, technology, and operations) to allow data exchange within a data ecosystem. This either sets the conditions for a market among participants or allows for collaboration among varied, interrelated players who rely on one another for mutual gain. For example, industrial data spaces can allow various degrees of trustworthy and secure commercial data asset sharing and trading, with automated and robust controls on legal compliance and payment. Personal data spaces enforce regulations and provide data subjects and holders with a choice over their data and how it is used. Many fundamental technical, organisational, legal, and commercial challenges exist in developing and deploying data spaces to support data ecosystems. These challenges create a huge barrier for data providers to adopt data spaces. The data space support centre aims to facilitate common data spaces that collectively create an interoperable data-sharing environment, enable data reuse and secondary use within and across sectors, fully respect the EU values, and contribute to the European economy and society.

METHOD

The Support Centre investigates the needs of the data spaces projects, standard requirements, and best practices in collaboration with all stakeholders. At the core of the network of stakeholders are the existing and emerging data space initiatives and the potential implementers of the building blocks. These form the Community of Practice (CoP) in data sharing, and they create and adopt the Blueprint and its building blocks in sectoral data spaces. Furthermore, the Support Centre closely engages with the European Data Innovation Board throughout the development of the Blueprint so that the Board can adopt elements as a significant part of its guidelines, such as cross-sectoral data sharing standards, requirements for security and access procedures.

RESULTS AND DISCUSSION

The Support Centre delivers the Data Spaces Blueprint, composed of standard building blocks encompassing data spaces' business, legal, operational, technical, and societal aspects. The Blueprint continuously evolves with a user-centric approach as the result of co-creation with the stakeholders. It combines the already implemented solutions and pinpoints those still needed for delivering the data spaces. The Support Centre will continuously translate policy objectives and regulations into design principles and implementation requirements as part of the Blueprint. Also, the support Centre creates toolboxes that prove a specific aspect of the Blueprint by deploying a selection of technical and non-technical building blocks.

The support Centre is developed within the scope of Digital Europe Program that involve the following partners: Fraunhofer, BDVA, CAP, FIWARE, Gaia-X, IDSA, KUL, MyData, NUI, Sitra, TNO, and VTT.

Effective Usage of Thermal Imaging Technology for the Development of Extended Forward Vision Systems for Advanced Vehicular Systems

Muhammad Ali Farooq[1]; Peter Corcoran[1].

1. Center for Computational, Cognitive, and Connected Imaging (C3I)

INTRODUCTION: Computer Vision algorithms have shown great potential for diversified real-world applications. This work will focus on using thermal imaging technology for designing an intelligent forward sensing system that should be effective in all weather and environmental conditions. The systems work by deploying the thermally tuned deep learning networks on GPU & single-board EDGE- GPU computing platforms for onboard automotive sensor suite testing. The state-of-the-art object detection models are trained and fine-tuned on a large-scale locally acquired novel C3I thermal dataset comprising of more than 35K distinct thermal frames along with 4 different large-scale publicly available thermal datasets. The trained network variant of the YOLO object detector is further optimized using SoA neural inference accelerator (TensorRT) to explicitly boost the frames per second rate and cut the overall inference time. Further we have designed a thermal tiny-YOLO multi-class object detection (TTYMOD) system for deployment on a low powered raspberry pi computing board thus evaluating the real-time feasibility performance of an optimized version of the thermal object detection network for the automotive sensor suite.

MATERIALS AND METHODS: The thermal dataset is acquired using prototype LWIR thermal 640 x 480 imaging module in different weather and environmental conditions. The locally acquired data along with four different publicly available datasets are further used for fine-tuning the state-of-the-art YOLO-v5 network variants. The performance of trained networks is analyzed on both GPU as well as ARM processor-based edge devices for onboard automotive sensor suite feasibility testing.

RESULTS: On GPU the large network variant of the YOLO-v5 framework comprising 47.4 million parameters has achieved the best mAP score of 84.1% and 86.6% using the test time with augmentation (TTA) method. On edge devices, the optimization methods help in achieving the 11 frames per second on jetson nano, while the Nvidia Jetson Xavier delivered 60 frames per second results.

Figure 1: Thermal object detection inference results with class confidence scores on sixteen different frames from four different public datasets a) results extracted using small network variant, b) results extracted using medium network variant, c) results extracted using large network variant, and d) results extracted using x-large network variant.

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A multivariate exploratory data analysis of a crisis text messaging service to measure the impact of the COVID-19 pandemic on mental health in Ireland

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INTRODUCTION

A range of public health non-pharmaceutical intervention (NPI) strategies were implemented in the year 2020 and 2021 to mitigate the transmission of COVID-19. The drastic changes in everyday life due to lockdowns had the potential for a significant negative impact on mental health, and a key public health goal is to now assess the evidence from available Irish datasets to provide useful insights on this issue. Text-50808 is an online text-based mental health support service in Ireland. Its dataset can provide a measure of revealed distress and mental health concerns across the population. The aim of this study is to explore statistical associations between public mental health in Ireland and the COVID-19 pandemic, through several statistical analyses.

MATERIALS AND METHODS

It is found that COVID-19 related chats are the key drivers of overall chat volumes at Text-50808 between June 2020 to July 2021. Surges in text volumes at Text-50808 immediately prior to new restrictions in Ireland indicate an association between a sudden rise in mental health concerns following the announcement of the new restrictions. Through segmented breakpoint modelling via breakpoint regression with multiple turning points, seven distinct breakpoints were identified across weekly chat volumes at Text-50808, majority of which are co-incident with events when considerable changes in NPIs were made in Ireland. In additional statistical analysis, two measures of emotional wellbeing in Ireland are combined: (1) weekly text volume at Text-50808, and (2) emotional wellbeing indicators reported by respondents of the Amárach public opinion survey, carried out on behalf of the Department of Health, Ireland. A significantly high cross-correlation between emotional well-being variables in the Amárach dataset and the number of weekly texts at COVID-19 related chats at Text-50808 is found.

RESULTS AND DISCUSSION

This analysis confirms the benefits of the texting service as a community surveillance indicator for mental health in the population. It also confirms that changes in the stringency of COVID-19 related NPIs triggers short-lived bursts in the number of people reporting negative mental health in Ireland.

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Monitoring energy use and indoor environmental quality of new build and retrofit homes

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INTRODUCTION

In Ireland, residential buildings are responsible for 25% of national energy use. Improving the energy efficiency of buildings via retrofitting is seen as one of the key mitigation measures to reducing the energy demand of the built environment. However, while energy efficiency retrofits for buildings are effective in theory, a 'gap' in the energy savings estimated by statistical or engineering models is commonly found.

Reasons for the 'gap' in actual energy usage to the theoretical energy usage of engineering energy demand models have been associated with inaccuracies relating to the technical characteristics of the building (e.g. building thermal fabric performance), building occupants (e.g. heating demand behaviours) and malfunctioning technical equipment (e.g. heating system commissioned incorrectly). As part of the SEAI funded HEAT-CHECK project and EU funded NET ZERO CITIES project , the project team aims to investigate homes in Ireland for factors driving the performance gap between expected and actual energy demand and indoor environmental quality levels with the overall aim to improve the energy audit procedure in the DEAP energy compliance tool.

MATERIALS AND METHODS

In collaboration with Galway City Council, the HEAT-CHECK and project team are monitoring the energy demand and indoor environmental quality of up to 100 homes. This includes the use of IoT sensors and occupant surveys to assess the thermal fabric performance (air tightness and heat loss coefficients), disaggregated energy demand (space heating, water heating, cooking, appliance and lighting) and indoor environmental quality (temperature, humidity and carbon dioxide) of homes.

RESULTS AND IMPACT

The monitored data provides an evidence base for numerous applications such as:

- Performance levels of various building technologies (see Figure 1 for example).
- Comparing assumptions in building energy models (thermal fabric performance, heating profiles, etc.) to in-situ performance data.
- Narrowing the performance gap in models that are used for estimating the energy and carbon emission savings associated with government policies.

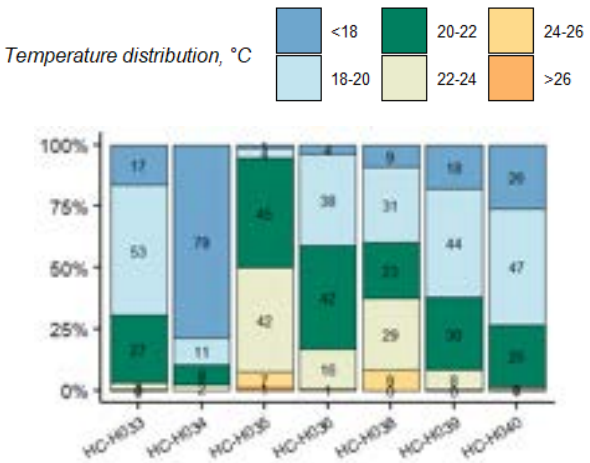

Figure 1: Indoor temperature distribution of timber framed homes in heating season with heat pump based heating system

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Exploring the Effect of Misinformation on Infectious Disease Transmission

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INTRODUCTION

Vaccines are one of the safest medical interventions in history and can protect against infectious diseases and ensure important health benefits. Despite these advantages, health professionals and policymakers face significant challenges in terms of vaccine rollout, as vaccine hesitancy is a global challenge. The internet has rapidly become a widely used information source for health-related issues, and a medium where misinformation in relation to vaccines on social media can spread rapidly and influence many. This research involves two interacting contagion models, one for the disease itself, and the other for the public's views on vaccination. The results show that higher vaccine confidence can mitigate against the impact of misinformation, and by doing so can contribute to the enhanced control of an infectious disease outbreak.

MATERIALS AND METHODS

The system dynamics approach is recognised as a powerful method for understanding and addressing complex health issues. In system dynamics, Loops that matter (LTM) method is used to explore, which links and feedback loops are responsible for generating observed model behaviour. System dynamics sensitivity analysis combined with loop impact analysis to explore the impact of different parameter values on the model's feedback loops, and this approach is taken in our paper. The LTM method is used to explore the loop dominance behaviour in our model.

RESULTS AND DISCUSSION

Fig 1 shows box plots for the disease *Attack Rate*: Scenario SA3 shows a significant increase in the disease attack rate as compared to SA1 and SA2, where R_0d varies between 2-4, and R_0m is fixed at 18. This shows the impact of high misinformation leading to lower vaccine uptake, and so providing the disease with more opportunities to spread. Fig 2 presents feedback loops behaviour between model runs from two of the scenarios. When R_0d = 4, and R_0m varies between 12-18, scenarios (S7, S8 and S9) the reinforcing loops' average relative scores change from 16% to 23%. With R_0m fixed at 18 (S3, S6 and S9), the reinforcing contribution decreases from 41% to 23%. The decline in the reinforcing contribution is caused by *Vaccine Confidence* stock, which is a goal seeking structure.

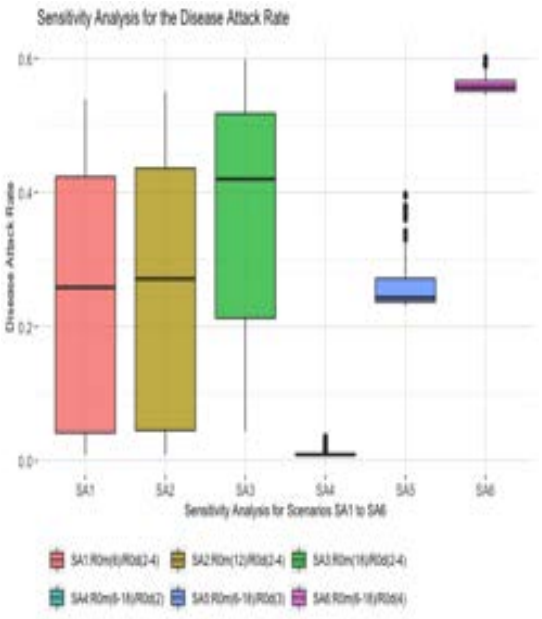

Figure 1 Sensitivity Analysis for Disease Attack Rate

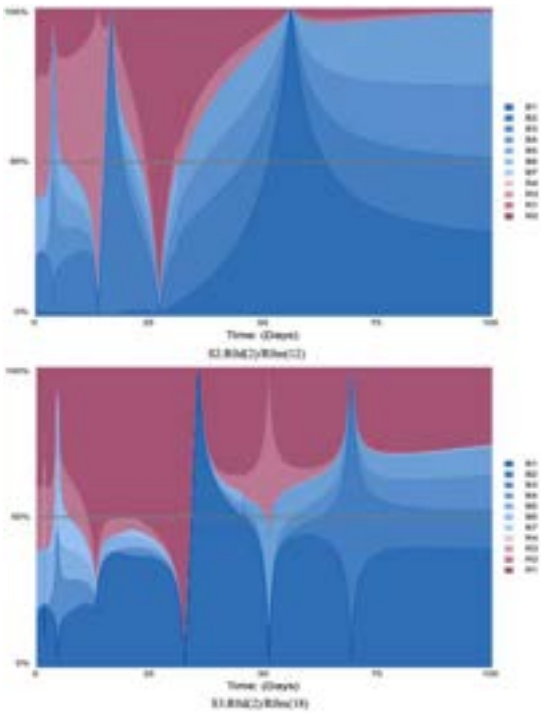

Figure 2 LTM: Feedback Loops Behaviour Until T_{100}

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Improving Human Trafficking Detection Through Audio Event Classification and Semantic Ontologies

Eoin Jordan

Audio event classification is an emerging technology that has the potential to revolutionize the way crime is prevented. This paper explores the potential of audio event classification as a tool for crime prevention by enhancing failures in Banking record processing to link human trafficking related events to transaction times. It examines the current state of the technology, including its capabilities and limitations, and evaluates the potential for its use in crime prevention. Additionally, the paper examines the ethical considerations of using audio event classification for crime prevention, such as privacy and civil liberties. Finally, the paper outlines the TAHO ontology and suggests possible future applications.

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Novel mechanobiological modelling of bone metastasis reveals that substrate stiffness, biochemical bone cell signaling and mechanical stimulation alter metastatic activity

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INTRODUCTION

For more than 70% of breast cancer patients, cancer cells spread from their primary site and metastasize to bone. How the coupled mechanobiological responses of tumor and bone cells contribute to osteolysis and tumor growth is not fully understood. Current 3D in-vitro models[1-3] either do not fully recapitulate the multicellular niche within a mineralized matrix or do not incorporate extrinsic mechanical loading to represent the role of daily physical activity in bone health. The objective of this research is to develop advanced models that can enable an enhanced scientific understanding of the effects of biophysical stimuli and tumor cell-bone cell signalling on tumor growth and remodelling of the bone microenvironment.

MATERIALS AND METHODS: 4T1 breast cancer cells were cultured in monoculture and co-culture conditions with osteoblast and osteoclast precursors cells within hydrogels of three different stiffness (0.58kPa, 0.85kPa, and 1.1kPa) and cultured for 7 days to investigate the coupled influence of tumor cell-bone cell signalling and hydrogel stiffness on tumor spheroid growth. To investigate whether tumor spheroid growth was stress-dependent and whether it is modulated by the biochemical signals (TNF-α, TGF-β, and IL-6) released in the culture of tumor cells and bone cells, an adaptive computational finite element model was also simultaneously developed. We developed an advanced in vitro 3D bone-like and metastatic models to investigate how mechanical loading influenced breast cancer cell activity, signalling for osteoclastogenesis, and osteoblast activity during early-stage bone metastasis.

RESULTS AND DISCUSSION: These results reveal for the first time a synergistic influence of osteoclast precursors, osteoblasts, and 3D matrix stiffness on tumor spheroid growth. This work reported the development of an advanced biomimetic 3D in vitro mineralized multicellular model, which successfully recapitulated the osteolytic-metastatic process. Using this model, the inhibitory effect of mechanical loading on osteolysis in early-stage bone metastasis was highlighted.

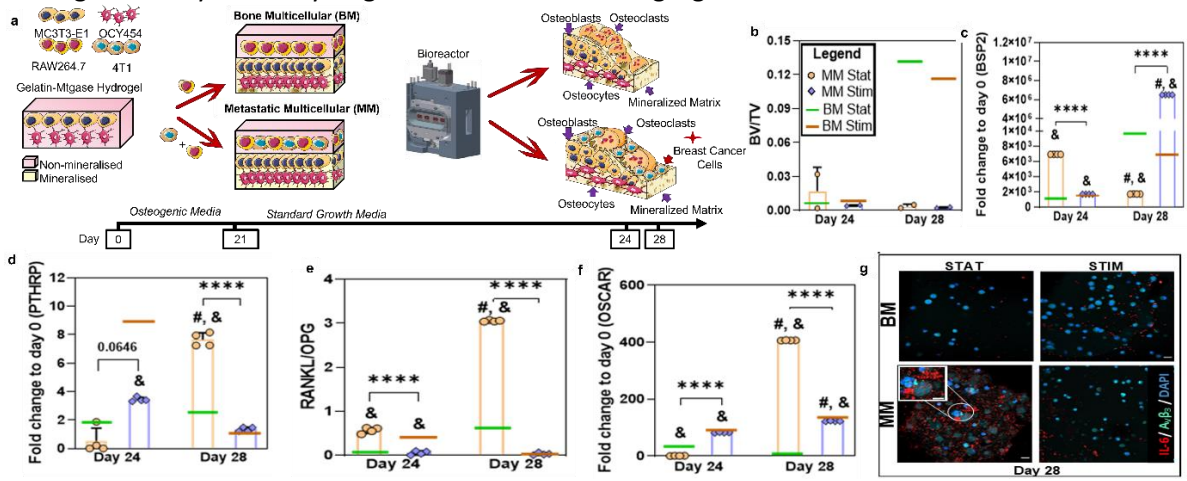

Figure 1: (a) Bone Multicellular (**BM**) and Metastatic Multicellular (**MM**) model development. (b, c) Quantitiatve mineralisation (BV/TV) and calcium assay. (d, e, f) Genes expression for osteogenesis (BSP2), tumour cell signalling (PTHrP) and osteolysis (RANKL:OPG, OSCAR). (g) Immunofluorescence reveals IL-6 and $\alpha_V\beta_3$ positive micrometastasis-like cell aggregates in the MM model under static condition (scale bar: 20 µm). Statistical significance &: between metastatic (MM) and respective bone (BM) groups, #: compared to day 24,*: $p \leq 0.05$, **: $p \leq 0.01$, ***: $p \leq 0.001$, ****: $p \leq 0.0001$.

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ACKNOWLEDGEMENTS: This research was funded by College of Science and Engineering Postgraduate scholarship and IRC Laureate Award Programme 2017/18, MEMETic, IRCLA/2017/217.

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Computational Optimization of Insulin Release from Macroencapsulation Devices

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INTRODUCTION

Implantable macroencapsulation devices which encase transplanted pancreatic cells in semi-permeable membranes are being developed for treatment of Type 1 diabetes. These devices have shown some success but limited long-term viability, in part due to the diffusion barrier they pose[1,2]. Local fluid flow has recently been explored to enhance drug transport[3]. We are using computational and experimental methods to explore how increasing fibrous capsule thickness resulting from the foreign body response (FBR) impacts the transport of insulin, and how local fluid flow may counteract these effects.

MATERIALS AND METHODS

A model of a macroencapsulation device was created in COMSOL Multiphysics® consisting of a cell reservoir (10x10x0.5mm) with a 0.15mm thick membrane (10µm pores, 3.5% porosity). The initial concentration of insulin in the reservoir was calculated from insulin secretion results for INS1E pseudoislets assuming 10% v/v cell packing density and idealized instantaneous insulin secretion. The membrane diffusion coefficient was then determined using a Franz cell. The additional diffusion barrier posed by formation of a fibrous capsule in vivo was modelled simulating days 1 (D1) and 7 (D7) after implantation. Fluid flow velocity (0.25[3], 3.18mm/s) over the device with the lowest diffusion (D7) was then explored.

RESULTS AND DISCUSSION

When assessing insulin release with respect to the fibrous capsule, our model captures the expected decrease in insulin transport resulting from the FBR in vivo. At 15 minutes insulin release was 31.4, 18.7, and 6.1% with increasing fibrous capsule thickness (Fig. 1A). Conversely, increasing fluid flow velocity (0.25, 3.18 mm/s) past the device with the lowest diffusion (D7) was able to restore insulin release respectively to 7.2 and 8.3% at 15 minutes (Fig. 1B). As macroencapsulation device failure is often a consequence of poor transport understanding to what degree this occurs and how it can be counteracted is crucial to future device design.

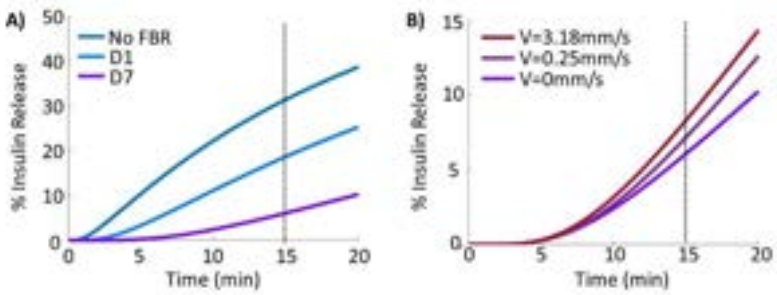

Figure 1: A) Insulin release from device with fibrous capsule (D0, D1, D7). B) Insulin release from device (D7) with increasing fluid flow.

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Unravelling the protease-inhibiting role of *Fasciola hepatica* serpins in host-parasite interactions

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Background

Fasciola hepatica is a trematode parasite that infects most mammals by evading host defences and establishing parasitism. To do so, it has evolved a family of serine protease inhibitors (serpins) that regulate proteases involved in crucial biological processes, including digestion, coagulation, inflammation and immune responses, particularly complement. The *F. hepatica* serpins (FhSrps) are encoded by a gene family of seven members that share high sequence identity and each member exhibits tight regulation of temporal expression throughout the parasite's life cycle. Most members are highly expressed by the invasive newly excysted juvenile (NEJ) stage that initiates infection of the mammalian host.

Approach

In this study, we characterized individual members of the FhSrp family, given the key roles they might play during host invasion. Alignment of the seven FhSrps reactive central loop (RCL) revealed unique predicted P1-P1' sequences for each serpin, suggesting they form a diverse arsenal of inhibitors capable of regulating different host serine proteases. Three distinct members (FhSrp1, FhSrp2, and FhSrp6) predominantly expressed by the NEJ stage and falling into different phylogenetic clusters were selected for further investigation of their molecular properties and functions.

Results/Discussion

The recombinant FhSrps expressed in *Escherichia coli* exhibited varied inhibitory activity; rFhSrp1 showed preference for trypsin-like proteases such as kallikrein and thrombin, while rFhSpr2 and rFhSrp6 inhibited chymotrypsin-like proteases including chymotrypsin and neutrophil elastase. Additionally, rFhSrp1 and rFhSrp2 inhibited Mannose Binding Serine Proteases (MASPs) critical to complement activation via the lectin pathway. Immunolabelling studies showed high expression of serpins on the NEJ's surface, reiterating their role in protecting the parasite against damage caused by various host’s proteases. Elucidating the functions of FhSrp family will enhance knowledge on host-parasite interactions, potentially offering new ways to prevent and control fascioliasis. Their unique and diverse activity may also lead to the development of biologics that regulate host physiological systems.

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SOCIAL ISOLATION-INDUCED TRANSCRIPTOMIC CHANGES IN MOUSE HIPPOCAMPUS IMPACT THE SYNAPSE AND SHOW CONVERGENCE WITH HUMAN GENETIC RISK FOR NEURODEVELOPMENTAL PHENOTYPES

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INTRODUCTION

Early life stress (ELS) can impact on how the brain develops and is a risk factor for neurodevelopmental disorders such as schizophrenia. Post-weaning social isolation (SI) is used to model ELS in animals, using isolation stress to disrupt a normal developmental trajectory. We aimed to investigate how SI affects the expression of genes in mouse hippocampus and to investigate how these changes related to the genetic basis of neurodevelopmental phenotypes.

MATERIALS AND METHODS

C57 BL/6J mice were exposed to post-weaning SI (PD21-25) or treated as group-housed controls (n = 7-8 per group). RNA sequencing was performed on tissue samples from the hippocampus of adult male and female mice. After quality control (QC), high-quality reads were mapped back to a transcriptome. Differentially expressed genes (DEGs) were defined at a false discovery rate (FDR) of < 0.05 between SI and control.

RESULTS AND DISCUSSION

Four hundred and 1,215 differentially-expressed genes (DEGs) at a false discovery rate (FDR) of < 0.05 were detected between SI and control samples for males and females respectively. DEGS for both males and females were significantly overrepresented in gene ontologies related to synaptic structure and function, especially the post-synapse. DEGs were enriched for common variant (SNP) heritability in humans that contributes to risk of neuropsychiatric disorders (schizophrenia, bipolar disorder) and to cognitive function. DEGs were also enriched for genes harbouring rare de novo variants that contribute to autism spectrum disorder and other developmental disorders. Finally, cell type analysis revealed populations of hippocampal astrocytes that were enriched for DEGs, indicating effects in these cell types as well as neurons. Overall, these data suggest a convergence between genes dysregulated by the SI stressor in the mouse and genes associated with neurodevelopmental disorders and cognitive phenotypes in humans.

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A Fully Coupled Computational Framework for Bone Fracture Repair in the Presence Of Bioabsorbable Magnesium Fixation Devices

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INTRODUCTION

Magnesium (Mg) alloys have significant potential in orthopaedic applications as they avoid long-term complications associated within permanent metallic implants. However, understanding the biomechanics of implanted Mg-based devices presents distinct challenges as they exhibit a non-uniform pitting corrosion process, which occurs simultaneously alongside the complex tissue repair process of the implanted region.

MATERIALS AND METHODS

This study presents the coupling of a fracture repair and surface-based Mg corrosion algorithm to predict the long-term viability of titanium and biodegradable Mg fixation plates for tibial fracture repair. Bone fracture repair consisted of (i) bone fracture healing and (ii) bone remodeling. Bone fracture healing was implemented according to biphasic mechanoregulatory theory, whereby cells differentiated into different cell phenotypes based on the local biophysical stimulus. Bone remodeling was determined by local strain energy density (SED) and microdamage. Mg corrosion considered the role of β-phase components throughout the material volume to simulate non-uniform corrosion within the bone plates. The outlined algorithms were fully coupled allowing for bone ingrowth into regions once occupied by Mg components.

RESULTS AND DISCUSSION

Non-plated models underwent indirect fracture healing resulting in an indirect healing response, while the introduction of fixation plate stabilised the fracture region allowing for a direct healing response (see Figure 1A). Direct healing resulted in accelerated fracture healing outcomes. Overly stiff titanium plating disrupted normal physiological loading, stress shielding cortical regions proximal to the plate. Mg implant strength decreased as Mg corrosion occurred allowing for restoration of normal loading, allowing for the tibia to remodel to pre-fractured morphology (see Figure 1B), highlight the long-term benefits of bioresorbable orthopedic fracture fixation.

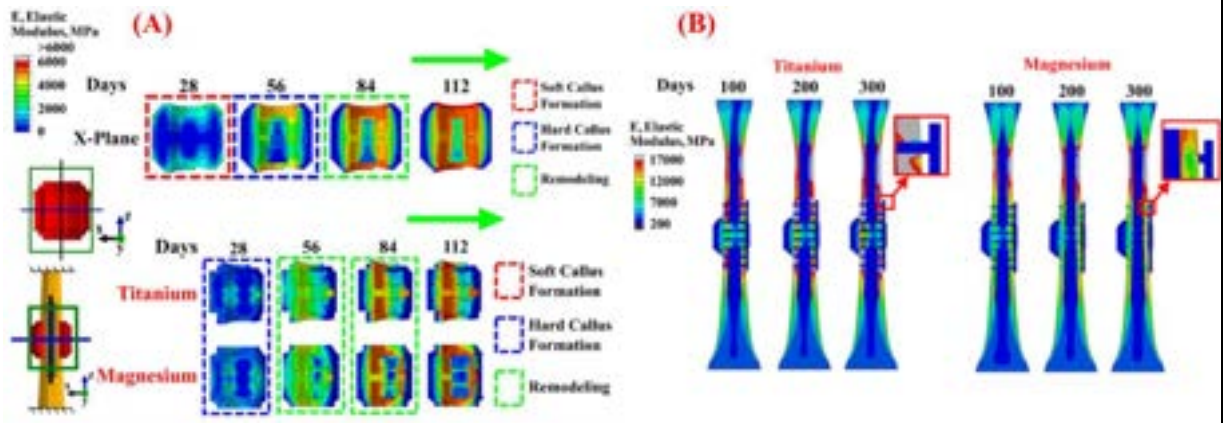

Figure 1: (A) Stages of fracture healing within non-plated and plated tibial fractures. (B) SED and micro-damage-based remodeling within titanium and Mg bone plates.

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Impact of Probe Typology and Electrode Size on the Accuracy and Repeatability of Conductivity for Left Atrial Appendage Electrical Characterization Bellow 100kHz.

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INTRODUCTION

Atrial fibrillation (AF) is a common cardiac arrhythmia that can be treated using non-thermal pulse field ablation. Accurate measurement of the electrical conductivity of the left atrial appendage (LAA) is essential for ensuring the safety and efficacy of this treatment. However, there is no standardized approach for measuring the electrical conductivity of the LAA, which can lead to variations in the typologies and electrode sizes used in previous studies.

MATERIALS AND METHODS

This study aimed to investigate the effect of probe typology and electrode size on the accuracy and repeatability of conductivity measurements for the electrical characterization of the LAA. Two probe typologies were investigated in this study, the polar probe, and the collinear probe, and six variations of those typologies were investigated. The study also investigated the influence of electrode size on the measurement using the collinear probe with different electrode sizes.

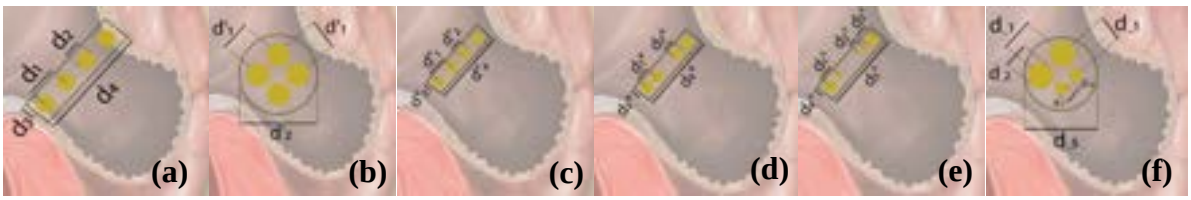

Figure 1. Diagram showing the dimensions of the tow proposed typologies of tetrapolar probe used in this paper (a) collinear probe (b) polar probe (c) small colinear probe (d) Small asymmetric colinear probe (e) small asymmetric and unequal colinear probe (f) unequal polar prob.

RESULTS AND DISCUSSION

The results showed that the repeatability of the measurements using each probe was consistent, with low variance. However, the conductivity varied between probes with differences ranging from 12% to 32%. Based on the results of the accuracy and repeatability analyses, the collinear probe with small electrodes was identified as the best-performing probe and will be tested with ex vivo samples in future work.

In summary, the study emphasizes the importance of adapting the probe for the measurement of electrical conductivity of biological tissues in the treatment of AF using non-thermal pulse field ablation. The results suggest that the probe typology and electrode size can significantly influence the accuracy of conductivity measurements. Not adapting the probe design to the tissue under study can impair the data acquisition, with a difference in accuracy of 26% between the proposed probes.

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A Clot Composition Dependant Hyperelastic Model in The Simulation of Direct Aspiration Thrombectomy

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3. Biomechanical Engineering Department, TU Delft, the Netherlands

INTRODUCTION

Despite recent advancements in ischemic stroke treatment, complete recanalization of the occluded cerebral vessel is achieved in only 85% of cases [1]. In Direct Aspiration (DA) thrombectomy, a catheter applies a suction pressure to an occluding blood clot to remove it from the vessel [1,2]. The influence of catheter design and blood clot composition on DA outcomes has not yet been systematically investigated [2-4]. This study outlines the first analysis of the effect of these factors using a finite element framework.

MATERIALS AND METHODS

Considered is a cylindrical clot in direct contact with a catheter of various diameters (Figure 1A). A negative suction pressure results in aspiration of the clot into the catheter (u). The clot material is modelled using a customized composition-dependent anisotropic non-linear hyperelastic constitutive law implemented as a user defined material subroutine (UMAT) in Abaqus [3,5].

RESULTS AND DISCUSSION

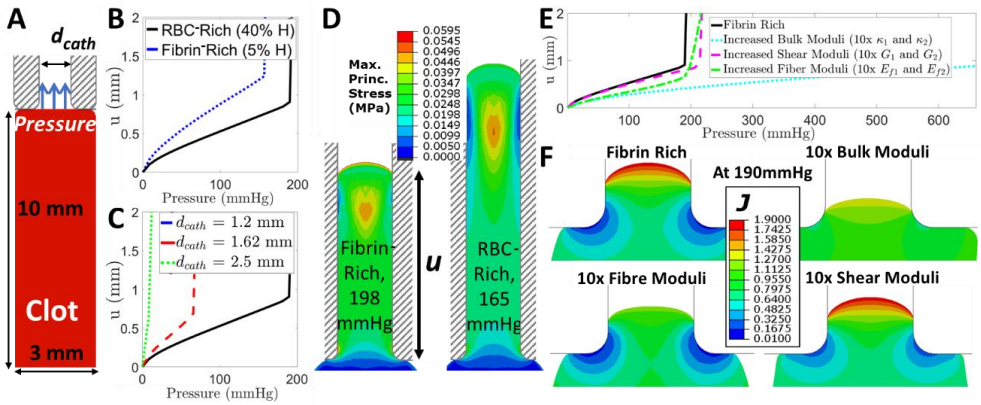

Figure 1: A) FE model of the clot and catheter. B), C) Aspiration length (u) versus applied pressure (d_{cath}=1.2 mm). D) Distribution of maximum principal stresses (d_{cath}=1.2 mm). E) Parametric investigation on the effect of material moduli. F) Volume change of clots during DA (J is the Jacobian).

RBC-rich clots aspirate further than fibrin-rich clots at any given pressure (Figure 1B). An increase in catheter diameter reduces the critical pressure for full ingestion (Figure 3C). The RBC-rich clots' maximum principal stresses exceed the measured fracture strength (0.01 MPa), whereas the fibrin-rich clots' do not (0.045 MPa) (Figure 1D) [2]. Clot compressibility is a key determinant of the success of DA (Figures 1E and 1F).

These results support clinical reports that fibrin-rich clots are more resistant to full ingestion during DA and that RBC-rich clots have a higher fragmentation risk [3,6]. They further indicate that the use of large-bore catheters increases the probability of full ingestion and reduces the fracture risk.

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A Design Outlook of Augmented Reality Exergames for People with Osteoporosis: Improving Stability and Engagement to Reduce Falls

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INTRODUCTION

Osteoporosis is one of the greatest societal and economic health challenges today, affecting more than 200 million people. Studies show that physical exercise is a powerful fracture prevention strategy for people with osteoporosis and/or those at risk of falls. However, the participation in and adherence to an exercise regimen by the elderly is often low due to a lack of time and motivation, boredom, a fear of falling, and/or environmental considerations (i.e., inconvenience, accessibility, safety and/or cost).

Despite its obvious potential, there is a notable scarcity of research on Augmented Reality (AR)/Virtual Reality (VR) task-oriented physical therapy training and exergames (i.e., games that are delivered through AR/VR and require the participants to be physically active) for people with osteoporosis.

MATERIALS AND METHODS

In collaboration with physiotherapists, occupational therapists and rheumatologists, a set of physical therapy exercises were approved. These physical therapy exercises were then mapped into a related set of exergames deployed using AR.

The exergames use an AR headset (Microsoft Hololens 2) and a body tracking camera (Azure Kinect). The AR headset is connected to the camera to allow real-time feedback on the posture during the training.

Note:The AR game design is underpinned by an extensive literature review.

RESULTS AND DISCUSSION

The outline of the intervention protocol and the conceptual design of the exergames in addition to a justification of their choice, repetition and timing are presented. The exergames are linked to primary and/or secondary outcomes. The main outcomes of this study include; improvement in both physical (i.e., balance, muscle strength and flexibility) and mental (i.e., confidence, engagement with the training, fear) capabilities.

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Genome-wide CRISPR/Cas9 Loss-of-Function Screens Reveal Genes that Determine Cell Responses to CDC7 Kinase Inhibitors

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INTRODUCTION

CDC7 kinase is a key switch for the initiation of DNA replication. Several CDC7 inhibitors (CDC7is) have been developed as anti-cancer drugs. Importantly their anti-proliferative activity greatly varies across cell-types indicating that genetic background influences how cells respond to the drugs.

METHODOLOGY

We aim to identify the genes modulating the response to CDC7is and we have established CRISPR/Cas9 genome-wide loss-of-function screen capability. Our workflow utilizes a breast-derived cell line expressing Cas9 (MCF10A^{EditR}) and a pooled lentiviral-vector library consisting of 155,000 sgRNAs targeting ~19,000 protein encoding genes.

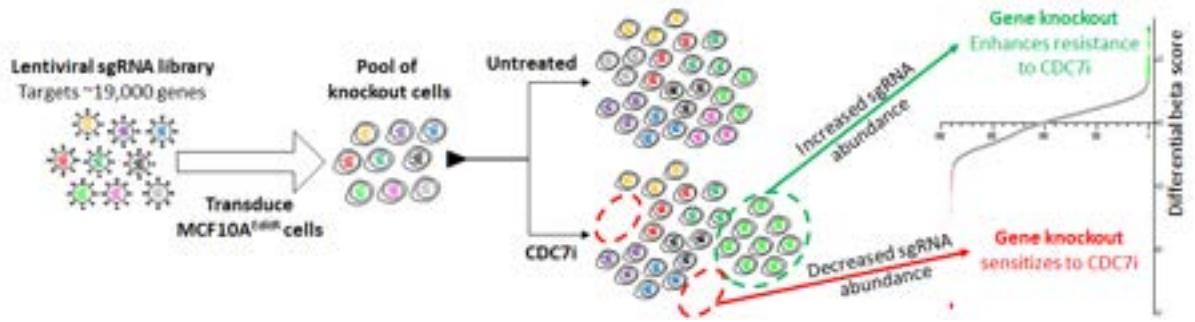

Figure 1: Lentiviral CRISPR/Cas9 genome-wide screening workflow

RESULTS AND DISCUSSION

In a pilot screen, MCF10A^{EditR} cells were infected with the library and then treated with a high dose of CDC7i that strongly inhibits cell proliferation. sgRNA representation before and after treatment was determined by next-generation sequencing, revealing few genes that upon editing, allow cells to grow better in presence of the CDC7i. Among these hits was ETAA1 an activating subunit of the replication stress-response kinase ATR. We show that ETAA1 with ATR is important to restrain replication origin activation and to prevent mitotic catastrophe when CDC7 function is impeded[1].

A much large screen now identifies ~270 genes that upon editing either enhance resistance or sensitize cells to CDC7is. CDK8, a kinase previously solely involved in transcriptional regulation, is the top sensitizer. We find that the synergistic effect of CDC7 and CDK8 inhibition on cell proliferation is related to the decrease in the rate of DNA synthesis, involving CDK8 also in the control of DNA replication. Ongoing studies are uncovering the molecular mechanism by which CDK8 together with CDC7 regulates DNA replication.

Our results increase understanding of how human DNA replication is regulated and point to targets and possible drug combinations that may enhance the activity of CDC7i.

[1]Rainey,M.D. *et.al:*ATR Restrains DNA Synthesis and Mitotic Catastrophe in Response to CDC7 Inhibition.*Cell.Rep.***32.**(2020).DOI:10.1016/j.celrep.2020.108096.

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SUSTAINABLE FUTURES

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Interplay between microbial sulfur reduction, methanogenesis, and transition metals supplementation

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Keywords: *Anaerobic digestion; Transition metals; Wastewater treatment; Sulfur reducing bacteria; Methanogenesis*

Introduction

Anaerobic digestion is an established technology for the upcycling of organic waste in wastewater to biogas, a renewable energy source. Sulfur contamination of wastewater, however, is often reported for its negative impact on biogas quality and yield.

Methods

Between January 25th and March 22nd, 2021 (excluding February 22nd), sludge samples were collected by-weekly from two PAQUES IC® full-scale reactors (**R1** and **R2**) treating industrial wastewater. **R1** and **R2** treated the same wastewater stream, but **R2** was additionally supplemented with transition metals (Biopaq Micromix Forte® by PAQUES and PIX Ferric sulfate by Kemira). Sludge samples were analyzed for solid content, metal content, specific methanogenic activity (SMA), and sulfate-mediated inhibition.

Results

The data obtained from the SMA assay show that methylotrophic methanogenic activity increases after 6 weeks of transition metal supplementation. Additionally, the data obtained from the sulfur-mediated inhibition assay suggests that transition metal exposure increases resilience to sulfur toxicity, allowing for both higher methanogenic rate and yield. It should be noted that no transition metals were supplemented during the inhibition assay. This suggests that the observed resilience is mediated either by ecological changes in the microbial community, the accumulation of transition metals in the biofilm, or a combination of the two.

Conclusions

This study suggests that transition metal supplementation could be used to increase the resilience of mixed microbial communities to sulfur-mediated toxicity. This could increase the organic waste-to-energy conversion in wastewater treatment facilities.

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Estimating Soil Moisture at High Resolution using Sentinel 2 Data

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Soil drainage capacity is the degree and frequency at which the soil is free of saturation. Accurate information on drainage conditions, which in turn is governed by soil moisture, is crucial for crop production and management and fundamental in developing strategies to achieve environmental sustainability goals. This is particularly important in Ireland where a high proportional of soils are poorly drained, that negatively impacts plant growth and productivity.

We develop a model to derive normalised surface soil moisture estimates on two sites dominated by soils with low hydraulic conductivity. The model incorporates a physical relation between soil moisture and Short Wave Infrared (SWIR) reflectance and is traditionally formed by the distribution of the shortwave infrared transformed reflectance (STR) and Normalized Difference Vegetation Index (NDVI) to define wet and dry edge curves. Normalised surface soil moisture (nSSM) is then estimated by measuring the vertical distance between the curves. Along with NDVI, we test other vegetation indices such as the Enhanced Vegetation Index (EVI) and Modified Soil Adjusted Vegetation Index (MSAVI) and estimate nSSM for each of the indices. Sentinel 2 images for the time period 2015-2022 is used in the model for the two sites respectively. The results obtained from remote sensing data has been validated using in situ soil moisture sensors.

We show that at a spatial resolution of 10m, our model is able to distinguish between different degree of wetness in soils for wet (high rainfall) and dry (low rainfall) conditions. This study could pave way for producing high resolution national level soil moisture maps.

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BIOPLASTICS: AN EVALUATION OF SUSTAINABILITY THROUGH FIELD EXPERIMENTS AND LIFE CYCLE ASSESSMENT

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INTRODUCTION

Billions of tonnes of conventional plastics have been generated globally with over two-thirds being disposed of in landfills or ending up in the natural environment. The accumulation and production of conventional, fossil fuel-based plastics has been linked to adverse effects on human and environment health and is largely considered unsustainable.

Bioplastics are a potentially viable and sustainable alternative. Being produced from renewable resources, bioplastics could contribute to the transition to a circular (bio)economy. However, bioplastics can have the same properties and traits of conventional plastics, and research has shown that some bioplastics can result in higher negative environmental impacts, particularly during the production phase.

The manufacturing of bioplastics has grown exponentially in recent years, but research into the long-term sustainability of bioplastics from 'cradle-to-grave' and 'cradle-to-cradle' are research areas that has yet to be extensively explored.

This research aims to investigate the long-term sustainability of bioplastics and their impacts on environmental health. Objectives include: 1) evaluate sustainability of bioplastic production 2) contribute to knowledge on bioplastics and 3) contribute to and stimulate the discussion around bioplastic framework/policies.

MATERIALS AND METHODS

Through a systematic literature review, field and laboratory experiments, including soil burial and rainfall event simulation, as well as a life cycle assessment of biodegradable bioplastics, this study will evaluate bioplastics for sustainability credentials and safety for the environment when compared to conventional plastics.

RESULTS AND DISCUSSION

Preliminary research has shown conflicting conclusions on the environmental impact and sustainability of bioplastics, and in general, many studies neglect to account for the end-of-life (grave) stage of bioplastics.

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Combined statistical, hydrodynamic and machine learning modelling of water levels in coastal basins

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This research presents a robust cost-effective framework for assessment of risks and impacts of extreme water levels due to compound action of multivariate dependent drivers. In this methodology the statistical model, used to determine probabilities of multiple-driver extreme water level events, is linked with the hydrodynamic model to assess the total water levels. Subsequently, the hydrodynamic model outputs are used to train and test a range of machine learning algorithms. The best performing algorithm was ultimately used to predict spatially variable water level patterns resulting form a combination of hydro-meteorological drivers occurring simultaneously.

The statistical method involves individual and combined extreme value analysis, assessment of dependencies and interactions between high water level drivers, and multivariate joint probability determination accounting for dependencies. The high-resolution hydrodynamic modelling system was used to simulate a range of hydro-meteorological scenarios derived from a multivariate statistical analysis, and to map coastl water levels. The multivariate joint exceedance probability scenario represents a more realistic representation of the spatially variable water surface profiles then the univariate and combined marginal scenarios. For an ensemble of statistically derived water level scenarios, the hydrodynamic model was used to simulate extreme water levels and a flood wave propagation over urban floodplains. The hydrodynamic model runs explain the mechanisms of extreme water level generation and allow a quantification of contribution of each driver to the total water level. In total, 23 machine learning algorithms were trained and tested using the ensemble hydrodynamic outputs to confirm that the machine learning algorithm can be used successfully to predict the water depths for a given set of compound flood drivers. As such, the machine learning based flood model can replace the traditional cost-inefficient hydrodynamic models for operational water level forecasting and extreme event warning.

The investigation based on the proposed statistical-hydrodynamic-machine learning method allows one to draw inferences about extreme water level generation and mechanisms under various compound scenarios.

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Commercialisation of a Recyclable and Innovative Manufacturing Solution for an Optimised Novel marine turbine (CRIMSON)

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INTRODUCTION

River and tidal current energy can play a substantial role in the de-carbonisation of Europe's electricity production. In recent years several companies have been developing technology to harness the power of the world's waterways, including the Ocean Renewable Power Company (ORPC). The technology to harness water current energy is still at a relatively early stage of development, hence de-risking of components plays a vital role on the road to commercialisation. In this study, a demonstrator foil from the ORPC device (shown in Figure 1) will be tested in a novel dynamic loading setup where the load will be generated by the rotation of an offset mass by an electric motor fixed to the blade. Such a test setup allows for efficient testing up to very high cycle numbers not normally achieved in classic hydraulically actuated testing. Data generated from the testing will contribute to the modelling and validation of future tidal blades.

Figure 1: ORPC device during installation in Alaska

MATERIALS AND METHODS

The aim of this project is to build industry confidence through extensive mechanical testing of a tidal energy blade manufactured using novel materials. This will be done through a full programme of static and high-cycle fatigue testing of a demonstrator blade at the Large Structures Test Laboratory at the Alice Perry Engineering Building.

RESULTS AND DISCUSSION

The immediate impact of this disruptive technology will be to demonstrate the technical and commercial potential of harnessing marine hydrokinetic energy; the longer term impact will be to reduce the Levelised Cost of Electricity for the European citizen – the ultimate beneficiary of this innovation. CRIMSON will also deliver significant positive impacts in terms of industry/EU competitiveness and scalable company growth in revenue & jobs.

College of Science and Engineering, Inaugural Research and Innovation Day 2023

Seismic performance assessment of a novel self-centring concentrically braced frame system

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INTRODUCTION

A novel self-centring steel concentrically braced frame (SC-CBF) structural system has been developed for seismically active regions. The novel system allows for energy dissipative structural elements (e.g. braces) to be easily replaced after a large earthquake. This is facilitated by using a post tensioning (PT) arrangement that will allow the structure to return to its original position, eliminating residual deformations that are typically observed for traditional CBFs after large earthquakes. This self-centring system makes strategic use of post-tensioned interfaces between the main structural elements (such as, beam-column) where the PT elements are placed along the beams to create rocking joints behaviour under seismic loads. This system not only improves the resilience and robustness of CBF structures, it also improves their sustainability. .

MATERIALS AND METHODS

A series of laboratory experiments at the material and frame level have been conducted to investigate the behaviour of the novel self-centring system. Experiments on the coupons include monotonic tensile tests and low cyclic fatigue tests. Frame tests include the shake table and cyclic pushover tests.

OpenSees is used to develop and verify a numerical model using the results from tested frames. Material and geometry nonlinearity are incorporated in the model. This finite element model allows for improving the understanding of seismic behaviour in self-centring braced frame systems, and assessing seismic requirements for performance-based design. Fig. 1 shows typical frame used in the tests.

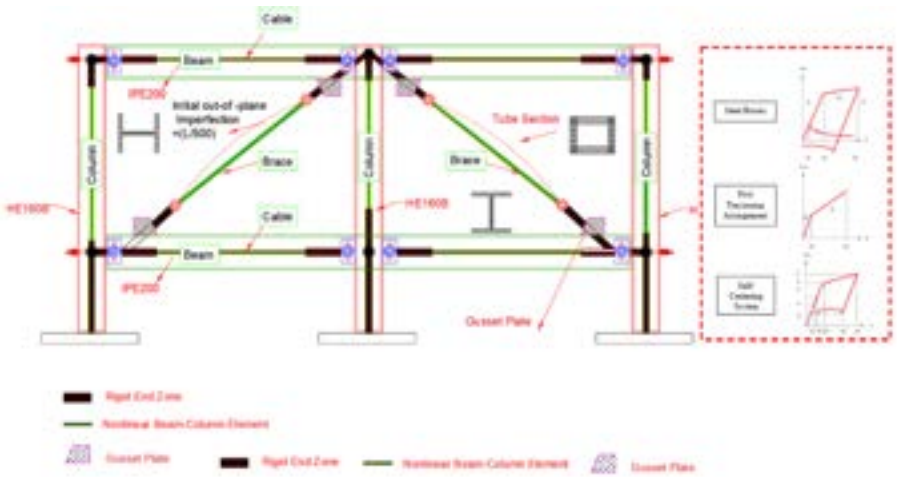

Figure 1: Schematic of proposed Self-Centring Concentrically Braced Frame (SC-CBF).

EXPECTED IMPACT

The main goal of this research project is to validate and further develop the novel SC-CBF system proposed by University of Galway to be used in CBF buildings subjected to natural hazards such as earthquakes. It is expected that this novel system will be adopted by industry to improve the performance of CBF steel structures in seismically active regions.

College of Science and Engineering, Inaugural Research and Innovation Day 2023

Evaluating existing One-Stop-Shop retrofit services in Ireland and the householder retrofit journey

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4. Construct Innovate, University of Galway, Ireland.

INTRODUCTION

Ireland's Climate Action Plan set ambitious targets for substantial retrofitting of existing dwellings. This includes retrofitting 500,000 existing dwellings to a B2-Building Energy Rating or better by 2030, at an average rate of 50,000 dwellings per annum. In 2022, 27,199 homes underwent dwelling retrofits using grant aid. However, only 8,481 homes were retrofitted to a B2 BER or better. Projections state that 75,000 homes will need to be retrofitted annually from 2026-2030. To achieve the targets set, significant barriers for homeowners to retrofit their homes must be alleviated. The Climate Action Plan has outlined strategic actions for the achievement of the retrofit targets, including the establishment of One-Stop-Shop (OSS) retrofit delivery models (Figure 1). OSSs aim to remove retrofit barriers by offering full service retrofitting, providing the initial dwelling evaluation, retrofit proposal, coordinated implementation and quality assurance, and a single point of contact to guide homeowners. This research evaluates existing OSS and retrofit services in Ireland, from the perspectives of retrofit professionals and experts, and householders who have completed / partially completed their retrofit journey.

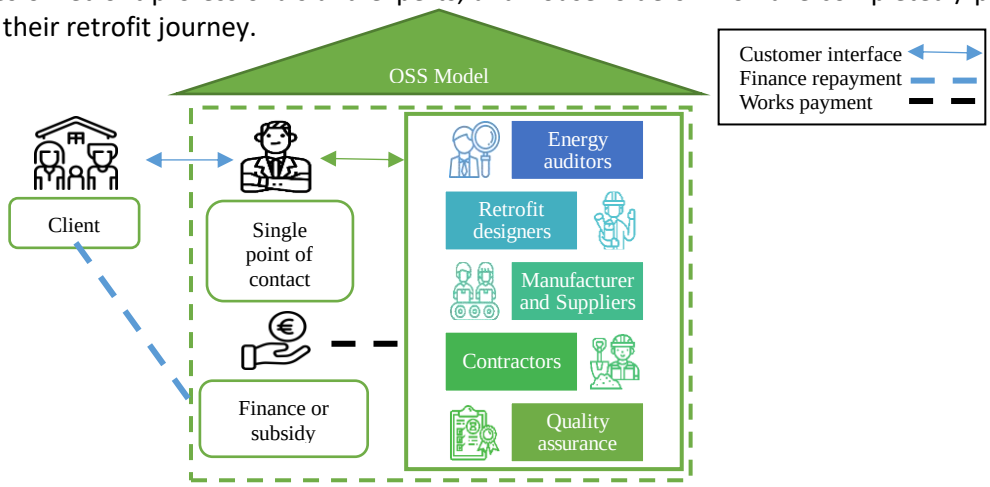

Figure 1: One-stop-shop retrofit delivery models

MATERIALS AND METHODS

Semi-structured interviews with retrofit professionals and experts, and in-depth householder interviews and case studies were implemented. The householder retrofit journey was examined in detail, including the drivers and barriers faced. The performance of implemented retrofits was also evaluated by analysing a set of economic, social, and environmental Key Performance Indicators, using a combination of interview data and data collected during pre- and post-retrofit dwelling monitoring.

EXPECTED IMPACTS

This research will contribute to understanding how OSS and retrofit services can be improved, while serving to support the design of future retrofit policy measures that aim to drive and enable extensive deep retrofitting towards the achievement of the Climate Action Plan targets.

College of Science and Engineering, Inaugural Research and Innovation Day 2023

A novel strength-based method for fatigue life prediction of composite wind turbine blades

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INTRODUCTION

The energy transition towards clean energy sources has led to an increased demand for wind turbines, which are considered one of the most economical and practical forms of renewable energy. Wind turbine blades are a critical component of these systems, accounting for approximately 22% of the total cost of all components. To improve their performance, composite materials, such as fibre-reinforced polymers, are often used due to their superior mechanical properties, such as higher fatigue resistance and lighter weight. However, wind turbine blades are subject to severe excitation and vibration conditions during their lifetime, which can negatively affect their dynamic behavior and fatigue life. The estimation of fatigue life is, therefore, a fundamental step in the wind turbine industry.

MATERIALS AND METHODS

The aim of this study is to develop a new strength-based method to predict the fatigue life of a 13-meter wind turbine blade under realistic spectrum loading, while requiring minimal experimental effort. The method involves three steps: sorting loads using the Rainflow Counting technique, modelling S-N curves and CLDs for the UD material in the fibre direction and transverse to the fibre direction using the Sendeckyj model with the novel estimation method and the piecewise linear CLD, respectively, and employing the new strength-based method to consider the sequence effect and strength conversion effect. The new strength-based method is based on two models: Schaff and Davidson model is used to calculate the residual strength, and the Afrooz method is used to estimate the Schaff and Davidson model parameter. Finally, the Miner's rule is used as a benchmark to compare the accuracy of the new method.

RESULTS AND DISCUSSION

The study's results indicate that both the Miner rule and the new strength-based method predict that the wind turbine blade is likely to fail after 11 years of operation, which is less than the 20-year standard for wind turbine blades. The areas of greatest danger on the blade are the trailing and leading edges at the blade root, where gravity has a dominant sinusoidal impact on the edgewise bending moment. This highlights the importance of considering the effect of gravity in fatigue analysis, even for small wind turbine blades.

The new strength-based method effectively considers the sequence effect and strength conversion effect due to randomly ordered loading spectra, resulting in more accurate predictions of the remaining life of the blade. Importantly, this improvement is achieved with a similar experimental and computational effort as that is required for Miner's rule. Therefore, the new strength-based method is a practical and effective tool for predicting the remaining life of composite structures, such as wind turbine blades, and has the potential to inform future improvements in wind turbine design and maintenance.

College of Science and Engineering, Inaugural Research and Innovation Day 2023

Treatment of cattle paunch contents, an agri-waste, with novel marine and terrestrial fungal secretomes.

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INTRODUCTION

Cattle paunch contents (PCs), or bellygrass, is the lignocellulosic material found in the cow rumen. Its composition varies, but in Ireland it is usually composed of perennial/Italian ryegrass and/or white clover. After slaughtering, the cow rumens are emptied. This material is then usually spread on land as a fertilizer. PCs retain a lot of energy trapped in the lignocellulosic matrix that could be utilised during anaerobic digestion for biogas production. However, this requires pre-treatment to break down the matrix to make the PCs more accessible for the digester microorganisms. Secretomes (crude protein cocktails (CPCs)) from novel deep-sea & terrestrial fungi have the potential to degrade recalcitrant lignocellulosic wastes such as PCs prior to anaerobic digestion for bioenergy recovery. This in turn can be utilized as heat or electricity by the slaughterhouse producing it.

MATERIALS AND METHODS

Fungal CPC production

Fungal CPCs were produced by novel marine and terrestrial strains of *Penicillium rubens*, *Talaromyces stollii* and *Emericellopsis maritima*. The fungi were grown in a liquid wheat bran medium to induce lignocellulolytic protein production. The supernatants were harvested from the flasks and centrifuged. The liquid fraction of these samples were used as the hydrolytic CPCs.

Treatment of PCs

PCs were incubated with CPCs and the total carbohydrates released from the PCs were measured to determine the hydrolysing abilities of the CPCs.

RESULTS AND DISCUSSION

The effect of the CPCs on release of total carbohydrates from PCs is represented in Fig. 1. *T. stollii* hydrolysed 20% of the total carbohydrates available in the PCs. Further optimisation is underway to increase the hydrolysis.

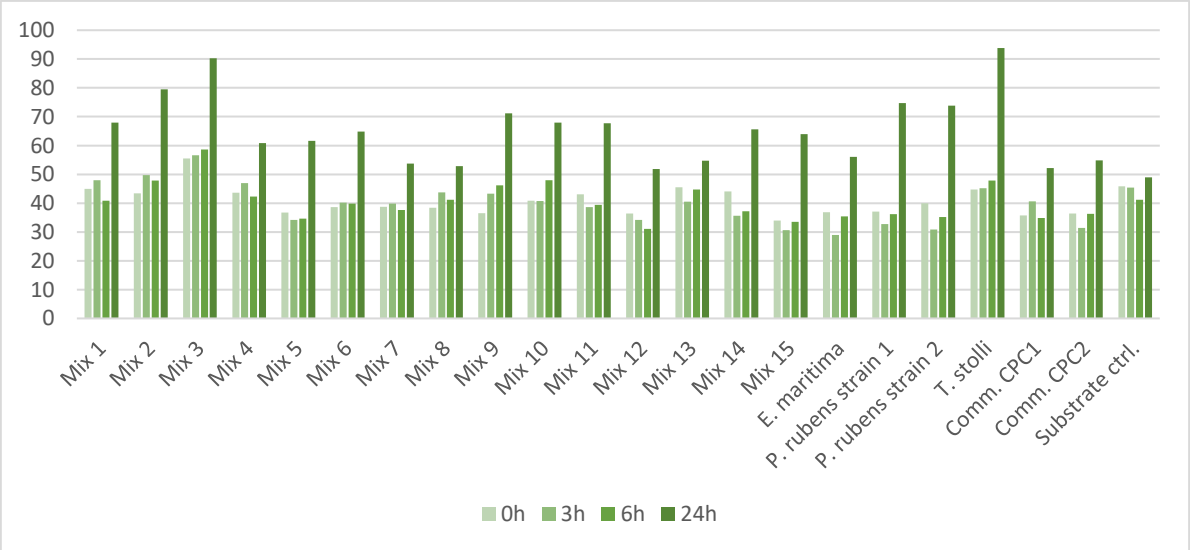

Figure 1: Total carbohydrates released from PCs after treatment with individual CPCs and mixtures of CPCs from 0-24 hours.

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A review on building-integrated photovoltaic/thermal systems for green buildings

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INTRODUCTION

Building integrated photovoltaic thermal systems (BIPV/T) are used in buildings to improve their energy and environmental performance. These systems utilise solar energy in the photovoltaic panels, and thus, enable buildings to meet their thermal and electrical energy demand. Net zero energy buildings are one of the most suitable applications for BIPV/T systems. Reducing energy consumption, improving indoor environmental conditions and reducing greenhouse gas emissions are among the most important goals of the BIPV/T systems, which contributes toward achieving a sustainable built environment.

MATERIALS AND METHODS

This research presents recent developments in BIPV/T systems and their possible contributions to net-zero energy buildings. A systematic review of scientific literature relating to BIPV/T systems was carried out (Figure 1). The review identified 341 articles (research, review and proceedings) highly relevant to this topic.

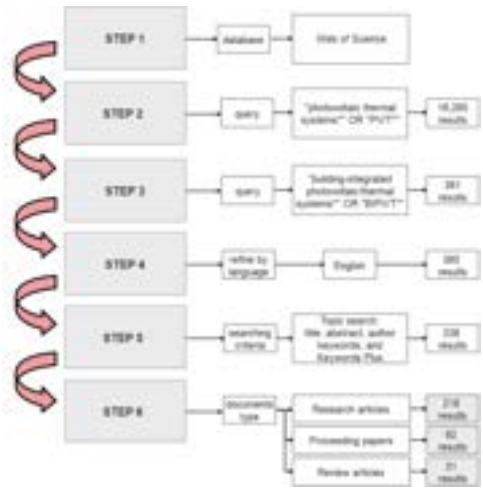

Figure 1. Systematic review of scientific literature.

IMPACT

BIPV/T systems have potential to contribute towards net zero energy buildings; however, these systems also face some challenges, including climatic conditions, economic and technical constraints. Material selection and system layout are crucial in designing those systems. Innovative materials such as concentrators, phase change materials (PCMs) and extended heat transfer surfaces can be utilised to improve performance. BIPV/T systems are a promising technology, flexible to improvement that can help achieving sustainable buildings and providing safe, healthy and comfortable indoor conditions.

College of Science and Engineering, Inaugural Research and Innovation Day 2023

Develop new protocols for introducing complex cyclic loading spectra during fatigue testing of full-scale tidal turbine rotor blades

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INTRODUCTION

Tidal energy has gained increased attention and investment due to its potential and advantages, in terms of reliability and predictability. Horizontal axis tidal turbines are similar to wind turbines in both geometry and principle of operation, yet they need to withstand much heavier loadings and extreme conditions in a harsh operating environment. Consequently, the loadings on tidal turbine blades need to be accurately evaluated within the design stage to ensure they can withstand loadings with little need for repair.

MATERIALS AND METHODS

With the advancement of computational capabilities, computational fluid dynamics offers a relatively inexpensive method of simulating working conditions and estimating loadings. In this research, a computational fluid dynamics model of a tidal turbine rotor has been developed using commercial code ANSYS CFX, where the blade geometry is developed from the prototype turbine used in the Round Robin Tests in the framework of the H2020 MaRINET2 Infrastructures Network project. In addition, the wave and towing tank at University of Galway will be utilized to conduct experimental investigation on the fluid-turbine interaction.

RESULTS AND DISCUSSION

The outputs from the numerical model are validated against the experimental results, where it is revealed that with an increasing rotating speed of the tidal turbine, the thrust force that turbine experienced increases, while the torque force experiences a rise firstly, reaching a maximum value and then decreases gradually. In addition, the experimental results show that during the operation of ocean tidal turbines, the turbine blades experience frequent and large-scale fluctuation of hydrodynamic loads, including thrust and torque, which may lead to tidal turbine blade damage due to fatigue. Therefore, the next stage of development with this numerical model is fatigue loading evaluation, to improve the present fatigue design and testing of tidal turbine blades, while gaining a greater understanding of the damage mechanisms.

College of Science and Engineering, Inaugural Research and Innovation Day 2023

MIDRONE: Advanced Manufacturing Technologies to enable Intelligent DRONE delivery

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INTRODUCTION

The MIDRONE project, funded by the disruptive technologies innovation fund (DTIF), is developing the next generation of consumer delivery drones. The demand for last mile delivery is rising rapidly. Currently, this demand is being met using traditional road transport, such as cars, vans and bicycles. These activities are labour intensive, hazardous and environmentally unsustainable. The MIDRONE project looks specifically at the application of advanced manufacturing technologies to drone production, in order to provide environmentally friendly and cost effective manufacturing solutions.

MATERIALS AND METHODS

The goal of the project is to manufacture a full-scale drone using advanced composite manufacturing techniques. Each of the project partners, Eirecomposites, the University of Galway and Manna Aero, have brought their own expertise to the project in order to fulfil the overall project goal . An overview of the methodology which shows how the background knowledge that has been used in the project and results in the final drone is shown in Figure 1.

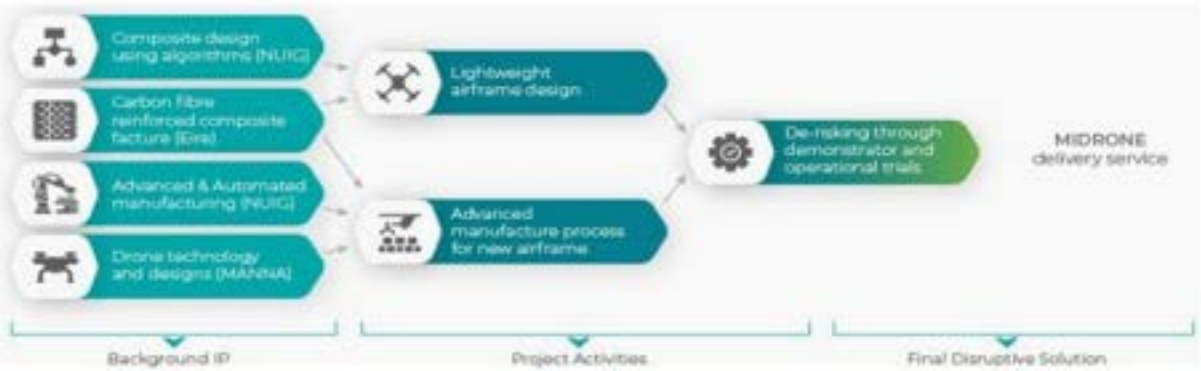

Figure 1: Overview of the methodology of the MIDRONE project.

RESULTS AND DISCUSSION

The project has resulted in the successful manufacture and test of two drone airframes. These airframes have been manufactured using advanced manufacturing techniques such as Automated Tape Placement and 3d printing of carbon fibre composites. Furthermore the use of recycled carbon fibre has also been developed as part of the project. Full-scale dynamic and static testing has also been performed on the airframes, to demonstrate their structural integrity, and an advanced fatigue testing programme is currently underway, to demonstrate the ability of the airframe to withstand operational loads over its design life. Novel recycling and 3d printing techniques have also been developed and tested as part of the project. The project has helped MANNA Aero to de-risk their drone design and continue to develop their drone delivery service.

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Sustainable Development of Ireland's Offshore Renewable Energy Sector: Wave, Tidal and Offshore Wind

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INTRODUCTION

As the world strives to remove its reliance on fossil fuels, tidal energy offers the potential for a reliable, predictable renewable source of energy. However, the development of tidal turbines remains at an early stage compared to wind turbines, due to commercial confidentiality and lack of available test results. In the meantime, as one of the main materials used for tidal turbine manufacturing, the carbon fibre (CF) demand was estimated to exceed supply by as much as 24,000-50,000 metric tonnes by 2022. But currently, less than 1,000 MT (5%) of CF waste is recycled. This project aims to bring to market a reliable, sustainable marine energy turbine through the application of recycled carbon fibre (rCF) material and novel technologies over the complete life cycle of the product.

MATERIALS AND METHODS

The project starts with selection of suitable rCF Material for manufacturing the marine energy turbine through coupon testing. Then, a new sustainable rCF marine energy turbine will be designed and manufactured. To validate the feasibility of the design, structural testing, numerical modelling and full-scale operational trials will be carried out. Through performing structural design, manufacturing, experimental testing, digital-twin development, and advanced health monitoring of a full-scale marine energy turbine, the feasibility and reliability of rCF made submarine system will be validated.

IMPACTs

The project will open the market for novel uses of rCF, achieve reductions on CAPEX and OPEX for turbine manufacture operations, and deliver scalable turbine design technologies for marine energy turbine manufacturers. The suitability of the material for use in other offshore renewable energy technology, such as wave energy convertors and offshore wind, will also be considered.

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Re-blading of Irish Wind Turbines using Novel Technologies

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INTRODUCTION

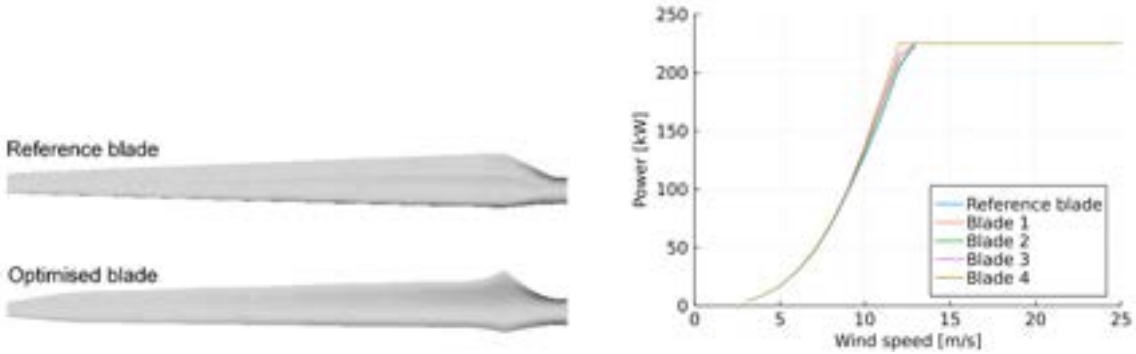
As the world moves towards a more sustainable way of life, Ireland must invest significantly in creating a carbon-free energy system. Currently, the largest source of renewable energy globally is from wind and Ireland has an installed capacity of wind energy of 4,137 MW, where 17% of wind turbines will reach their end-of-life by 2030. If solutions to extend turbine life are not found, 700MW of capacity will be decommissioned. To this end, this project aims to develop advanced technologies to retrofit aging turbines through re-blading with new highly efficient and resilient blades.

MATERIALS AND METHODS

There are two main steps involved in the blade design, namely the aerodynamic geometric design and the structural design. In the aerodynamic geometric design, the genetic algorithm-based optimisation is carried out to design the external geometry of the blade so it sees improved power production, compared to the original design. In the structural design, a screening method is employed to design the composite layup of the blade, with the aim to have increased stiffness and mass, compared to the original design.

RESULTS AND DISCUSSION

In this project, a highly efficient wind turbine blade was designed. Figure 1 compares the geometry and power production efficiency between the reference blade and the optimised blade. The optimised blade has 4.22% higher annual power production compared to the original design. The structural analysis revealed that a reduction of 12% in material usage is attained while an improvement of 15% in blade stiffness has been achieved. By analysing the performances of the new blade design, it can be concluded that the methodology developed in this research is efficient in designing new blades for upgrading existing wind turbines.



(a) (b)

Figure 1: Comparison between the reference blade and the optimised blade in terms of (a) geometry and (b) power curve

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Electro-thermal Modelling of Eco-efficient Magnet Wire in Motors/Generators

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INTRODUCTION

The Hi-Ecowire project is focused on the development of high-quality and eco-efficient magnet wire for use in a variety of motor/generator applications. The project aims to improve the overall efficiency of electric motors by developing magnet wire that has lower energy losses and higher thermal performance. The project is carried out by a consortium of partners from across Europe, who bring expertise in areas such as materials science, process engineering, and product development. The project involves the development of novel materials and manufacturing processes for magnet wire, as well as the testing and validation of the resulting wire products.

MATERIALS AND METHODS

The project also includes the development of advanced simulation and modelling tools for the design and optimization of electric motors. University of Galway is responsible for developing an electro-thermal model of the wire to enable analysis of its electrical and thermal performance in an electric motor/generator. This includes Finite Element Modelling (FEM) and validation of the thermal and electrical properties of the wires under standard test conditions, and in a demonstrator motor. Ultimately, the Hi-Ecowire project seeks to contribute to the ongoing transition towards a more sustainable and efficient energy system by improving the performance of electric motors, which are critical components in many applications.

Fig. 1 Photo of magnet wire produced by SHWire, Hi-Ecowire project partner[1]

[1] https://www.nweurope.eu/projects/project-search/hi-ecowire-high-quality-ecoefficient-magnet-wire/#tab-4

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ENACT (Enabling National Action of Commercial Take-up of Retrofit)

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INTRODUCTION

Ireland's National Climate Action Plan aims to reduce CO2 equivalent emissions from the built environment by 40%-45% relative to 2030 projections. Towards this goal, the Long-Term Renovation Strategy (LTRS) targets that one-third of commercial buildings should be renovated to a Building Energy Rating (BER) of at least B by 2030, and all commercial buildings should be renovated to this standard by 2050. There are approximately 109,000 commercial properties in Ireland, most of them owned or leased by SMEs. Many of these properties need to undergo energy retrofits to meet the targets set by LTRS.

Building on a broad range of research and expertise, the ENACT (Enabling National Action of Commercial Take-up of Retrofit) project aims develop a comprehensive package of concerted and targeted actions to tackle the barriers to energy renovation in commercial buildings.

MATERIALS AND METHODS

The aims of the ENACT project will be achieved through studies to gain insights into the attitudes, behaviours, and decision-making mental models around commercial retrofits which will help identify market, financial and technical contexts, and barriers. The NUIG component of the project includes:

1. Research state of the art in behavioural analysis – literature review on decision-making triggers, behaviours, and attitudes towards commercial retrofits.
2. Developing recommendations for Ireland using findings from literature review and outputs from nationwide discourse-based methods including focus groups, online surveys and workshops.
3. Design of a communication toolkit to encourage SMEs to renovate. Including a review of national and international messages around energy efficiency for SMEs to develop a communication toolkit.

EXPECTED IMPACT

Accelerating energy efficiency retrofits among SMEs through decision-support tools, communication toolkits, training and guidance documents, while providing policy insight to the government.

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

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Assessment and Extension of Energy Performance Contracting (EPC) to include metrics for Internal Environment Conditions (IEC)

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INTRODUCTION

Irish National Climate Action Plan (CAP) is ambitious and coherent regarding emission reduction in the built environment. All new buildings are being designed accordingly, and the National Residential Retrofit Plan further supports decarbonising existing building stock. Energy Performance Contracting (EPC) is an innovative financing mechanism that allows building owners and facility managers to upgrade the energy efficiency of their buildings without having to pay the full cost upfront and minimising the financial risk for the building owners, in common EPC models. My PhD project focuses on assessing and expanding Energy Performance Contracting (EPC) beyond energy-saving indicators alone to include metrics for Internal Environment Conditions (IEC). The proposed EPC framework will incorporate performance criteria for energy consumption, GHG emissions, indoor temperature, carbon dioxide levels, humidity, and other measurable parameters to ensure a healthy and comfortable indoor environment, specifically in the Irish context.

METHOD

A performance indicators-based EPC assessment framework is under preparation based on a review of EPCs-based studies in Europe and globally, as shown in Figure 1, which shall be used to assess the success of EPCs.

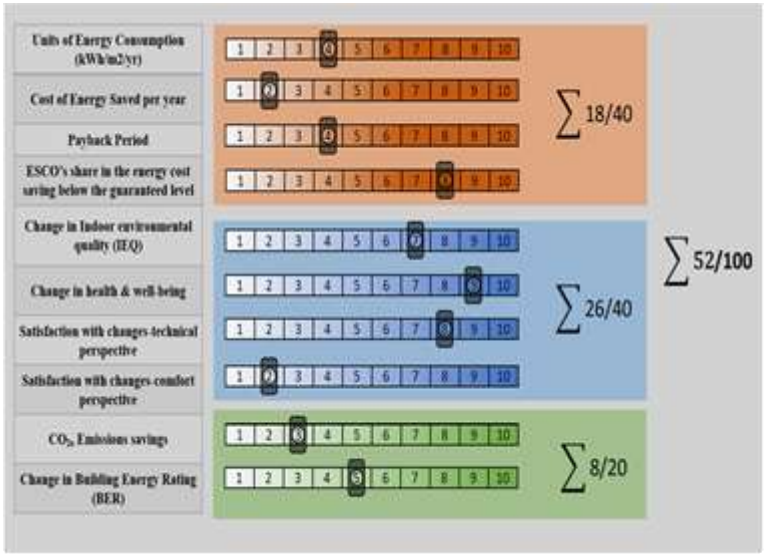

Figure 1: Performance indicators-based EPC Assessment Framework

The project also involves monitoring Galway houses to understand how occupants' various technical and socioeconomic factors influence energy demand practices. In addition to this, a survey from buildings occupants shall help develop a connection between energy usage, and occupant's comfort, health, and well-being.

RESEARCH IMPACT

The study results and framework development are expected to assess an EPC's success and extend the concept of EPC beyond a financial mechanism by including the matrices mentioned above. Building owners, Energy Service Companies (ESCOs), and local authorities will benefit from this framework, as it will provide a concise, single-page assessment of building performance and contractual terms.

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Thermodynamic Analysis of Extracellular Electron Transfer During Ethanol Oxidation in Anaerobic Digestion Systems

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INTRODUCTION

Anaerobic digestion is a microbial technology for breaking down biodegradable organic substrates and recovering renewable energy from waste. Ethanol is also a crucial intermediate during anaerobic digestion. It can be converted to acetate and hydrogen in the acetogenic process. However, this reaction is thermodynamically unfavourable under standard conditions. Extracellular electron transfer (EET), where an organism exchanges electrons with an electrode or another organism, plays an important role in anaerobic digesters. This study aimed to investigate the occurrence of EET in ethanol oxidation processes. The energy consumption/supply and biomass yield during ethanol oxidation were evaluated under conditions with or without incorporating EET.

MATERIALS AND METHODS

The catabolic reaction and anabolic reaction are linked by energy exchange, which could be coupled by incorporating a factor λ, representing the times of a catabolic reaction required to produce per unit biomass. The overall metabolic reaction could be described with $R_{MET}=\lambda\times R_{CAT}+R_{AN}$. The dissipated energy can be calculated with Equation 1:

$$\Delta_r G_{dis}=200+18\,(6\text{-NoC})^{1.8}+\exp[\{(3.8-\gamma)^2\}^{0.16}(3.6+0.4\,\text{NoC})] \quad (1)$$

Here, NoC stands for the number of carbon atoms, and γ is the degree of reduction of the carbon source. Finally, the biomass yield can be calculated with Equation 2:

$$Y=\frac{1}{\lambda\cdot Y_S^{CAT}+Y_S^{AN}} \quad (2)$$

Where Y_S^{CAT} and Y_S^{AN} are defined as the stoichiometric coefficients of electron donors in catabolic and anabolic reactions, respectively. The Gibbs energy of the EET pathway was -157.64 kJ/$mol_{Ethanol}$-4·F·E_{RAP}.

RESULTS AND DISCUSSION

Fig. 1 shows isolines of various biomass yields of ethanol-oxidizing bacteria (EOB, Y_E). The dashed line represents a negative Y_E of -0.0097 C-$mol_{Biomass}$/$mol_{Ethanol}$ without EET, indicating that the EOB growth is impossible. However, it was theoretically possible that Y_E could be positive when E_{RAP} was above -0.408 V. -0.427 V in Fig. 1 was the global potential. When E_{RAP} was higher than -0.427 V, an increase in the biomass yield Y_E at a constant EET fraction.

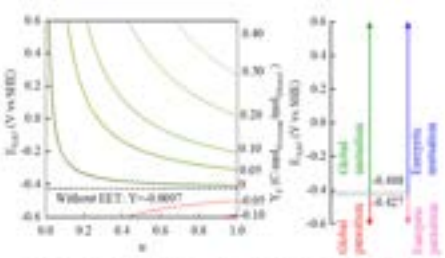

Figure 1. The yield of ethanol oxidizing bacteria coupling extracellular electron transfer during ethanol oxidation. Solid lines represent the isolines of various biomass yields.

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DeepWindDemo: Design, build and testing of a novel Deep-sea Wind energy Demonstrator

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INTRODUCTION

As the world moves towards a more sustainable way of life, Ireland must invest significantly in creating a carbon-free energy system. The Irish Government has set out a target of achieving 5GW capacity in offshore wind by 2030, with the ambition of taking advantage of a potential of at least 30GW of offshore floating wind power in our deeper waters of the Atlantic. The DeepWindDemo project proposes a disruptive and innovative solution for the Irish floating wind industry, by bringing to the floating wind sector a novel dual helical turbine on a single platform, which not only maximises the use of materials but also has performance benefits with the bypass velocity of one turbine used to increase the intake velocity of the other.

MATERIALS AND METHODS

The main aim of the DeepWindDemo project is to utilize optimised dual vertical axis wind turbines on a single semisubmersible floating platform. In achieving this aim, the feasibility of floating helical Vertical Axis Wind Turbines (VAWT) technology will be further established and de-risked.

The DeepWindDemo project will use the Powder Epoxy Technology (C-PET) to manufacture the six new helical blades (two three-bladed turbines), which will allow them to build lighter and stiffer blades. C-PET is an innovative, high-performing, cost-effective advanced composite manufacturing technology aimed at the marine industry and specifically environmentally friendly boats and tidal turbines, and by extension is very suitable for offshore wind blades.

Figure 1: Illustration of 2 kW DeepWindDemo device.

EXPECTED IMPACT

The expected impact relies on the development of expertise that will allow de-risking VAWT technology derived from the utilization of the inherent advantages of said VAWT architecture over that of a Horizontal Axis Wind Turbines, thus enhancing cost-effective performance of wind energy in Irish waters.

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LOGIC-TIDE: logistical and Industrial Co-design for Tidal Energy

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INTRODUCTION

As society moves towards a more sustainable way of living, tidal energy is beginning to emerge as a predictable and reliable source of renewable energy. At the end of 2022, the cumulative installation of tidal stream technology that has been deployed in Europe reached 30.2 MW.

Therefore, to support the development of tidal energy, the LOGIC-TIDE project will strive to advance the Optimor tidal energy concept of the Ocean Renewable Power Company (ORPC), as it moves towards commercial viability.

MATERIALS AND METHODS

The overall objective of the LOGIC-TIDE project is to advance the development of the Optimor tidal energy concept (shown in Fig. 1) towards commercialisation by following the guidance of the IEA-OES Framework. In order to achieve the LOGIC-TIDE project aim, the research activities will be broken down into the following areas:

- Turbine design and optimisation, along with chassis structural design
- Component manufacture and testing
- Installation, operations and maintenance (I,O&M) co-design

The LOGIC-TIDE project coordinator is ORPC, who will also lead the chassis structural design, with partners, ÉireComposites, who will lead the turbine design and tidal component manufacture, Rockall Research Ltd., who will lead the I,O&M co-design, and the University of Galway, who will perform large-scale structural testing on the composite tidal component.

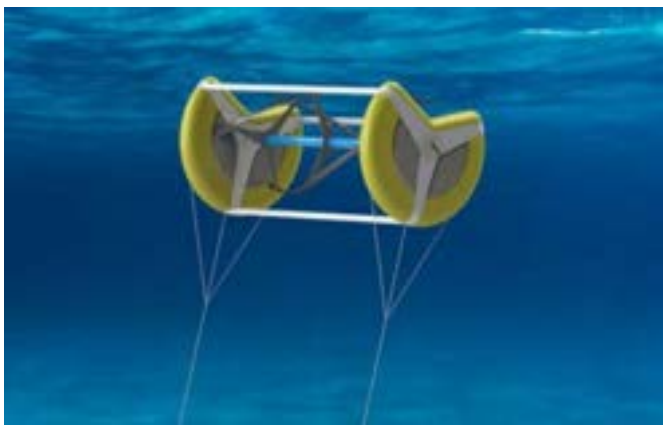

Figure 1: Illustration of the full-scale Optimor tidal energy concept in operation

EXPECTED IMPACT

The main project outcome will be the de-risking and advancement of the Optimor tidal energy concept, with the aim of installing an Optimor device in Irish waters in the coming years.

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Fuzzy vs. Crisp in Uncertainty-aware Service Selection: Enabling Sustainability on Multimedia Event Processing

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The high energy consumption projections of Cloud/Edge applications urge the development of ecologically sustainable Multimedia Event Processing (MEP) systems. In these applications, a Multi-Criteria Decision Making (MCDM) problem must be solved when selecting the best service workers alternatives for processing user queries, according to the user-specific performance criteria requirements of energy, accuracy and speed. Moreover, fuzzy logic provides a well-established method, such as the fuzzy TOPSIS, for dealing with the uncertainties arising from real-world scenarios, where ambiguities of user requirement interpretations and imprecision of measurement of the computing devices may directly impact this decision-making process. However, this fuzzy method is more complex and computationally intensive than the original (crisp) TOPSIS. Therefore, it is crucial to understand to what degree the fuzzy and crisp methods may be used interchangeably and still get the same results to avoid unnecessary complexity in sustainable MEP solutions in a real-world context.

In our work, we developed a fuzzy TOPSIS ranking method for handling the uncertainties of the user criteria weights and service worker alternative ratings. Contrary to a previous study, we provide evidence that replacing the fuzzy TOPSIS method with its crisp counterpart significantly affects the ranking results when applied to a real-world scenario, with contradiction rates higher than 60% in most scenarios explored, which suggests that it is not viable to interchange these methods without consequences to the sustainability efforts of an MEP application.

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REWET: Hydrologic impacts of water table management on carbon-rich grassland soils

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Artificially draining carbon-rich soils, a common practice to increase agronomic production on water-logged lands, can lead to the release of carbon dioxide to the atmosphere. The intrinsic value of these organic soils for the services and functions that they provide related to carbon storage and sequestration is now recognised. Therefore, the restoration of these areas to reduce greenhouse gas emissions is being considered. In Ireland, there are an estimated 300,000 ha of permanent grassland on drained organic soils, of which 80,000 ha are targeted in the Climate Action Plan for restoration by removing and blocking existing artificial drainage features. This process of water table management is referred to as 'rewetting' and more research is needed to determine where this will be feasible, how it can be carried out, what benefits it would provide, the implications for the surrounding lands and what land use options are viable after rewetting. REWET seeks to identify lands suitable and available for rewetting, examine practical methods of rewetting, assess the effects on hydrology at the designated sites and surrounding lands and quantify associated impacts. This project will provide a deeper understanding of the hydrologic impacts of water table management on organic grassland soils by measuring changes in hydrology and the impact of rewetting on soil moisture and storage, water table depth and discharge dynamics. It is expected that the sensitivity of water table depth to external manipulation will vary by site, as will the associated costs and benefits. The project will identify site characteristics that influence site suitability for rewetting, inform water table management strategies to reduce the impact of greenhouse gas emissions on the environment and support sustainable land management practices on carbon-rich soils.

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Development of decision-making tools for end-of-life of wind turbines

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INTRODUCTION

The service life of wind turbines is an essential determinant of their end-of-life management and the overall sustainability of wind energy. The WindLEDDeR project's emphasis is on developing a decision-making tool for the end-of-life management of wind turbines in Ireland. The project initiative seeks to maximise the utilisation of wind turbines while minimising their environmental impact and associated risks by incorporating service life information into the decision-making tool.

MATERIALS AND METHODS

The main aim of the WindLEDDeR project is to develop a decision-making tool to facilitate the end-of-life management of wind turbines in Ireland to maximise the potential of wind energy as a sustainable and renewable resource. Therefore, the following research activities are to be completed:

- Testing the various components of wind turbines and collecting data
- Model developing and structural health monitoring (SHM) for wind turbines
- Establishing a predictive protocol and decision-making software

The WindLEDDeR project coordinators are Trinity College Dublin, who will lead the aero-elastic-servo-soil model of HAWT, with partner University College Dublin, who will lead the Structural health and lifetime monitoring methodologies; GDG, who leads the Foundation inspection and lifecycle assessment; University College Cork, who will lead the Multifactorial Decommissioning Decision Support Framework; Munster TU, who will lead the Repurposing of decommissioned wind turbine blades; University College Dublin, who will lead the Project management and dissemination; and the University of Galway, who will lead the Development of end-of-life structural prediction models for wind blades.

Expected Impact

The WindLEDDeR project will create a risk-free decision-making tool that gives a reliable and complete guide for the end-of-life management of wind turbines in Ireland. This will reduce the potential environmental and financial risks of wind energy, along with further promoting its use as a sustainable and renewable resource.

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Faults Can't Hide: How GAN and TCN Unlock Accurate RUL Prediction in Complex Mechanical Systems.

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Remaining Useful Life (RUL) is a crucial metric in industrial settings, as it provides an estimate of the time left before a component fails or requires maintenance. The accurate estimation of the RUL of industrial assets enables successful planning of the maintenance operations, minimizes downtime, increases availability, and avoids disastrous outcomes. Machine Learning (ML) and Deep Learning (DL) based methods have been extensively utilized to predict the RUL of industrial equipment because of their high ability to learn from historical data. However, the ability to predict the RUL using these data-driven methods relies on having adequate prior knowledge of the degradation process of critical components. In real-world industrial scenarios, faults occur less frequently than in normal working conditions. This results in an imbalanced data distribution, with smaller fault samples than normal samples. Thus, making it difficult to train ML models due to the absence of enough historical information about the fault conditions. This study proposes an RUL estimation framework based on Recurrent Conditional Generative Adversarial Network (RCGAN) and Temporal Convolutional Network (TCN) to address this challenge. The proposed framework generates realistic synthetic fault instances and leverages the temporal dependencies present in the time-series data. The TCN utilizes dilated causal convolutions to capture long-range dependencies in the data, thus enhancing the RUL prediction accuracy. Our findings indicate that learning fault samples through underlying noise distribution, data augmentation, and TCN training improves RUL prediction accuracy as compared to previously published imbalanced work on the C-MAPSS dataset.

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GAPS: Building a Toolkit to Enhance Green Public Procurement
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Green public procurement (GPP) is a process in which public authorities seek to source goods, services or works with a reduced environmental impact. The Irish Government spends about €9 billion on goods and services annually (12% of GDP) and has enormous potential to reduce emissions and protect our environment, saving money over the full life cycle of goods and services and leading by example. This research strategically partners with South East Energy Agency and Climate Action Regional Office and builds a living bank of state of the art knowledge on GPP policy and practice, the successes, the barriers, the quick wins and where policy and practice in Ireland should focus. Recent EU directives enhance the existing possibilities under the 2004 directives for GPP and provide greater clarity in several areas. Best EU practice categorises GPP case studies and purchases/services and looks beyond the EPA focus in *Green Procurement – Guidance for the Public Sector.* Using discourse based approaches (DBA) we explore GPP policy and practice with procuring professionals and identify solutions. These approaches engender deep participation and foster a cascade of reflection and thought on GPP policy and practice allowing inter-disciplinary investigation and consensus dialogue. Based on the DBA we develop and test a pilot GPP toolkit in live situations future proofing it for use in our public sector. Testing will enable identification of issues and solutions. Issues that arise may include inter alia regulatory, policy, process, cultural, behavioural, and market characteristics. Reasons for, and solutions to, GPP inertia in Ireland will be identified. This research delivers a GPP toolkit capable of catalysing GPP going forward.

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A new BEMT model for analysing spiral-bladed vertical axis tidal turbines

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INTRODUCTION

Designing tidal turbines is a challenging task due to the harsh environment and strong forces generated by tidal currents. Therefore, accurate and efficient modelling frameworks are needed to analyse and design complex blade geometries. Blade Element Momentum Theory (BEMT) is commonly used to analyse tidal turbines as it provides an analytical framework to model the hydrodynamic interaction between the turbine and fluid flow, which is more computationally efficient than CFD simulation. However, standard BEMT formulations are not suitable for accurately simulating complex blade geometries such as spiral or helical blade geometries.

MATERIALS AND METHODS

This study presents a modified BEMT formulation for analysing vertical axis tidal turbines (VATTs) with spiral blade geometries. The method accurately incorporates alterations in lift and drag forces due to the non-orthogonal orientation of the blade's leading edge with respect to the fluid velocity vector. The modified BEMT formulation was implemented in MATLAB and validated using experimental data for a VATT. The researchers then conducted a VATT design parametric study to investigate the relationship between blade helix angle and power output. In addition, The modified BEMT approach was extended to analyse turbine self-starting capability, which is advantageous in remote and small-scale tidal sites.

RESULTS AND DISCUSSION

The model predicted that the helix angle of the blade influences peak power output and peak TSR, and an increase in blade helix angle results in increased torque and reduced power fluctuations. Moreover, the model predicted that fluctuations in tangential and normal forces acting on the blade are reduced, which lowers the risk of blade fatigue failure. Helical blade turbines were found to have wider self-starting capabilities compared to straight blade turbines. The study demonstrates the usefulness of the modified BEMT approach in designing and analysing complex blade geometries in tidal turbines, and the importance of considering blade helix angle in maximizing turbine performance.

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Review of connections in a multi-storey modular CLT building

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INTRODUCTION

Cross-laminated timber (CLT) has emerged as an excellent material in terms of structural properties and environmental impact due to the shift in focus towards sustainable construction materials. Ireland has an increasing supply of Sitka spruce timber, which is primarily graded as C16. However, the timber grade which is commonly used in construction across the rest of Europe is typically C24-grade timber. As such, the data and literature regarding connections in CLT construction are mainly available for C24-grade timber. A modular building consists of stackable and scalable prefabricated modular units manufactured off-site, transported, and assembled on-site resulting in a rapid means of construction. An integral part of the system is the connections which are designed to resist vertical loads due to gravity as well as horizontal loads due to wind and seismic action. While there has been a significant research focus on this area in recent years, most of these connections were tested for C24-grade CLT panels and a limited number of studies have focused on C16-grade material. Experimental studies of commercially available connectors like steel plates and angle brackets are carried out on C16-grade CLT panels, which will be further validated using numerical models.

MATERIALS AND METHODS

CLT panels are engineered wood products manufactured from at least three layers of boards glued together with adjacent layers orientated at right angles to each other. The layers are bonded together with adhesives under pressure. Connections using industry-standard angle brackets and shear/tension load transfer plates will be examined for a number of screw lengths. In Figure 1, a Rothoblaas TTF200 shear transfer plate is connecting C16-grade CLT with 40 mm screws (LBS540) and is subjected to testing under shear load.

Figure 1: Shear test on TTF200 steel plates connected using 40 mm screws (LBS540)

RESULTS AND DISCUSSION

The load-displacement curves from the experimental results are analysed and have provided significant information on the structural performance of these connections. They will be compared to the load-displacement curves obtained from the numerical models for validation. Future research needs for using these connections for a modular building made of C16-grade CLT shall be identified and highlighted.

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Gaps in LCA practices for wood products between Ireland and worldwide

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Timber Engineering Research Group & Ryan Institute, University of Galway

INTRODUCTION

Ireland committed to halving GHG emissions by 2030 from the 2018 levels and achieving net zero by 2050, where the building sector is allocated about 50% burden for carbon reduction. However, the predicted population increase by 2051 brings roughly 33,000 new home demands each year by 2040. Considering wood has already been identified as a low-carbon material, and the roundwood supply from Irish forests is forecasted to double from 2016 to 2035, timber is an excellent choice for balancing the housing demand and emissions requirement. Although the potential rise in carbon emissions can be minimised by applying timber in construction, the benefits are hard to quantify due to lacking comprehensive lifecycle data for Irish wood products. Moreover, the absence of related LCA regulations might limit the scale of timber application. Therefore, the SAOLWood project first identifies the gaps in LCA practices for wood products between Ireland and worldwide through a holistic review.

MATERIALS AND METHODS

The review covers Europe, Canada, the USA, Australasia, and Asia, and is conducted from macro and micro levels. At the macro level, international and countries' national LCA methodologies related to embodied carbon estimation are compared from (1) mandatory regulations, (2) time in force, (3) limit values, (4) national LCA database, and (5) LCA details. At the micro level, 5 EPDs for each product including sawn timber, MDF, OSB and CLT are collected, and the LCA information is compared from (1) LCA scope, (2) LCI analysis, (3) indicator assessment, and (4) interpretation.

RESULTS AND DISCUSSION

At the macro level, the Netherlands ranks first within Europe; it enforces LCA regulations and limit values for construction earlier than other countries (except for Germany), and its LCA quantification is more comprehensive since it covers all required modules for embodied carbon estimation and aggregates various climate impact indicators into shadow cost, while most countries only consider GWP. For Ireland, there is no customised national LCA methodology, although the IGBC is currently developing such a methodology. At the micro level, Ireland is under the average level in terms of LCA scope performance as 50% of total analysed EPDs cover all the required modules and 80% incorporate the environmental impacts from the wood waste treatment and corresponding benefits and burdens beyond the product life, but the EPD of MDF from MEDITE omit module D and the EPD of OSB from SMARTPLY only declares modules A1-A3. Regarding indicators, the GWP related to land use and land use change is waiting to be included in Irish EPDs. Moreover, the end-of-life (EoL) stage of Irish wood products is an assumed value due to the absence of more reliable data but initial studies would indicate that there is a significant discrepancy with reality. In the future, the review scope will be expanded, and more gaps will be identified.

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DECISIVE DATA

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Improving algorithm for retrieving Chlorophyll-a using remote sensing incorporating artificial intelligence technique

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Abstract

For the purposes of monitoring of surface water quality, cutting-edge satellite remote sensing (RS) technique has received wider attention as a complementary data source for typical monitoring approach. Several studies have utilized the RS technique in order to estimate optically active water quality indicators (e.g., chlorophyll-a, coloured dissolved organic matter, total suspended matter, turbidity, secchi disk depth). Among these indicators, Chlorophyll-a (CHL) plays a crucial role in linking nutrient input and algal productivity. Moreover, several studies have utilized remotely sensed CHL in order estimate optically inactive WQ indicators (e.g., pH, biological oxygen demand, chemical oxygen demand, dissolved oxygen, total phosphate and dissolved inorganic nitrogen) from satellite images. Therefore, accurate retrieval of CHL from RS technique is crucial for total WQ monitoring. However, a number of literature have reported significant amount of uncertainty within the remotely sensed CHL concentration for coastal and transitional water(s) due to the improper utilization of band combinations in the retrieving algorithms. Being the case, a number of the state-of-the-art machine learning (e.g., Extreme gradient boosting, Gaussian process regression, Partial least squares regression, Random forest, Support vector machine) and deep learning algorithms (e.g., Bayesian probabilistic neural networks, Convolutional Neural Networks, Long short-term memory, Mixture Density Network, Recurrent neural network) are being widely employed in handling big data, like as RS data. Hence, the aim of the research is to identify the most suitable band combinations for retrieving CHL concentrations using the machine learning and deep learning algorithms. Finding from the research could be effective to develop a retrieval algorithms using more efficient band combination of RS data in order to retrieve CHL more accurately.

Keywords: surface water quality; remote sensing; chlorophyll-*a*; band combination; machine learning; deep learning.

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Advanced Irish Water Quality Index (IEWQI) Model: Can the IEWQI be a reliable tool for environmental regulators to monitor water pollution?

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Abstract

This study presents the Irish Water Quality Index (IEWQI) model, a new tool that utilizes cutting-edge machine learning and artificial intelligence techniques to evaluate the quality of transitional and coastal (TrC) waters in Ireland. The model aims to provide a more effective approach for environmental regulators to combat water pollution. The IEWQI model consists of five components: indicator selection, sub-index rescaling, indicator weighting, aggregation function, and score interpretation. The model's performance was evaluated using 2021 water quality data from four coastal waterbodies in Ireland during both summer and winter seasons. Advanced statistical measures were used to analyse the model's sensitivity, uncertainty, and efficiency. Results demonstrated that the IEWQI model performed well with high sensitivity, low uncertainty, and minimal error rates. The model was also effective in predicting water quality and reducing model ambiguity and eclipsing problems. The IEWQI model is applicable in any geospatial magnitude and can be utilized in other waterbodies beyond TrC waters. Overall, the IEWQI model provides a reliable and efficient approach to assess water quality, supporting environmental regulators in reducing water pollution in Ireland. Additionally, the IEWQI model has been widely implemented in various waterbodies across EU member states and some Asian countries. Results from the model's applications outside of Ireland, such as Northern Ireland, UK, India, Bangladesh, and others, indicate its effectiveness in monitoring and assessing TrC waters at any geographical resolution.

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A comparison of various retrieval techniques for assessing dissolve oxygen in marine ecosystems using remote sensing techniques

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Abstract: Among the water quality indicators, dissolved oxygen (DO) is one of the crucial one. According to literature, critical concentration of DO often cause hypoxia in aquatic organisms. Typically, the measurement of DO is relied on the point-sampling based *in-situ* technique, which is costly, time consuming and unable to provide a synoptic view of the waterbodies. To overcome these issues, currently a number of cross sectional studies are utilizing the cutting-edge remote sensing technique to estimate DO in surface water. Although in terms of optical remote sensing, DO is an optically inactive water quality indicators, it can be retrieved based on the empirical relationship between remote sensing band reflectance, band combinations and *in-situ* dissolve oxygen. Additionally, a number of studies have utilized various methods like statistical and state-of-the-art machine learning/artificial intelligence technique for retrieving DO from the remote sensed data. However, these approaches are computationally complex and if not tuned properly, the retrieval algorithm produce significant uncertainty due to the compound architecture of remote sensing technique. Therefore, the aim of the present study is to compare various retrieval techniques in order to measure DO from the remotely sensed data. The outcome of different comparison may be helpful to determined by the best approach to retrieve DO from marine waters.

Keywords: Dissolve oxygen, water quality, remote sensing, machine learning, artificial intelligence, marine ecosystem.

Presenting author's information

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College of Science and Engineering, Inaugural Research and Innovation Day 2023

Will your Doorbell Camera still recognize you as you grow old?

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INTRODUCTION: Robust authentication for low-power consumer devices such as Doorbell cameras pose a valuable and unique challenge. Our previous work has studied the main factors such as illumination and pose that affect facial authentication, which shows the feasibility of implementing a robust authentication method for low-power consumer devices. In this work, we are focusing on another challenging factor, age, i.e., how age bias affects the state-of-the-art Face Recognition (FR) method. Due to collecting data on a person from birth to old age being difficult and the lack of large-scale age data from multiple identities in existing age datasets, a generative adversarial network (GAN) based aging technique has been used to create a synthetic dataset. In this way, the robustness of the FR model to aging can be verified without a need to collect data from human subjects over long periods of time.

MATERIALS AND METHODS: Two public age datasets, AgeDB and Morph-II have been used as baselines in this work. A photo-realistic age transformation method has been employed to augment a set of high-quality facial images with various age effects. Some synthetic aging samples are shown in **Figure 1**. Then the effect of these synthetic aging data on the high-performance deep-learning-based FR model is quantified by using various metrics such as Receiver Operating Characteristic (ROC) curves and match score distributions.

RESULTS AND DISCUSSION: This work illustrates the potential value of synthetic age data in analyzing the robustness of face authentication systems. Initial experiments associated with synthetic age data have shown that it is valid to use synthetic data to enlarge the dataset for analysis of how aging affects FR models. Long-term age differences are still a significant challenge for the current facial authentication method. Future work will explore the quality and genuineness of synthetic age data, and the gap between the real age data and the synthetic age data.

Figure 1: The aging samples synthesis by GAN-based technique.

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Uptime: Component Failure Prediction System for Agricultural Machinery

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INTRODUCTION

Grass silage production is where farmers conserve excess grass, grown in the summer, as a nutritious feed for livestock during winter. Grass is mowed and collected using self-propelled machinery or towed implements which preserve it as hay or silage.

In many European countries, the use of farm machinery and implements are outsourced to a single vendor or, machinery contractor, with state-of-the-art machinery. Incorrect implement operation will lead to easily avoidable delays (such as blockage of the machine intake) and in extreme cases, can damage the equipment. A breakdown for a contractor incurs direct and indirect costs. Delays to repair components, of even a few days, can lead to a significant degradation of the crop's nutritional value.

In this project, a *Component Failure Prediction System for Agricultural Machinery* is proposed. The system will utilise novel sensing and analytics to approximate measurements on machine loading via a data fusion approach. The aim is to develop a cost-effective solution to monitor machinery to ensure that jobs can be completed in an efficient and predictive manner, increasing turnover and overall efficiency, even with inexperienced operators.

MATERIALS AND METHODS

Figure 1 illustrates the work completed so far. Geo-referenced time series tractor and implement data was aggregated from the 2018-2021 seasons of silage baling in Galway, Ireland. Torque, LiDAR, angle, vibration and hall effect sensors were attached to points of interest on the harvesting implements to monitor crop characteristics and machine loading.

A custom telematics unit has been developed to increase machine monitoring capacity. An AWS serverless backend was prototyped to work in conjunction with the telematics units to automate the massive data collection.

RESULTS AND DISCUSSION

Several publications have resulted in the work completed in so far.

- Analysis on mower implement efficiency has shown that over 24% of contractors' costs can be attributed to machinery transport.
- An automated field geometric boundary delineation algorithm to segment trajectory data of machinery between adjacent fields, connected by short off-road pathways. The results demonstrate that the algorithm achieves an accuracy of 100% on a baler implement dataset and 98.84% on a mower implement dataset.

- A novel cost-effective method to approximate machine loading. State-of-the-art load measurement systems are neither cost-effective (€5000+) or robust enough for long-term

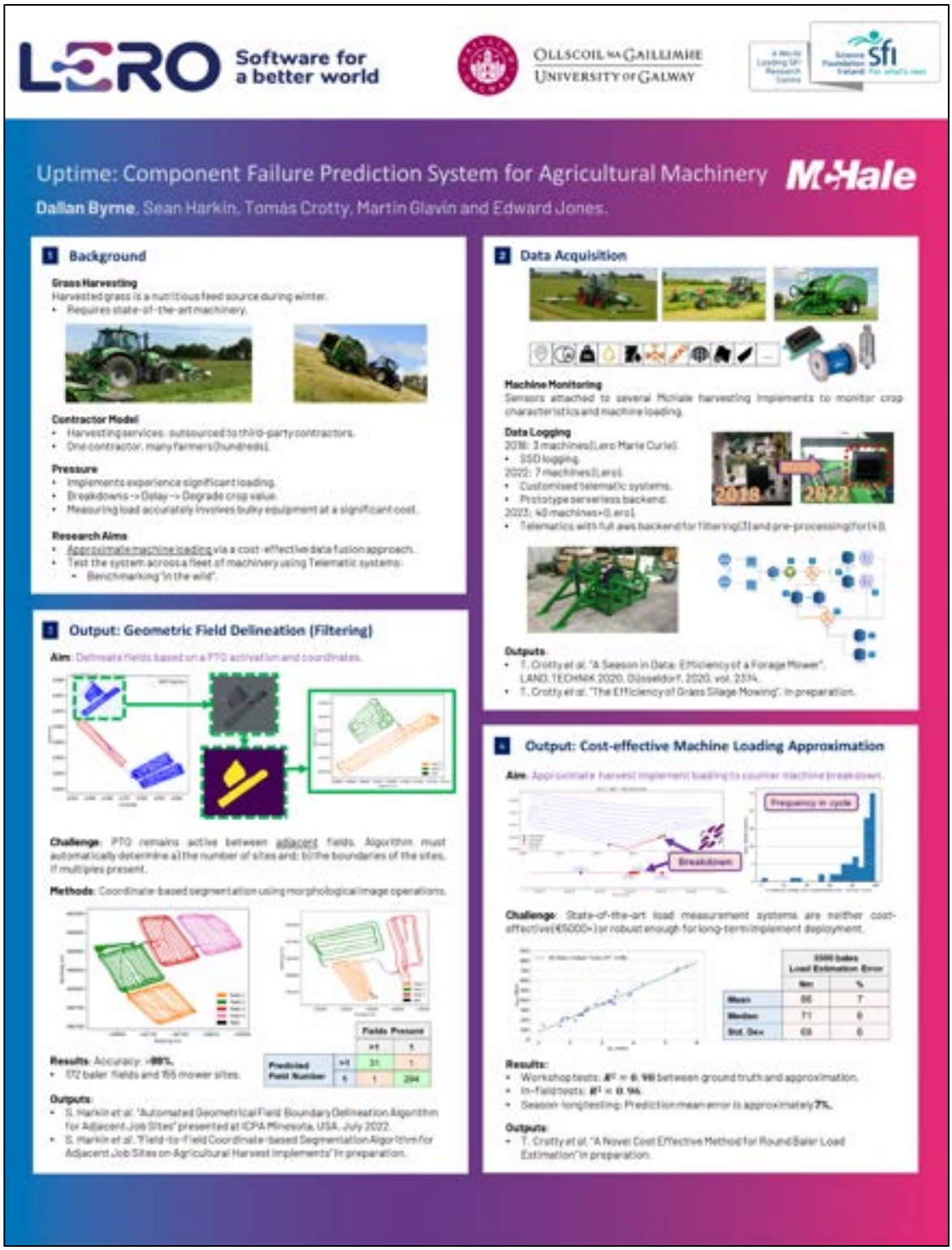

Figure 1: Project is divided into four components. 1. Problem background and need for a cost-effective component failure prediction system. 2. Data acquisition journey. 3. Field Boundary Delineation solution using only PTO activation and GPS coordinates. 4. Novel method to approximate machine loading.

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Towards Suggestion Extraction from Short Texts: Approach and Dataset on Social Media

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INTRODUCTION

Microblogs, such as Twitter, offer users all over the world a novel way of communication to share ideas, opinions, and suggestions in the form of short text posts. They have gained prominence in recent times, particularly during the COVID-19 pandemic. This paper introduces (the first) method(s) for suggestion extraction from short texts (e.g., social media posts). We also provide the dataset along with this task for suggestion extraction.

MATERIALS AND METHODS

The idea behind suggestion extraction is that, given a text (e.g., a social media post) we need to find (and extract) the span of text (a continuous string of text) where the suggestion occurs. We use two approaches to achieve this task.

1. Rule-based approach: We use hand-coded linguistic patterns and a pre-defined lexicon to identify the suggestion span from a given text.
2. Deep-learning-based approach: Supervised approach to identify suggestion span. We developed two models with different hyper-parameter setting in this approach.

We used two datasets in our training and evaluation process for both the above mentioned methods: 1) Software forum reviews dataset - SemEval 2019 - Task 9 and 2) COVID-19 tweets - (Lamsal, 2020).

RESULTS AND DISCUSSION

We use the BLEU score to compare the quality of suggestions extracted by each approach. Fig 1 shows the result for both rule-based and deep-learning-based approaches. The results show that the rule-based approach performs significantly better than the deep learning-based approach.

Approach	BLEU score
Rule-based	**0.82**
Deep-learning model 1	0.13
Deep-learning model 2	0.26

Figure 1: Results of rule-based and deep-learning-based approach using BLEU method

The task poses a main challenge of the lack of datasets available for training and evaluation. We tried to overcome this challenge by first using the proposed rule-based approach to create weakly annotated data for using supervised approaches like a deep-learning-based approach.

The experiment conducted shows promising results with the proposed rule-based approach which can be used to extract suggestions from given texts. Though the results from the deep-learning approach are not yet convincing, we believe there is a great scope to explore this approach in future, especially by further developing the model.

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Generation and Analysis of Dataset for Dynamic Malware Classification of Windows Portable Executable (PE) Files

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The proliferation of malware attacks poses a formidable challenge to cybersecurity, wherein malicious actors deploy encryption mechanisms to hold user data hostage following system infection. Recently, malware strains using advanced obfuscation techniques and offline command and control (C2) server capabilities have targeted both individual users and large corporations, resulting in business disruptions and financial losses.

The methodology is adopted to aid cybersecurity researchers in conducting dynamic malware analysis and classification for future malware predictions. Our proposed approach aimed to study, analyse, and classify malware families using this new malware dataset from Malwarebazar (a project from abuse.ch), which will enable further malware analysis.

For experimentation, we have adopted the following 3 steps approach. (1) generated an in-house dataset by analysing 642 Windows Portable Executable (PE) files using the Cuckoo sandbox environment. The report generated by the sandbox provided insights into system activities during malware execution. (2) Using the VirusTotal API, we labelled different eleven malware families, including Trojan (27%), Ransomware (22%), Downloader (11%), Dropper (11%), Generic malware (11%), Backdoor (5%), Stealer (5%), Spyware (4%), Adware (3%), Rootkit (1%) and Worm (1%). (3) Four feature sets were extracted from the data for analysis, including the list of API calls, PE import functions, and various fields of PE Header and Sections, from the Cuckoo sandbox report and included in our generated dataset.

The newly generated dataset will be publicly available to encourage machine learning researchers for improved dynamic malware detection. It will also serve as a benchmark for researchers and security analysts in predicting malware evolution in future work.

METHODOLOGY

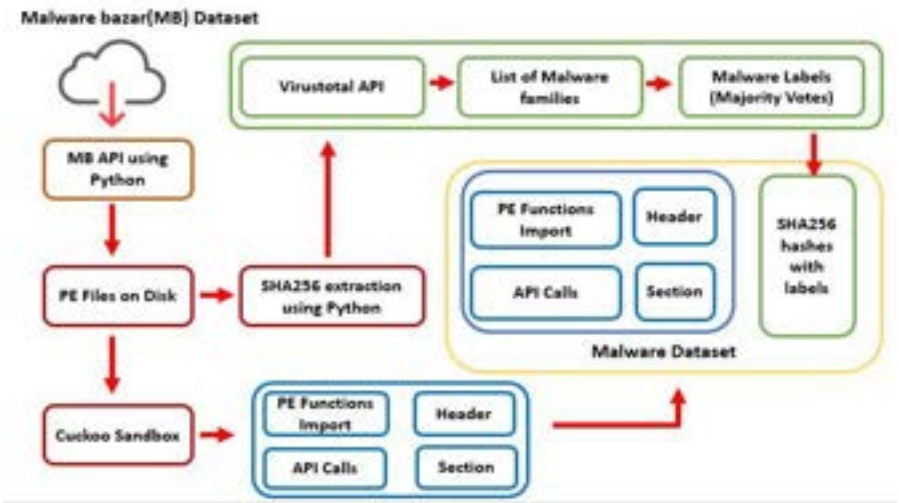

Fig 1: Methodology for data extraction and Dataset creation

RESULTS

1. **Malware family's extraction**

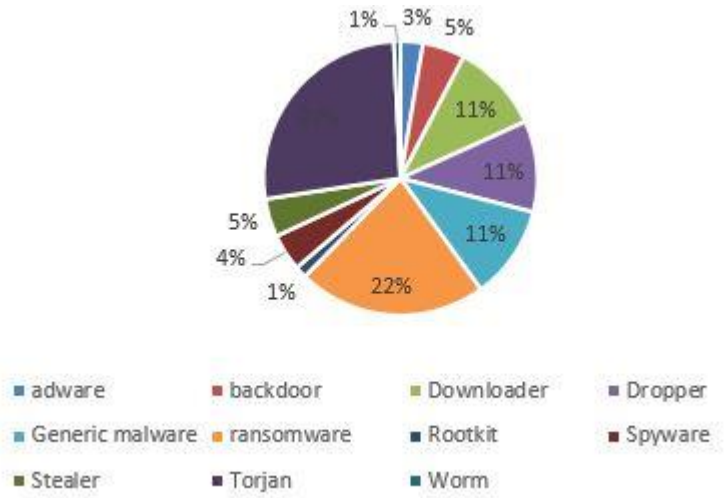

Fig 2: Malware families extracted by Virus-total API.

1. **Dataset Creation**

A dataset is created in csv format and will be uploaded to GitHub for future research.

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Multivariate flood analysis based on copula and parametric and non-parametric distributions

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ABSTRACT

Since flood is described as a multivariate stochastic phenomenon, it is necessary to adopt multivariate approaches in its analysis. The traditional methods of performing multivariate analysis are based on applying classical multivariate distributions with parametric marginal functions. However, the use of classical multivariate distributions with parametric distributions faces serious limitations such as the necessity of defining the marginal distribution functions and their parameters and the sameness of the functions. Also, in using parametric distributions for marginal variables, a default distribution is used to interpret the data, while it may not describe the actual data distribution well. So, in this study, combined analyzes of flood variables have been performed using copula functions that do not have the limitations of classical distributions, in such a way that marginal distributions are selected from both parametric and non-parametric distributions.

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Bootstrapping a Chatbot on Industrial Heritage through Term and Relation Extraction

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INTRODUCTION

We describe work in developing a methodology for the automatic generation of a conversational agent or 'chatbot' through term and relation extraction from a relevant corpus of language data. We develop our approach in the domain of industrial heritage in the 18th and 19th centuries, and more specifically on the industrial history of canals and mills in Ireland.

MATERIALS AND METHODS

We used the Saffron toolkit to extract relevant terms and relations between the terms from relevant newspaper reports and Wikipedia articles and leveraged the extracted knowledge to query the British Library Digital Collection and the Project Gutenberg library. We further used the extracted terms and relations in identifying possible answers for a constructed set of questions based on the extracted terms, by matching them with sentences in the British Library Digital Collection and the Project Gutenberg Library. In a final step, we took this data set of question-answer pairs to train the generative model.

RESULTS AND DISCUSSION

The evaluation of responses of open-domain conversational agents, such as chatbots, is still an open question since a variety of answers can be considered as correct. Therefore, we randomly selected 50 question-answer pairs and evaluated manually the automatically generated answers (Figure 1).

Question #1	Tell me about a cotton and a sawmill
Generated Answer	A sawmill or lumber mill is a facility where logs are cut into lumber.
Question #2	What is the relation between a gate and a river?
Generated Answer	On the clare side of the river, at the foot of thomond gate 587 limerick.
Question #3	Tell me about a city and a lock
Generated Answer	287 the gates of the city to be put in repair with locks and keys
Question #4	What is the relation between a log and water?
Generated Answer	Availability of railroad transportation for logs and lumber encouraged building of rail mills away from navigable water.
Question #5	What is the relation between a lumber and a paper?
Generated Answer	The larger pieces of wood that wo n't make lumber are chipped into wood chips and provide a source of supply for paper mills.
Question #6	What is the relation between a lumber and a mill?
Generated Answer	A sawmill or lumber mill is a facility where logs are cut into lumber.

Figure 1: Examples of the generated answers from the generative model.

The current limitations of the approach are in data collection, term and relation extraction and evaluation. In particular, our current data set consists only of a small number of contemporary documents of general but not of specific relevance to the application under consideration, i.e. industrial heritage of Ireland in the 18th and 19th centuries.

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Creating a Pandemic Surveillance Dashboard for Europe

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In early 2020, European public health agencies began reporting the first cases of COVID-19, the respiratory illness caused by the SARS-CoV-2 virus (See Figure 1). Although European public health agencies had long anticipated and planned for a pandemic, the COVID-19 outbreak highlighted several shortcomings in data reporting and sharing across European borders. The Pandem2[1] EU project, coordinated by the University of Galway has developed a suite of tools that can be deployed by European countries to assess healthcare systems and workforce readiness, to improve pandemic preparedness and training based on scenarios of likely future pandemics. A key objective was to research and develop human-computer visual interaction models that cater for the analytical workflows of the public health analyst using participatory design methodologies, which are tailored to include the end user in the design process. This poster describes the design and development and evaluation process for a multi-indicator pandemic dashboard system for European countries. It describes how the requirements were gathered from multiple European public health stakeholders and how an asynchronous participatory design process allowed public health end users to contribute remotely during lockdowns to the design and development process. The poster describes how the dashboard was evaluated in a live functional exercise with public health agencies from Germany and the Netherlands, who were required to respond in real time to a realistic scripted scenario concerning an outbreak of highly contagious avian influenza. The outcome of the functional exercise has led to a plan of revision and improvement of the dashboard system, which will be made available to European states and pan-national public health agencies, such as ECDC[2]

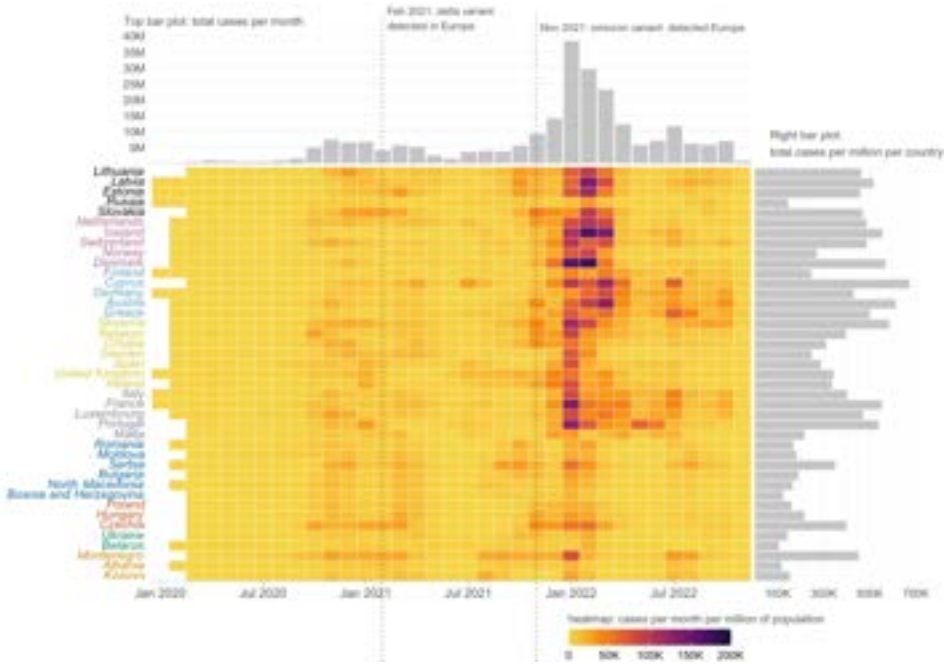

Figure 1: A heatmap illustrating the COVID-19 cases per month per million of the population for European countries from January 2020 to December 2022. Countries are grouped based on the similarity of their reported case outbreaks

[1] https://pandem-2.eu/
[2] https://www.ecdc.europa.eu/en

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CALM: Causality-Aware Language Models and Benchmarks for General Causal Reasoning

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Data Science Institute, University of Galway

INTRODUCTION

Causal reasoning is a critical component of human cognition and is required across a range of question-answering (QA) tasks (such as abductive reasoning, commonsense QA, and procedural reasoning). Research on causal QA has been underdefined, task-specific, and limited in complexity. Recent advances in foundation language models (such as BERT, ERNIE, and T5) have shown the efficacy of pre-trained models across diverse QA tasks. However, there is limited research exploring the causal reasoning capabilities of those language models and no standard evaluation benchmark. To unify causal QA research, we propose CALM-Bench, a multi-task benchmark for evaluating causality-aware language models (CALM). We present a standardized definition of causal QA tasks and show empirically that causal reasoning can be generalized and transferred across different QA tasks. Additionally, we share a strong multi-task baseline model which outperforms single-task fine-tuned models on the CALM-Bench task

MATERIALS AND METHODS

We conduct sixty experiments to see if causal reasoning can be generalized and transferred across various QA task. We also train a unified model to support general causal QA using multi-task learning. Our experiments consider two different language models, BERT (Devlin et al., 2019) and ERNIE 2.0 (Sun et al., 2020). BERT and derivative models contain unspecified distributional knowledge which is learned through denoising pretraining. In a contrast, ERNIE 2.0 injects external knowledge through a variety of knowledge-guided pretraining objectives such as masked knowledge prediction.

RESULTS AND DISCUSSION

We provide empirical evidence which validates the intuition that causal reasoning and knowledge are transferable across the CQA tasks. Knowledge-enriched language models like ERNIE are likely to outperform distributional models (i.e. BERT) across all tasks in both the single-task fine-tuning and multi-task fine-tuning settings. Our multi-task model further demonstrates this transferability outperforming single-task finetuned models and exhibits strong performance in the zero-shot setting for commonsense causal question answering.

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Identifying rice cultivation in the Senegal River Valley using multi-wavelength earth observations and ensemble classification methods

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Global crop masks perform effectively in well-studied geographic locations using earth observation data (USA & Europe) but fail to classify croplands accurately in other regions of the globe. The ESA WorldCover land cover map works well in Europe but fails in many regions of sub-Saharan Africa.

Here, we studied the growth of rice in northern Senegal, particularly in the Senegal River Valley (SRV) and the river delta. This region has been the focus of hundreds of millions of dollars of intervention from NGOs over decades and is a high-risk area for the impacts of climate change and desertification. Rice is a staple household food in Senegal, and one of the most popular crops to grow nationally. Determining the true amount of crop production is important for national agricultural policy decisions, individual farmers, crop markets, and determining climate impact in the Sahel region. Methods for determining true cultivated area are usually done intermittently on the ground through traditional survey methods or at the mill. The dynamic nature of tillage farming makes the issue more complex. Farmers may choose to change crop season-to-season based on the fluctuating markets and gate prices.

By using machine learning methods and un-biased earth observation data from both the Sentinel-2 (optical and infrared) and Sentinel-1 (radar) missions we can determine the true amount of rice grown per season in the most heavily cultivated region in the country, the Senegal River Valley. We demonstrate the accuracy of using ensemble classification methods combined with traditional image analysis over single classification methods by using multiple algorithms to find the best prediction season-to-season. By doing so we gain an accurate representation and trend of total rice crop area cultivated from 2019 to 2022.

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Opportunities and Barriers around Sustainability Reporting at Higher Education Institutions

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INTRODUCTION

This project aims to identify barriers and highlight opportunities that Higher Education Institutions (HEIs) have when it comes to reporting on sustainable development. Measuring Education for Sustainable Development (ESD) in the curriculum and measuring scope 3 carbon emissions were identified as two areas which had significant barriers around them and hence became the focus areas of this project.

MATERIALS AND METHODS

The measurement of ESD was tackled through two approaches, a keyword scan and a survey. The objective of the project was to create a tool which could automatically and accurately scan for SDG related keywords in curriculum material, producing a "baseline measure" of ESD in a given module, programme or College. The survey was used as a comparison. Lecturers and module owners were asked to rate their modules in terms of SDG coverage.

Measuring scope 3 emissions was quickly identified as an area that has been neglected and specifically scope 3 category 1, purchased goods and services. This project compares two methodologies of reporting on this category, firstly using broad sectors of purchase and secondly using life cycle assessment emissions for the products of one of the University's suppliers.

RESULTS AND DISCUSSION

The ESD project has seen the creation of an SDG keyword scanning tool. This tool was created through a process of critically analysed SDG related keyword lists sourced online from other research projects. This keyword tool was used to scan modules within at the University of Galway, accompanied by a survey of staff and the tool showed strong consistency with the survey. A first draft version of the SDG keyword scanning tool has been published on the University of Galway website.

When comparing the two methods of measuring emissions from purchased goods and services, it was found that when using the best practice approach of life cycle analysis emissions, the total CO2 equivalent was 59% less than the figure attained when using the broad sector of purchase approach.

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Comparative Analysis of RL Algorithms with Transfer Learning for Cross-Building HVAC Optimization

Kadamala, Kevlyn[1], Barrett, Enda[1].

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INTRODUCTION

Traditionally, building control systems for heating, ventilation, and air conditioning (HVAC) rely on classical approaches. These approaches require building plans, thermal dynamics, and building-specific knowledge. Deep Reinforcement learning techniques do not require this explicit knowledge encoded into them; hence, they have proved to be a viable alternative exhibiting remarkable cost and energy savings. However, these data-driven methods require considerable time and data to learn effective policies without prior knowledge. Fields like computer vision and natural language processing have large pre-trained models for fine-tuning domain-specific tasks. Performing transfer learning using these pre-trained models avoids the need to learn the underlying data from scratch, thus, saving time and resources. However, RL hasn't widely adopted this practice of sharing weights from different RL models. Hence, we propose a transfer learning methodology in this work and evaluate whether transfer learning is viable for RL on a building control task.

METHODOLOGY

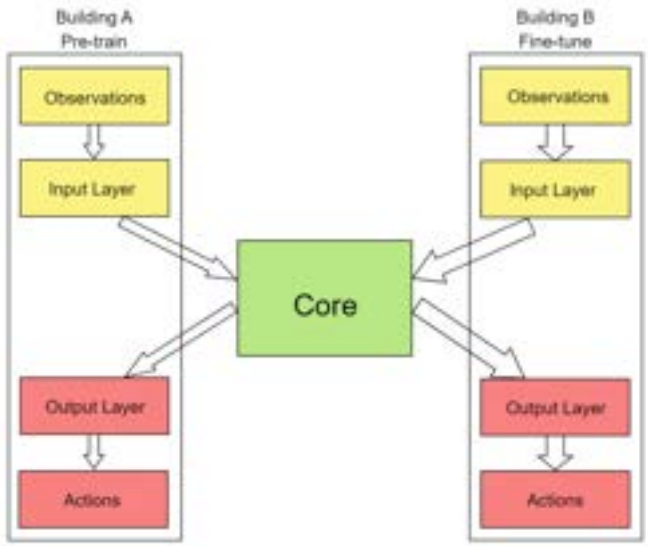

Figure 1: Overview of the Transfer Learning Methodology

Consider Figure 1, Building A is our source building with an observation space $O_A = \{o_1, o_2, \ldots o_n\}$ and an action space $A_A = \{a_1, a_2, \ldots a_n\}$. We pre-train a Deep RL agent on this building using PPO or SAC. We save the neural network weights for the actor and the critic, which will be used for the transfer process. Consider a target building (Building B), with an observation space $O_B = \{o_1, o_2, \ldots o_m\}$ and an action space $A_B = \{a_1, a_2, \ldots a_m\}$, such that $n \neq m$. Here, the input and the output dimensionalities of the neural networks will not match. Hence, a direct transfer would not be possible. To solve this issue, we initialise new input and output layers to match the dimensionality of the new observation and action spaces. We then transfer the Core with the pre-trained weights onto the new network to create a combined architecture. The combined architecture is then fine-tuned using the same algorithm.

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Measuring intensification of cropping cycles in Northern Senegal using time-dependent classifications with Time-Series-to-Image Transformations and Convolutional Neural Networks

Trearty, R., Geever, M., Ó'Fionnagáin, D., O'Farrell, J., Tessema, Y., Codyre, P., Spillane, C., Golden, A.

School of Natural Sciences, Ryan Institute, University of Galway, TAPAS

As part of the TAPAS project we want to measure the effects of investment in the Senegal River Valley as applied to rice production. To do this we can look to satellite data to detect the change in spectral signals coming from the farm land. One change in particular is the move from single to double cropping. There are various ways of detecting the number of crop cycles in a given site (i.e peak detection), however these can often be unreliable. In this poster, we present a technique that converts each time series of satellite data into a single image using the Gramian Angular Field (GAF) approach, and then employs a Convolutional Neural Network (CNN) for cropping classification.

The phenological cycle of rice can be represented by three satellite signals. 1. VH polarization from synthetic aperture radar data obtained from Sentinel-1. detects the flooding of rice paddies, (i.e. the start). 2. The vegetative indices NDVI/EVI tracks the growth of the rice and 3. NDYI (Normalized Difference Yellow Index) detects the ripening stage of the rice. These latter indices are derived from imagery from different optical sensors on Sentinel-2.

The GAF technique transforms each time series into an image that encodes the angular relationships between data points. This allows us to capture the temporal dynamics and patterns of each signal in a compact and interpretable format. The resulting GAF images are then combined into one image by assigning each signal a colour channel (RGB). This final image is then used as input for a CNN, which is trained to classify rice paddies into seasonal cropping groups based on the image patterns.

To evaluate the proposed technique, we created images from the time series of known double cropped, dry season single cropped, wet season single cropped and fallow sites in the SRV. These labelled images were used to train and test a CNN. This technique achieved high accuracy, demonstrating its effectiveness in classifying cropping practices.

Our proposed technique has the potential to significantly improve the efficiency and accuracy of rice cropping classification satellite data. This method could also be extended to a general crop classifier or even a way of measuring crop quality. The combination of GAF and CNN provides a promising approach for leveraging the rich temporal information in satellite data for agricultural applications.

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Adaptive Anomaly Detection Using Reinforcement Learning-based Dynamic Thresholding

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INTRODUCTION

Anomaly detection has been extensively studied in numerous research areas and application domains. It refers to the problem of finding patterns in data that deviate from the expected normal behaviour. Typically, an anomaly score is compared with a domain-specific threshold to determine the degree of abnormality. However, with the dramatic increase in complexity and scale of IT systems, traditional static or expert-defined thresholding approaches have limited adaptability to non-stationary and evolving time series data.

Reinforcement Learning (RL) is promising for its capability of providing advantageous control for dynamic complex systems. It models the sequential decision-making problem as a Markov Decision Process (MDP), where an agent learns iteratively by interacting with the environment and receiving rewards. The goal for the agent is to maximize the total rewards over time. Applying RL in optimal thresholding control is therefore a worthwhile study.

METHODS

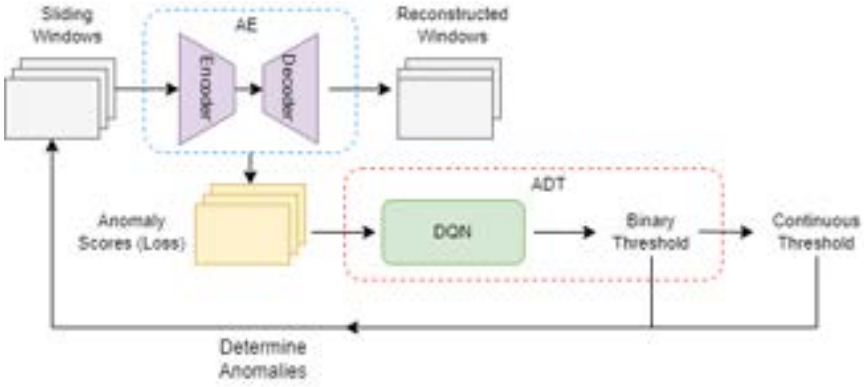

Figure 1: Adaptive Anomaly Detection with Agent-based Dynamic Thresholding

Our study proposes a novel agent-based dynamic thresholding (ADT) framework that utilizes the Deep Q-Network (DQN) algorithm to model thresholding problem as a MDP. An autoencoder (AE) is employed to obtain feature representations and perform anomaly scoring on time series data. ADT uses the anomaly scores as inputs and perform appropriate binary thresholding. Furthermore, the binary thresholds can be easily converted to more fine-grained continuous thresholds that adapt to different user requirements and real-world scenarios.

RESULTS AND DISCUSSION

Experiments on real-world datasets demonstrate that our method has outstanding thresholding capability, data-efficient learning, stability, and robustness, leading to significantly improved anomaly detection performance. In the future, we would like to apply ADT in more complex systems and scenarios.

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Enhancing Data-driven Neuro-Symbolic Visual Understanding and Reasoning with Common Sense Knowledge

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2. Insight SFI Research Centre for Data Analytics, Data Science Institute

Artificial intelligence has made incredible progress in basic vision tasks using deep learning techniques that can accurately detect concepts in visual content. However, the existing techniques rely on labelled datasets that have biased distributions of visual relationships and lack common sense knowledge about visual concepts. As a result, these techniques have limited visual relationship prediction performance, limiting the expressiveness and accuracy of high-level visual understanding and reasoning techniques. We employed deep neural networks to predict visual concepts, including objects and visual relationships and linked them to generate semantic image representation. To alleviate the challenges above, we leveraged rich and diverse common-sense knowledge in heterogenous knowledge graphs to systematically refine and enrich the generated image representation. As a result, we observed significant improvement in recall rates of visual relationship prediction (7% increase in Recall@100), expressiveness of the representation, and the performance of downstream visual reasoning tasks, including image captioning (15% increase in SPICE score) and image reconstruction. The encouraging results depict the effectiveness of the proposed approach and the impact on downstream visual reasoning.

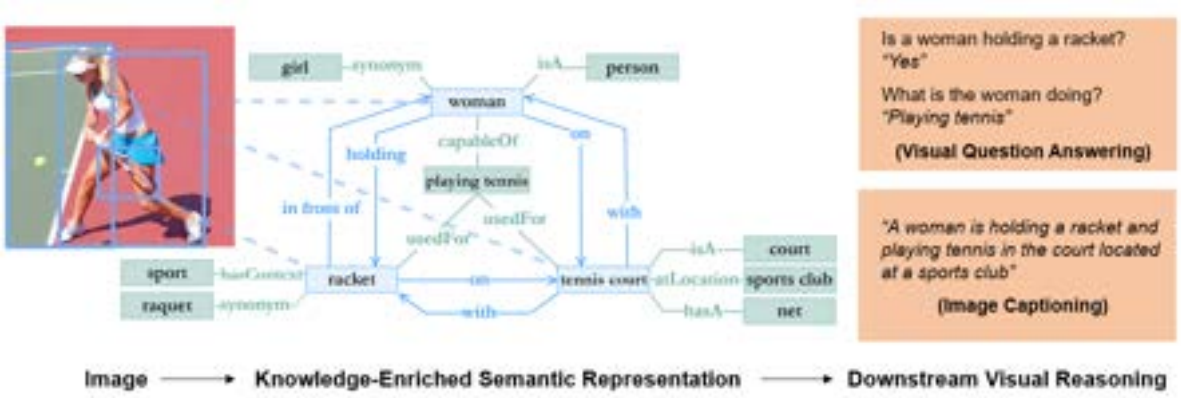

Figure 1: An illustration of the proposed approach, which integrates data-driven deep learning techniques for object detection and visual relationship prediction with common sense knowledge enrichment to enhance the accuracy and semantic expressiveness of visual understanding and reasoning techniques.

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A Robust Elemental Screening Method for Cell Culture Media used in Biopharmaceutical Manufacturing based on Microwave Plasma Atomic Emission Spectroscopy.

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INTRODUCTION

Cell culture media (CCM) are raw materials required for biopharmaceutical manufacturing. CCM is a mixture of inorganic salts, sugars, amino acids, and other additives required for cell culture. Lot-to-lot elemental variability of CCM can lead to inconsistencies in manufacturing processes that affect the final product quality and yield. There is a need therefore for a low-cost, rapid, and robust elemental screening method that can help identify issues early and reduce process variability. Here, we evaluated MP-AES as a potential alternative to more expensive ICP-MS and ICP-OES based methods for media routine screening.

MATERIALS AND METHODS

Several dilution levels of a model chemically defined medium (eRDF) were evaluated to assess matrix effects. A panel of elements (n=10) ranging from high concentrations (Na, K, Ca, Mg) and low concentrations (Fe, Ni, Cr) were selected for screening. In addition to external standardization (ExStd), signal correctional strategies featuring traditional internal standardization (IntStd) and intrinsically occurring plasma molecular species (MolSpecCorr) were evaluated for their potential to improve method performance. Method performance was comprehensively assessed using accuracy, precision, linearity, and reproducibility.

RESULTS AND DISCUSSION

High dilution levels were found to reduce matrix and non-linear effects for high concentration elements, but decreased sensitivity for low concentration elements, necessitating different dilution levels for both levels. ExStd alone had acceptable method performance for spiked samples (<5% RSD, 100 ± 29% recovery). IntStd correction improved precision and accuracy for Ca, K, Cr, and Zn but decreased precision for remaining analytes, while also generally improving the linearity of calibration curves and reducing limits of quantification. MolSpecCorr was inadequate due to low intermediate precision. MP-AES has potential for use as a PAT in biopharmaceutical manufacturing, reducing costs and manual labour for routine elemental screening, but its instrumental design should be modified for simultaneous analysis to improve sample throughput and analysis times.

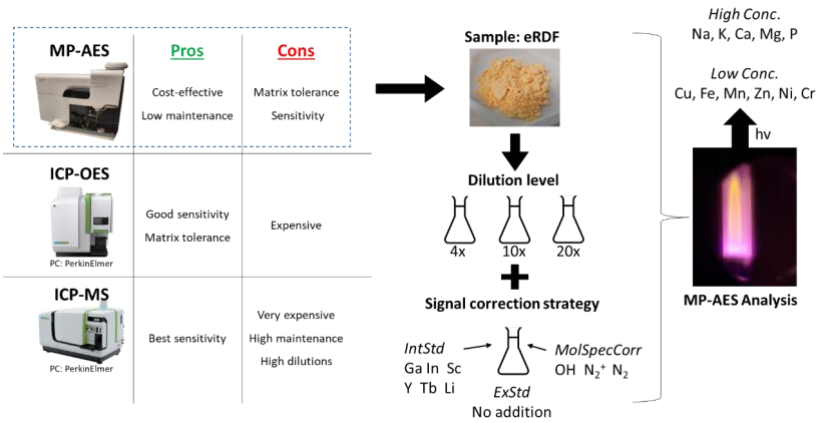

Figure 1: (Left) Comparison of MP-AES to conventionally used elemental analysis techniques. (Right) sample preparation, dilution levels and signal correction strategies employed for elemental screening using MP-AES.

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CHSH game with 3 players in a triangle with bi-partite and tri-partite entanglement

Victoria Sánchez Muñoz
Supervisor: Michael Mc Gettrick

The Clauser-Horne-Shimony-Holt (CHSH) inequality [1] is one of the most famous tests that provided a quantitative gap between the classical and the quantum theory. The CHSH inequality can also be illustrated using a simple game of 2 players with binary inputs and outputs, referred to as the CHSH game. In the present poster, the CHSH game is explained as well as a proposed extension to 3 players playing it pairwise in a triangle configuration (A with B, B with C, and C with A). Two situations are presented and analysed: when the players play the games sharing *two 3-qubit* quantum states; and *three 2-qubit* quantum states. The results show a clear distinction between both scenarios, leading to the conclusion that the type of entanglement used affects the performance.

Supported by the College of Science and Engineering at University of Galway.

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The Correlation between NDVI and Surface Temperature Using Remote Sensing Data: A case study of Delta area, Senegal River Valley

Tessema Y., Trearty R., Geever M., Ó'Fionnagáin D., O'Farrell J., Golden A., Spillane, C.

Land cover explains the physical nature of the Earth's surface in a specific area. Land cover is a reflection of the Earth's surface's observable spatial cover comprising complex classes such as agricultural areas, built-up areas, barren lands, forests, water bodies, as well as wetlands. Change detection and monitoring of the land use/cover assist decision-makers to understand the dynamics of the environmental change to assure sustainability development. Land use change such as paddy rice expansion influences regional climate through influencing diurnal, nocturnal and seasonal LST. Liu et al., (2019) and Liu et al., (2022) noted paddy rice land expansion in semi-arid areas affects near-surface temperature and regional atmospheric humidity. As part of the TAPAS project we are exploring the spatial and temporal trends of paddy rice expansion in the Delta area, Senegal River Valley using Earth Observation satellite images. Between 2010 and 2015 the Millennium Challenge Cooperation has been implementing project aiming to improve paddy rice farming expansion through enhancing the irrigation scheme. This poster focuses to explore the relationships between surface temperature and the vegetation spectral indices of NDVI using MODIS NDVI and LST data from 2010 to 2015 in the Delta area. This assessment helps to characterize the impact of paddy rice expansion on LST. Further, understanding the relationships of NDVI and LST can have an essential role in monitoring drought, soil moisture, rainfall, and tracking crop growth, crop yields, weather impact, and the environmental and economic effects.

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INNOVATION FOR HEALTH

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EXPLORING ECG AS A NON-INVASIVE TOOL FOR PREDICTING BIRTH ASPHYXIA IN NEONATES

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INTRODUCTION

Birth asphyxia is the failure of establishing breathing at birth and results in approximately 1 million neonatal deaths annually. Surviving neonates are at risk of developing long-term neurological abnormalities and disabilities. Current neonatal monitoring practices primarily rely on heart rate analysis, which has a high rate of false-positive results. The blood-gas analysis is a common diagnostic tool used to determine the presence and severity of asphyxia. Despite its usefulness, there are significant challenges associated with blood sample collection due to the small size of neonates and the limited amount of blood that can be safely collected. Additionally, due to the invasive nature of the procedure, it is not suitable for continuous monitoring. This study explores Neonatal electrocardiogram (ECG) analysis as a non-invasive alternative to blood gas analysis for continuous monitoring of neonatal asphyxia. The objective of this study is to identify specific ECG features that can be used to differentiate between healthy and asphyxiated neonates.

MATERIALS AND METHODS

A dataset containing recordings of neonatal ECG and intermittent pH values was used to extract various ECG features. ECG feature extraction algorithms were employed to extract relevant ECG features after pre-processing ECG signals for noise removal. Statistical analysis of extracted ECG signals was performed to identify the best features that can be used to detect asphyxia. Seven features were found to be significantly different among the normal and asphyxiated neonates. Moreover, a support vector classifier was employed to classify normal and hypoxic data, and the potential for estimating pH from these features was explored using linear regression and support vector regression.

RESULTS AND DISCUSSION

The study results indicate that the selected ECG features can successfully differentiate between normal and hypoxic data and predict pH levels. The proposed ECG-based approach offers a non-invasive and effective method for the early detection and monitoring of neonatal asphyxia.

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MEF2C Dysregulation and its Association with Neuropsychiatric Disorders and Cognitive Function in Human Neural Cells

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INTRODUCTION

Myocyte Enhancer Factor 2C (MEF2C) is a transcription factor that plays a crucial role in neurogenesis and synapse development. Genetic studies have identified MEF2C as a gene that influences cognition and risk for neuropsychiatric disorders, including autism spectrum disorder (ASD) and schizophrenia (SCZ). Here, we investigated the involvement of MEF2C in these phenotypes using human-derived neural stem cells (NSCs) and induced neurons (iNs), which represented early and late neurodevelopmental stages. For these cellular models, MEF2C function had previously been disrupted, either by direct or indirect mutation, and gene expression assayed using RNA-seq.

MATERIALS AND METHODS

We integrated the RNA-seq data with MEF2C ChIP-seq data to identify dysregulated direct target genes of MEF2C in the NSCs and iNs. Linkage disequilibrium score regression was performed to investigate if these genes are enriched for heritability contributing to the SCZ and cognitive function. Cell type enrichment analysis was conducted to identify the individual affected cell types and brain regions. Gene ontology analysis was performed to elucidate the underlying biological mechanisms.

RESULTS AND DISCUSSION

Several MEF2C direct target gene-sets were enriched for SNP-based heritability for intelligence, educational attainment and SCZ, as well as being enriched for genes containing rare *de novo* mutations reported in ASD and/or developmental disorders. Analysis of single-cell RNA sequencing data revealed that several excitatory glutamatergic neurons in the hippocampus and cortex, including deep layer pyramidal cells, CA1 principal cells, and entorhinal cortex, were enriched for MEF2C direct-target genes. Overall, our results suggest that genes dysregulated as a consequence of either direct or indirect MEF2C disruption contribute to SCZ development and cognitive function from early stages of neurodevelopment. These genes are involved in a wide range of biological processes including neural/glial cell differentiation, cell migration, protein modification and catabolism in NSCs, as well as mitochondrial function and energy production in iNs.

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Exploring Microcrack Formation and Propagation in Bone Ultrastructure: Insights from Computational Modeling

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INTRODUCTION

Bone is a natural biological composite material with exceptional mechanical properties resulting from its intricate structure across seven hierarchical levels [1]. At the macro-level, bone can be categorized into two types: a dense cortical shell and spongy trabecular core, both of which comprise lamellar bone at the ultrastructural level. Understanding structure-property relationships for bone elasticity has been a focus of much research. While power law equations have been commonly used to describe the relationship between elastic modulus and density at the macrostructural level, more intricate models are necessary for analysing tissue-level properties, particularly for failure behavior, where only a limited number of models currently exist [2], [3]. The objective of this study was to investigate the fracture behavior of lamellar bone and the onset and evolution of microcracks in bone ultrastructure.

MATERIALS AND METHODS

In this study, two-dimensional geometries of bone ultrastructure were created using the finite element package ABAQUS. The model comprised of cylindrical mineralized collagen fibrils (MCFs) embedded in an extra-fibrillar matrix, which is comprised of hydroxyapatite minerals (transversely anisotropic elastic material [4]) covered with interphase regions filled with non-collagenous proteins (NCPs) and water. The MCFs were modelled as transversely anisotropic elastoplastic material [5], while the interphases were described through a phase-field damage model. The phase-field approach was capable of capturing the onset and propagation of microcracks by introducing a non-local order parameter ϕ to describe the material condition [6]. The model was subject to uniaxial tension to study the onset and evolution of microcracks, and a parametric study was carried out by varying the MCFs volume fraction and interphase strengths.

RESULTS AND DISCUSSION

The study found that microcracks emerged from the mineral-rich area of the extra-fibrillar space under both transverse and axial loading when the interphase strength of MCFs was higher than that of the minerals. Under uniaxial loading, microcracks showed no preference between the interphase regions when the interphase strength of MCFs was lower than that of the minerals. Simulating crack propagation in notched specimens demonstrated that MCFs did not affect the crack path at low MCF volume fractions but could either facilitate cracking or act as a barrier to crack propagation at high volume fractions. This research shed insights into the role of the hierarchical organization of collagen fibrils and NCP interphase regions on the fracture properties of bone in ultrastructural level.

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Employing Blockchain and Artificial Intelligence to innovate Sensitive Data Handling practices in Mental Health Services

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Safeguarding patient confidentiality in healthcare, particularly in mental health, is crucial. Unlike general medical records, mental health records contain delicate information which upon violation could result in severe repercussions. Therefore, it must be dealt with a customized approach. Several IT Solutions have been introduced for the governance of mental health records. We aim to evaluate existing practices and IT solutions for management of these records and propose a solution that offers security and privacy without compromising usability. Our research involves Irish Mental Health Services as a case study.

We designed an extensive methodology that involved a thorough literature review, interviews of mental health professionals, interaction with mental health organizations, analysis of inspection reports by Mental Health Commission (MHC) and a comparative evaluation of IT solutions to propose a suitable one.

The literature survey unfolded significant research gaps related to Blockchain and Mental Health. We then studied the MHC inspection reports and conducted interviews with professionals who had experienced working at the Irish Mental Health Services. Key findings revealed that data collection and storage primarily rely on paperwork, with limited use of technology. They brought our attention to the need of storing nursing notes electronically.

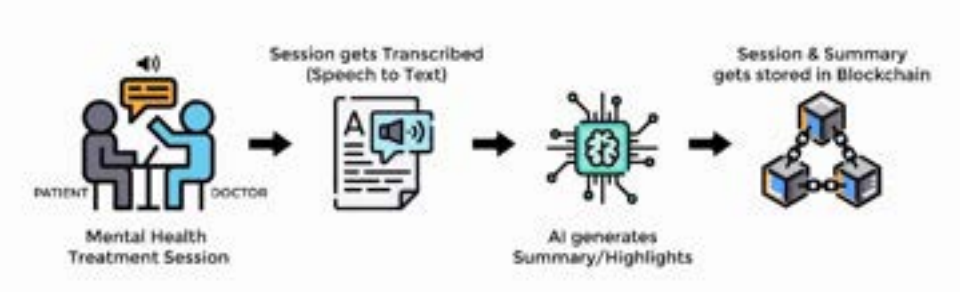

Figure 1: Proposed approach for Blockchain and AI-enabled Mental Health Data Handling

For experimentation, we evaluated two blockchain solutions; Ethereum and Hyperledger Fabric in terms of different attributes. Hyperledger Fabric turned out to be a more suitable option in all relevant aspects. Role-based access control (RBAC) governance would be used to regulate data access between medical and administrative staff. Data management architecture would have separate layers for storage, logic, and interface.

This led us to proposing an IT solution (Figure 1) with 3 attributes, i.e., security, privacy, and usability. Blockchain would ensure security and privacy, but it might lower the usability measure. Therefore, we propose using Speech-to-Text transcription. Simply put, the treatment session would get transcribed and recorded as an immutable Blockchain transaction once reviewed. We would also utilize artificial intelligence to summarize the nursing-notes with potential indications of disorders. This research would contribute to the future development of mental health specific IT solutions.

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Magnetics-free DC-DC Power Conversion using Piezoelectric Transformers

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The performance of Piezoelectric Transformers (PTs) in power converter applications is under investigation. PTs were used earlier in power supplies for LCD backlights in laptops, PDAs and TVs. Other recent proposed applications are X-ray generation, ozone generators, LED lighting, fluorescent lamp ballasts, image-forming apparatus, and AC-DC adaptors. Applications in medical equipment are considered in this work.

PTs are a special type of transformers which do not make use of electromagnetic energy transfer mechanisms. The principle is to use vibration as a coupling medium to transfer input electrical energy to mechanical energy and then again back to electrical energy at the output with different voltage amplitude. The input section is an actuator that converts input electrical signal to mechanical vibrations which then are coupled to the output section i.e transducer, which transforms it to electrical signal with different amplitude. Lead zirconate titanate (PZT) or modified PZT-type ceramic materials are being used for PT applications with their unique properties like high quality-factor, response-speed, and power-density, compared to other piezoelectric materials.

PT has very low Electromagnetic Interference (EMI) profile that makes it suitable for application in a high strength magnetic environment such as in Magnetic Resonance Imaging (MRI) and computed tomography applications where the presence of magnetic fields can affect the normal working of a magnetic transformer. The power density of PTs is higher than magnetic transformers and that makes them suitable for space applications where light-weight power converters are essential. A PT based power converter will be developed, tested and performance investigation will be carried out for a pulsed-power medical application.

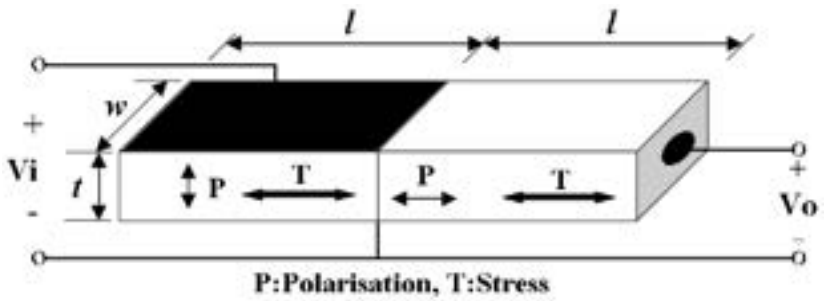

Figure 1: Basic structure of Rosen PT.

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Development of 3D Vascularized and Humanized Models of Healthy and Osteoporotic Bone

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INTRODUCTION

Our previous research has revealed that osteoporosis causes fundamental changes in bone composition and bone cell responses to mechanical loads. We recently developed a simplified 3D model of bone that uncovered the effect of estrogen deficiency on mineralization and mechanosensitivity of osteocytes. This research seeks to build upon these studies, particularly by providing advanced mineralisation bone models that are mechanically mimetic of bone tissue in vivo. Vascularisation can promote mineralization *in vitro* and *in vivo,* particularly in endochondral ossification. Thus, here we followed an endochondral ossification priming approach to develop a 3D vascularized bone model to study estrogen deficiency and bone mineralization.

MATERIALS AND METHODS

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 HUVECs and HBMSCs were added to the chondrogenic template to initiate vascularization. Constructs were cultured in osteogenic media with estrogen supplementation until day 43. Estrogen was withdrawn from the constructs at day 43 and were cultured for a further 21 days (until day 63). Biochemical assays, histological staining and real time PCR were performed to analyse the effects of vascularization and estrogen deficiency on the mineralization of the constructs.

RESULTS AND DISCUSSION

The current study provides an *in vitro* 3D vascularized and humanized bone model that recapitulates estrogen deficiency representative of the osteoporotic phenotype. Our results confirm the formation of CD31+ distinct vessel-like structures in the 3D constructs (Fig. 1 B, C, D). The expression of early osteoblast markers DMP-1 and BSP-2 confirmed the osteogenic differentiation of the 3D constructs (Fig. 1 G, H). A significant increase in the calcium content was reported in the non-vascularized and estrogen withdrawal group at day 52 and 63, which is in line with our previously published research findings (Fig 1 E, J). However, the total calcium content in the vascularized constructs is reduced due to estrogen withdrawal (Fig. 1 J). Such changes might explain the heterogeneity in mineral distribution in osteoporotic bone tissue.

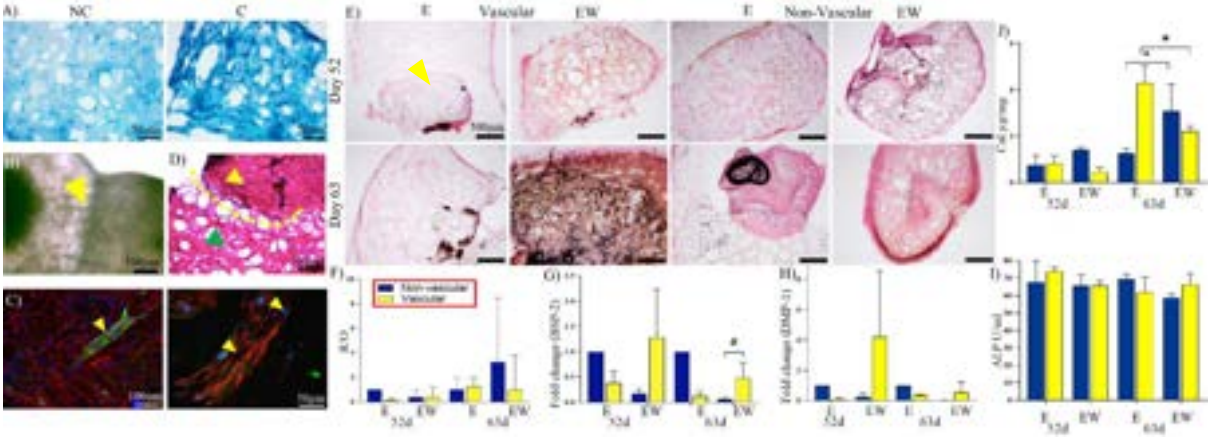

Fig. 1. (A) Alcian Blue staining Chondrogenic (C) vs Non-Chondrogenic (NC). (B, D) Cellular attachments between chondrogenic template and outer gel (H&E staining), (C) CD31(green), Actin(red), DAPI(blue) immunofluorescence staining of vascularized construct at D52, (E) Von Kossa staining, (I) ALP activity at all-time points, (J) Calcium (normalized to weight of construct), (F) Gene expression of RANKL/OPG ratio (G) BSP-2 and (H) DMP-1 normalized to NV-E+ at D52 and D63. Significant differences ($p < 0.05$) relative to continuous estrogen (*) and relative to non-vascular (#).

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A PET radiomic signature to predict survival in non-small cell lung cancer patients

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INTRODUCTION

Non-small cell lung cancer (NSCLC) is one of the significant causes of cancer death worldwide. ^{18}F-FDG positron emission tomography (PET) has become a significant imaging modality for diagnosis and treatment response assessment and has reached widespread approval in clinical practice. Radiomics extracts complex quantitative imaging biomarkers from different imaging modalities and can provide valuable information about tumours. The goal of this study was to build a PET-radiomic based model to predict survival outcome of NSCLC patients.

METHODS

Several NSCLC datasets from the Cancer Imaging Archive (TCIA) were access for analysis in this study (n=170) and were subsequently partitioned into training and testing cohorts (70:30). Tumour segmentation was performed in 3D-Slicer and 944 radiomics features were extracted from the segmented tumours. Feature selection was done through stability assessment. After identifying the list of most significant features via a cox-univariate analysis, we built a multivariate model combining PET-radiomic features and clinical risk factors to predict overall survival. The receiver operating characteristic (ROC) curve was generated to evaluate the model.

RESULTS AND DISCUSSION

After feature selection and univariate analysis, 47 radiomic features were selected to be analysed for model building. Three radiomic features containing *original_firstorder_90Percentile*, *wavelet-HLH_glcm_DifferenceEntropy*, *wavelet-LLL_glrlm_LongRunEmphasis* and age, N-stage and M-stage were included in the clinical-radiomic model ($P < 0.05$). The area under the ROC curve (AUC) values at 1-year and 3-year survival were 0.80 and 0.81 in the training set and 0.82 and 0.79 in the testing set. The results indicated the ability of PET-radiomic features to predict overall survival in NSCLC patients. Given that lung cancer is one of the most diagnosed malignancies, such radiomics analysis has significant potential to assist with the management and improvement of each patient's treatment.

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An *In ovo* platform for assessment of chemotherapies and immunotherapies against ovarian cancer

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INTRODUCTION: *In ovo* method, which allows delivery of various biologics and supplements to chicken embryos, was established to minimize the use of animal in research. This model served as an alternative for animal tumor models to investigate characteristics of tumor growth, metastasis, and efficacy of cancer therapies in preclinical oncological research[1]. Grafting of tumor cells has been successfully applied to address a broad range of scientific questions with diverse methodological approaches[2]. Engrafting of human immortalized cell lines and patient-derived xenografts already featuring a complex and unique microenvironment has successfully been applied. Though there is research gap to clarify if *in ovo* model represents a faithful epitome for evaluating immunotherapies in preclinical oncological research. To address this research gap, our group is establishing this model firstly for assessment of traditional chemotherapies, and then we will expand this to deliver chemotherapies along with natural killer (NK) cells.

MATERIALS AND METHODS: The dose response curve of cisplastin chemotherapy after 24 hours treatment was determined against the Luciferase-labelled human ovarian cancer cell line (Luc+OVCAR-3 cells) using an Alamar blue assay *in vitro*. 2×10^6 Luc+OVCAR-3 cells will be injected to the fertilized eggs through CAM. And then treated with either traditional chemotherapy (cisplatin) +/- novel cell immunotherapies (NK cells). This will be measured by bioluminescence Imaging (IVIS) and histopatholy. We have carried out a pilot study to establish this model.

RESULTS AND DISCUSSION: *In vitro* the inhibitory concentration (IC) of cisplatin that induces 20% (IC20) and 50% (IC50) Luc+OVCAR-3 cell death was determined to be 7.79µM and 13.63 µM respectively. We are now applying these concentrations to *in ovo* model to demonstrate a dose response with traditional chemotherapies. We will expand our model to assess novel cell immunotherapies with the overall aim of reducing the use of animal models for the assessment of cancer therapies.

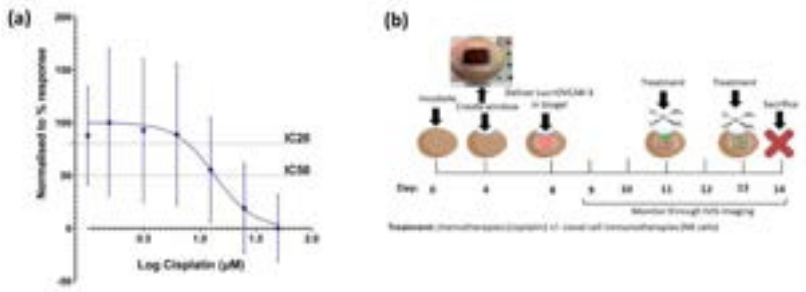

Figure 1: (a)*In vitro* cytotoxicity of cisplatin chemotherapy against Luc+OVCAR–3 (b) schematic of in ovo study plan

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Novel patient-specific beating heart model incorporating active contractility and a pseudo-fluid domain

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INTRODUCTION

In this study a framework to construct an efficient patient-specific finite element model of the left ventricle (LV) from tri-planar CINE echography scans is developed. A novel approach of implementing a pseudo-fluid domain inside the ventricle is proposed. Simulations are shown to be several orders of magnitude faster than conventional fluid-structure interaction (FSI) models of the LV.

MATERIALS AND METHODS

Patient-specific geometries were created by generating splines based on tri-planar CINE echography scans of healthy human hearts using MATLAB (Figure 1A). Tetrahedral meshes were generated across two separate domains: a solid domain representing the myocardium, and a pseudo-fluid domain representing the blood in the LV. We develop novel user material subroutines (UMATs) to simulate active contractility in the myocardium and the haemodynamic behaviour of the blood in the ventricle. During systole, the pseudo-fluid domain behaviour is based on a Windkessel formulation, where the total volume of all elements in the domain is tracked and used to determine the volumetric flow of blood from the LV to the aorta.

RESULTS AND DISCUSSION

Figure 1B shows the computed distribution of myocardium active stress and fluid pressure during isovolumetric contraction (IVC) and end-systole. Computed PV loops are shown in Figure 1C for a simulation of Inferior Vena Cava Occlusion (IVCO). These are consistent with the clinical finding that stroke volume and ventricular pressure reduce over a series of cardiac cycles. Furthermore, our novel approach for simulation of ventricular hemodynamics using a pseudo-fluid domain allows the simulation of a cardiac cycle in under five minutes in contrast to several hours taken by established FSI models.

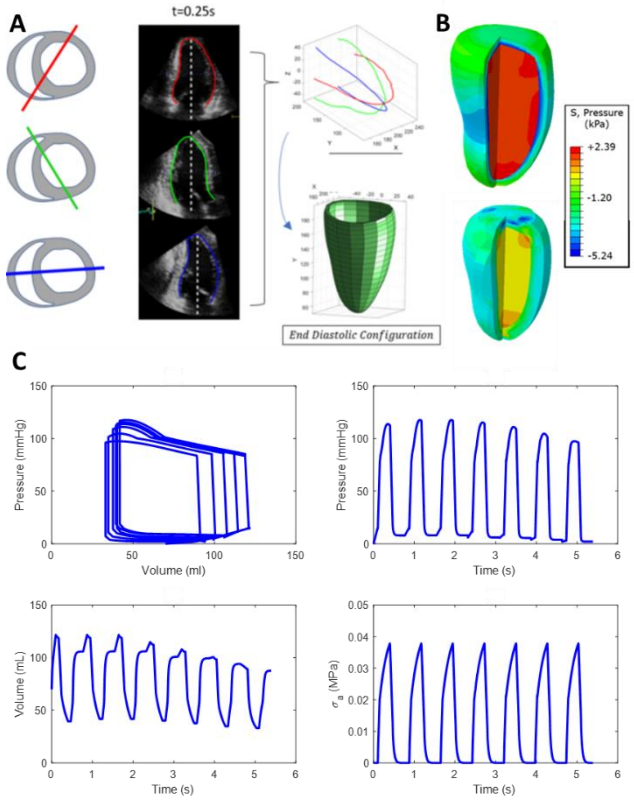

Figure 1: (A) Construction of FE model from tri-planar CINE echography scans; (B) distribution of myocardium active stress and fluid pressure during IVC and end-systole; (C) Computed PV loops and pressure, volume & active contractility-time relationships.

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The Effect of Actuation of a Medical Implant on Macrophage Polarisation

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INTRODUCTION

The Foreign Body Response (FBR) is a crucial obstacle to the clinical translation of medical implants[1,2]. As primary cells in the FBR, macrophages regulate inflammation and direct fibroblasts to form a fibrous capsule (FC) at the implantation site[3]. Our group's previous studies demonstrated that intermittent actuation (IA) of an implanted reservoir significantly reduced the FBR in rat[4] and mouse[5] models. We hypothesise that IA may affect the polarisation of pro-inflammatory (M1) and anti-inflammatory (M2) macrophages, as the M1/M2 ratio is a critical factor in the FBR.

MATERIALS AND METHODS

Human leukemia monocytic cells (THP-1) will be treated with 15 ng/mL Phorbol-12-myristate-13-acetate (PMA) to differentiate into macrophages. Macrophages will be stimulated with Interferon-gamma (IFN-γ) and lipopolysaccharide (LPS) (50 and 15 ng/mL, respectively) to the M1 phenotype. Fluorescence-activated cell sorting (FACS) analysis will confirm the M0 and M1 phenotypes. M1 cells will be seeded onto the actuatable membrane of the devices. Actuatable devices will be manufactured and actuated as previously described[4]. Experimental groups will include a static control group and two actuation regimens of 27.5 kPa and 68.9 kPa at 1 Hz for five minutes every 12 hours. The cell viability, metabolic activity, Arginase-1 (M2 marker), and iNOS (M1 marker) will be quantified, and actuated groups will be compared to controls (study plan in Figure 1).

RESULTS AND DISCUSSION

This study will investigate the effect of IA on viability, metabolic activity, and polarisation of macrophages. With few studies focusing on the role of macrophages on FC thickness, this investigation can enhance our understanding of the role of actuation in macrophage polarisation and function during the FBR. It can also give a better insight into the role of actuatable devices in tackling the issue of implant-mediated FBR, leading to improved therapy delivery and efficient treatment of various diseases.

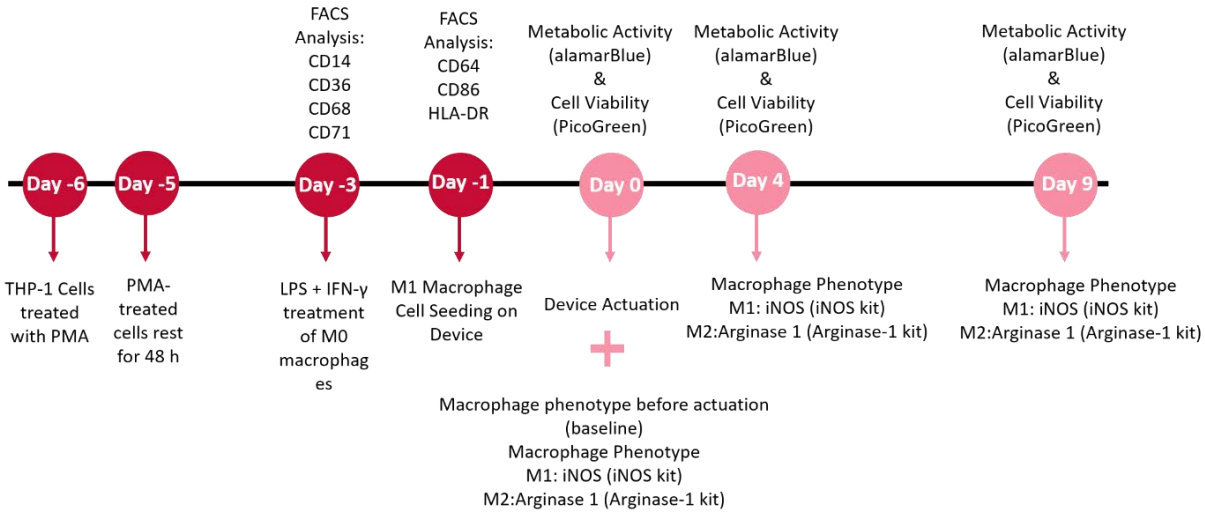

Figure 1: Study plan.

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In Silico Clinical Trials of Transcatheter Aortic Valve Replacement in the Bicuspid Aortic Valve

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INTRODUCTION

Transcatheter aortic valve replacement (TAVR) is an effective treatment for aortic stenosis. However, devices are being used 'off-label' to treat bicuspid aortic valve (BAV) patients, where patient-device interaction is not widely understood. Finite element (FE) analysis and computational fluid dynamics studies have investigated TAVR in the BAV [1,2]. More recently, fluid-structure interaction (FSI) approaches have investigated native BAV biomechanics [3], but not to consider the performance of TAVR in this cohort. Machine learning (ML) can be applied for deep-learning based patient-specific reconstruction and physics-informed ML models [4]. This research aims to develop a framework for conducting in silico trials of TAVR in the BAV.

MATERIALS AND METHODS

FE models of the ACURATE neo2 were developed using Abaqus/Explicit (Dassault Systemes), assuming representative material properties and pressure-based loading conditions. Models were validated by in vitro test data conducted within a ViVitro Pulse Duplicator. A fully-coupled FSI model of the TAVR device is in development coupling Abaqus to FlowVision (Capvidia).

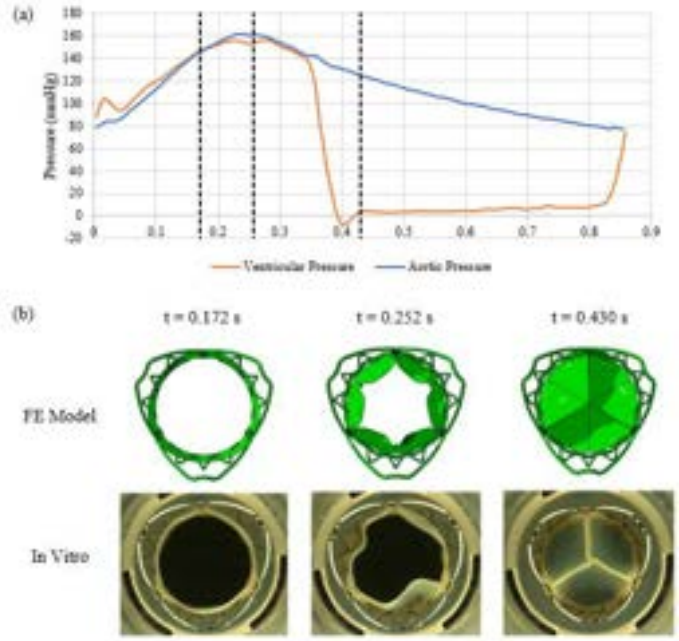

Figure 1: (a) Pressure-based loading conditions (b) Validation of FE model with in vitro testing data

RESULTS AND DISCUSSION

FE model predictions aligned with in vitro data (Fig. 1). Following development of FSI models, both kinematic and haemodynamic data can be evaluated. These results will inform the framework for assessing the performance of TAVR within BAV aortic root models constructed using MIMICS (Materialize). Following this, ML will be applied for patient-specific reconstruction to predict the performance of TAVR devices in these anatomies. The proposed framework may inform development of next-generation TAVR devices to mitigate complications in 'off-label' cohorts, whilst aligning with global initiatives to develop virtual health models.

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EXPERIMENTAL AND COMPUTATIONAL MECHANICS OF BONE FRAGILITY IN TYPE-2 DIABETES: A LONGITUDINAL INVESTIGATION USING ZUCKER DIABETIC FATTY RATS

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INTRODUCTION

Type-2 Diabetes (T2D) is associated with an increased risk of bone fractures [1]. Despite not having a reduction in bone mineral density (BMD) [2]. It has been hypothesized that unwanted non-enzymatic crosslinks form between proteins in the organic phase of bone, known as Advanced Glycated End-products (AGEs), impairing the tissues mechanical integrity. In this study, a combined experimental-computational approach is used to investigate the role of tissue microarchitecture and tissue composition on the fracture mechanics of T2 diabetic bone using a Zucker Diabetic Fatty (ZDF) rat model.

MATERIALS AND METHODS

A longitudinal study using Male [ZDF: fa/fa (T2D) and Zucker Lean: fa/+ (Control)] rats was conducted, with animals euthanized at 12-, 26- and 46-wk of age (n = 7-9, per age, per condition). Serum markers were evaluated to provide information on the glycaemic control, bone turnover and general health. Fluorescent and non-fluorescent AGEs were measured via fluorometric assays and high performance liquid chromatography, respectively. Micro-CT was used to image femurs pre- and post-fracture as well as the distal metaphysis trabecular and cortical microarchitecture. Femurs were fracture toughness tested until failure. Immediately after, a sideways fall test was simulated using a custom-built rig. Image-based finite element (FE) models were generated to simulate a sideways fall test.

RESULTS AND DISCUSSION

Our study uncovers the multi-factorial mechanisms that contribute to bone fragility in a Type-2 Diabetic animal model, showing that there are many more mechanisms at play other that AGE accumulation. Serum markers showed that the diabetic state disrupted normal bone maintenance, with possibly impaired osteoblast activity. Carboxylmethyl-lysine (CML), was significantly increased, indicating increased glycoxidative damage. Micro-CT also showed that trabecular bone morphometry of the diabetic (fa/fa) cohort was impaired, particularly at 46-weeks. Fracture toughness testing revealed that these sub-tissue alterations lead to significant reductions in tissue-level cracking toughness. Image-based FE results shown are preliminary and future work will build on this model to decouple any geometrical differences from tissue composition.

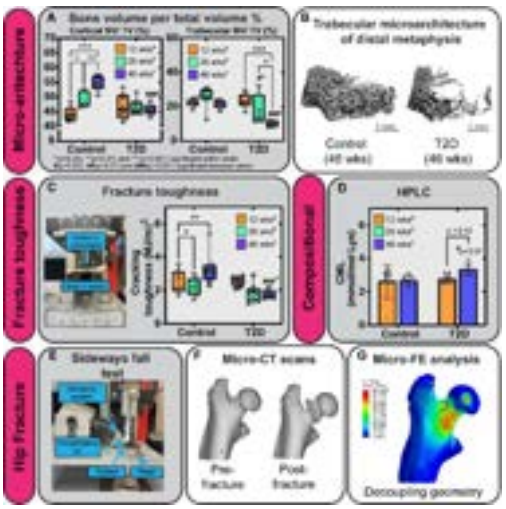

Figure 1 (A-B) Microarchitectural analysis; (C) Fracture toughness set-up/results; (D) CML levels from cortical bone; (E) Sideways fall test set-up; (F) Pre-and post-fracture CT-scans and (G) an FE model.

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Transcriptomic characterisation and identification of potential neoantigens in cancer-associated fibroblasts in breast cancer.

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* These authors jointly directed this work

INTRODUCTION

Cancer-associated fibroblasts (CAFs) are a heterogeneous cell type forming part of the tumour microenvironment. CAFs have been shown to support angiogenesis and tumour growth, and to induce therapeutic resistance through the production of extracellular matrix. Here, we investigate the therapeutic potential of targeting CAFs, either transcriptionally or via CAF-specific neoantigens.

METHODS

CAFs and matched tumour-associated normal fibroblasts were cultured from tissue taken from 12 patients with breast cancer. Bulk RNA-sequencing was carried out on all samples, and whole-exome sequencing (WES) was carried out on samples from 6 patients. CIBERSORTx [PMID:31960376] was used to characterise sample cell type proportions, with publicly available data from three distinct CAF subpopulations used as a reference. NeoFuse [PMID:31755900] was used to identify predicted fusion neoantigens from the RNA-seq data, and the WES data was analysed using the nf-core/sarek pipeline [PMID:32269765].

RESULTS AND DISCUSSION

The immunosuppressive-myofibroblastic subpopulation was found to be the most prevalent in our samples, however most samples also contained the normal-like CAF subpopulation. This analysis confirms the heterogeneity of the cultured fibroblasts, with important implications for therapeutic strategies targeting CAFs. Four of the 12 patients were predicted to have at least one fusion neoantigen specific to their CAF sample and a total of 213 putative missense single nucleotide polymorphisms (SNPs) were called across all samples. Seven SNPs remained following manual filtering using a combination of: visual inspection with Integrative Genomics Viewer (IGV), outputs of multiple variant callers, and expression of the variant in the matched RNA-seq data. Future work will focus on neoantigens arising from these SNPs as well as the identification of additional candidate neoantigens from indels, splice variants, and other sources.

Ollscoil na Gaillimhe University of Galway
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Microarray analysis reveals temporal changes in gene expression associated with matrix alteration and secondary mineralisation in long-term estrogen deficiency

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INTRODUCTION: Osteoporosis is associated with changes in bone matrix composition and osteocyte mechanotransduction, but the relationship between these changes and bone loss and formation is not yet fully understood. The objectives of this study were to (1) conduct comprehensive temporal analyses of gene expression associated with extracellular matrix degradation, matrix production, and mechanotransduction, and (2) correlate these findings with changes in trabecular microarchitecture and mineral and matrix composition in ovariectomized rat bone tissue.

MATERIALS AND METHODS: Female retired breeder Wistar rats were randomly assigned to either bilateral ovariectomy (OVX) or sham operation (SHAM). High-resolution micro-CT and raman spectroscopy were used to analyse trabecular microarchitecture and to assess mineral-to-matrix ratio and collagen maturity. To investigate the molecular changes associated with estrogen deficiency-induced bone changes, a microarray approach was implemented to facilitate temporal analyses of gene expression associated with extracellular matrix degradation, matrix production, and mechanotransduction.

RESULTS AND DISCUSSION: Microarray gene expression analysis revealed a downregulation of matrix degradation markers (Nfatc-1, Ctsk) and an upregulation in inflammatory marker IL1β at week 4 post-ovariectomy (Fig. 1a), which coincided with the end of rapid bone loss. By week 14, when the rate of bone loss had reduced and alterations in mineral and matrix composition were observed, microarray analysis reveled a significant increase in early matrix formation genes (Col1α1, Col1α2, and Ocn) (Fig. 1b). Mineral heterogeneity and collagen maturity were negatively correlated with osteogenic markers (OPG, Phex) and IFT88, which is implicated in mechanosensation by primary cilia (Fig. 1c). Early matrix formation genes were positively correlated with Connexin 43, which encodes Cx43 mechanosensory hemichannels (Fig. 1c). This study provides important insights into the temporal nature of gene expression during estrogen deficiency, revealing changes that may explain secondary mineralisation in longer-term estrogen deficiency.

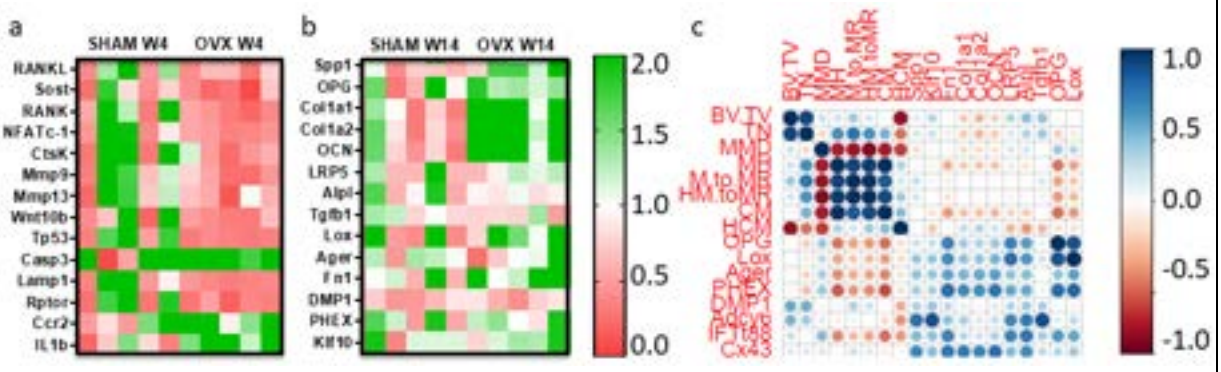

Figure 1: (a) Heat map reflecting bone catabolism and extracellular matrix degradation and (b) bone anabolism and extracellular matrix production gene expression, colours depict fold value of expression normalised to SHAM animals at respective time points; red, downregulation; white, no change; and green, upregulation. (c) Correlation Matrix comparing tissue microarchitecture, composition and expression of genes; dark blue = positive, dark red = negative, white = no correlation.

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The impact of complement-based polygenic risk score for schizophrenia on cognitive performance via cortical thickness in schizophrenia and healthy adults

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INTRODUCTION

Schizophrenia is a severe psychiatric disorder. Cognitive impairments have been defined as core symptoms of schizophrenia. Recent studies have demonstrated that variation in complement genes as a whole is a better predictor of cognitive performance than variation in individual complement genes alone. This study investigated whether the association between complement genes and different cognitive impairments observed in schizophrenia is mediated via whole-brain cortical thickness.

METHODS

To investigate the mediation effect of cortical thickness and the moderation effect of diagnosis on the relationship between complement-based SZ PRS and cognitive impairments, a moderated mediation analysis was employed. The sample consisted of both healthy controls and individuals with SZ collected through the Immune Response and Social Cognition in Schizophrenia project.

RESULTS

A direct effect of complement-based schizophrenia polygenic risk score on verbal (b = .50, p = .045, 95% CI [.01, .99]) and non-verbal (b = -3.04, p = .049, 95% CI [-6.05, -.01]) working memory performance for patients was observed. These relationships did not survive multiple testing correction. The conditional process analyses revealed no mediation or moderated mediation effects. Only diagnosis was observed to moderate the relationship between complement-based schizophrenia polygenic risk score and verbal working memory performance (b = .58, p = .025, 95% CI [.08, 1.09]).

DISCUSSION

We concluded that the relationship between high complement polygenic risk score and poor cognitive performance was not mediated by whole-brain cortical thickness. However, due to a number of methodological issues such as small sample size and unequal group size, one should interpret these findings cautiously.

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MICROWAVE IMAGING OF BONE FOR OSTEOPOROSIS MONITORING

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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 ionizing radiation is required for the monitoring of osteoporosis. Studies have reported that the demineralisation of bones may also result in the change of dielectric properties of bones. Therefore, dielectric properties measurement technology may be employed for monitoring osteoporosis. Microwave imaging (MWI) can measure *in vivo* dielectric properties and exploit the dielectric contrast between healthy and diseased tissues for diagnosis or disease monitoring. Despite the promising initial evidence that dielectric properties can be potentially used for osteoporosis diagnosis, no dedicated MWI system exists to measure *in vivo* dielectric properties of human bone in the microwave frequency range. To this end, a novel tomography-based bone imaging prototype has been developed at the Translational Medical Device Lab (TMDLab), University of Galway, Ireland. Moreover, an MWT imaging algorithm was developed to test both the numerical and experimental bone phantoms. The simulation results showed that the different diseased bones can be differentiated based on the reconstructed dielectric properties even for low values of the signal-to-noise ratio. Currently, the developed MWI prototype is under testing for the evaluation of anatomically accurate experimental phantoms. The initial findings suggested that the MWI can be used to monitor bone health based on the reconstructed dielectric properties.

(a) (b)

Figure 1: (a) The multilayered calcaneus phantom (b) The imaging prototype.

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Delivery of extracellular vesicles for tissue regeneration

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INTRODUCTION

Extracellular vesicles (EVs) are membrane bound nanoparticles containing proteins and nucleic acids that act as cellular signals and offer a nonimmunogenic, naturally-cell targeting therapeutic approach to tissue regeneration [1]. The aim of this project is to generate EVs in vitro from mesenchymal stromal cells (MSCs), characterize these EVs, and combine EVs with hydrogel biomaterials for tissue repair. Additionally, the aim is to assess whether a 3D cell culture bioreactor can aid in scale up and more closely simulate *in vivo* conditions for EV production to make EV therapies more clinically relevant.

MATERIALS AND METHODS

EVs were isolated from mBMSCs which had been stably virally transduced to express palmitoylated-tdTomato (gifted from Charles Lai) on their membranes so that EVs derived from these cells would also express this marker and be fluorescent red. EVs were isolated as shown in Figure 1 and were analysed for number and size distribution using nanoparticle tracking analysis (NTA) and visualized via fluorescence, confocal, and super resolution microscopes. EV fluorescence vs. number and protein concentration vs. number were assessed as methods for quickly quantifying EVs in experiments. A pilot study has begun in which mBMSCs were cultured in a hollow fibre bioreactor (KDBio, France) in 3D culture.

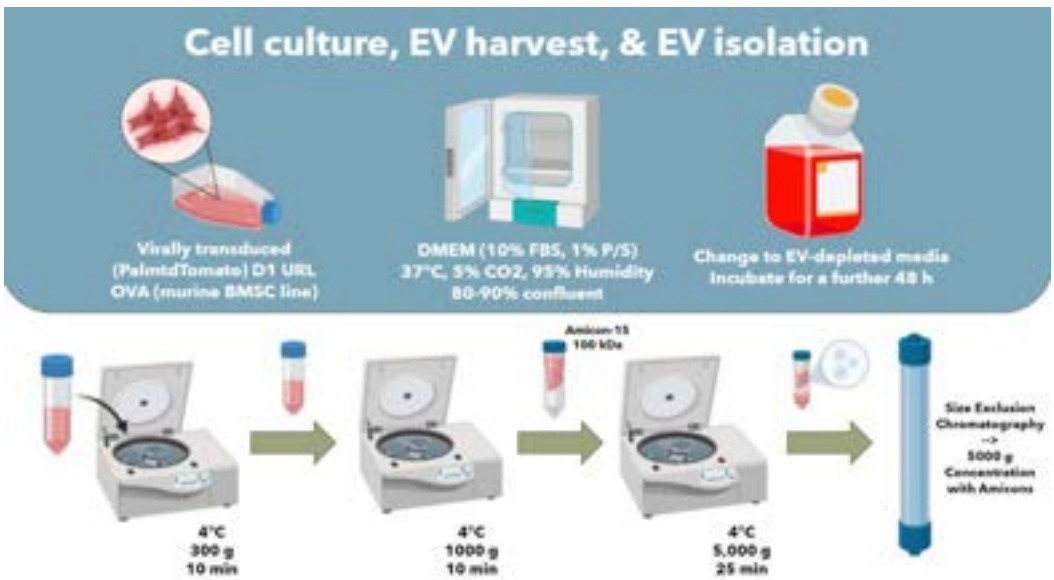

Figure 1: Method for EV harvest and isolation from cell culture of palm-tdTomato mBMSCs

RESULTS AND DISCUSSION

The average diameter of EVs obtained across multiple isolations was 132.1 nm, placing them in the category of small EVs. The average concentration obtained was $1.1x10^{11}$ EVs/mL. Highly linear relationships were established for EV fluorescence to number and protein content to number. EVs could be visualized via all three types of microscopes, with individual EVs being visible using the super resolution microscope. Thus far, the bioreactor cell culture system has the potential to yield $2x10^{10}$ to $2x10^{12}$ EVs in 4 weeks, aiding in scale up.

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

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INTRODUCTION

Improving classroom IEQ can improve the comfort and health of occupants and provide a better learning environment. In addition to improving IEQ, classrooms can be designed to be more energy efficient thus providing a sustainable and healthy learning environment. The aim of this research is to assess (i) how indoor air quality (IAQ) and thermal comfort impact wellbeing, productivity, and health of occupants in a classroom and (ii) what engineering solutions can be used to achieve proposed healthy IAQ and indoor thermal environment.

MATERIALS AND METHODS

This research will investigate the impacts of using engineering solutions through the existing literature review in this field, questionnaires, surveys, and tests. In the first stage, a comprehensive literature review is conducted to show the significant findings from previous studies relevant to the research topic. Then, the research method will be designed based on the research questions and previous findings in this field. Afterwards, experimental phase will assess the application of using selected measures on IEQ of classrooms. In the next step, the possibility of using these solutions, their positive and/or negative effects will be identified using simulations. In the final stage, the effect of using these solutions together will be indicated that can be used in classrooms to become resilient to future challenges.

IMPACT

The main finding of this research will answer the research questions and offer solution packages for current and to be built classrooms. Also, the results will not be limited to a specific geographical region and will be aligned with the third sustainable development goal (SDG). The proposed engineering solutions, that will be proposed at the end of this research, and their positive and/or negative impacts on the IEQ of classrooms will have impacts on:

- Students,
- Teachers,
- Policymakers that are responsible to provide adequate learning environment.

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MM/PBSA binding free energy calculations of heparin binding domain of fibronectin with self-assembled monolayers

Abstract

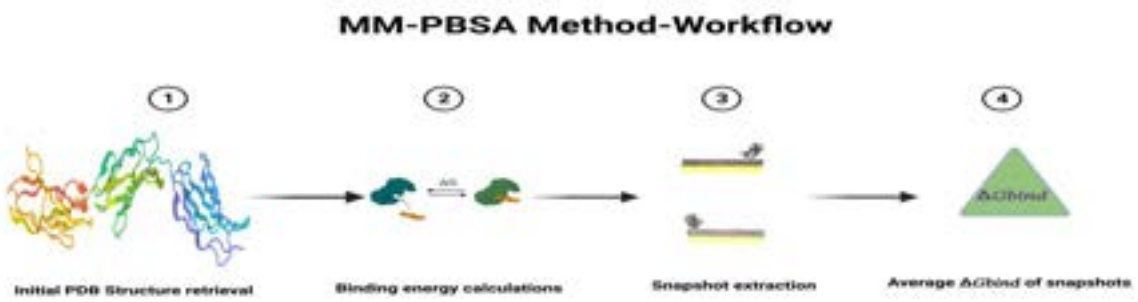

Figure 1: Workflow of MM-PBSA free energy calculations

Understanding protein-surface interactions is critical for designing biomaterials which enables to have a control over biological responses during interactions. A thorough understanding of protein adsorption onto surfaces is essential to optimize formation of functional biomaterials. Quantitative estimation of protein-surface binding affinities is critical towards understanding specific interactions that favours in revealing molecular mechanism in detail. In this research, we performed molecular mechanics Poison-Boltzmann surface area (MM-PBSA) analysis to compute binding free energies of Heparin binding fragments fibronectin with hydrophobic methyl (CH3)-self-assembled monolayer(SAM)surface. Average binding free energies of snapshots were determined by $\Delta G\mathrm{bind}$ after removing the solvent molecules from the system. The mean and standard deviation defining each portion of Delta G calculated using MM-PBSA computing method. Results showed mobility of fibronectin fragments is enhanced on adsorption to hydrophobic surface and further interactions between protein, surface and solvent were quantified. The research study highlights the importance of MM-PBSA in computing binding free energies of a complex system which favours the process of optimization of biomaterials and design of novel medical devices.

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Multivalency in a Host–Guest Protein–Calix[8]arene Complex

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Protein recognition by water-soluble (multivalent) calixarenes is a topic of broad interest.[1,2] We have shown that the anionic sulfonato-calix[8]arene (**sclx$_8$**, 1.5 kDa) induces the assembly and crystallization of different types of proteins.[2] The six-bladed β-propeller *Ralstonia solanacearum* lectin (RSL) co-crystallises with **sclx$_8$** in three distinct crystal forms, two of which rely exclusively on protein – calixarene complexation.[3] Here, we tested **sclx$_8$** complexation with a five-bladed β-propeller. A mutant of the designed pentamer PDB 5c2n[4] (~25 kDa) was selected for study. Despite the symmetry mismatch between the protein (C_5) and macrocycle (C_8), a tight 1:1 complex is formed (Figure 1). The calixarene sits in a shallow pocket and overlaps with the central water channel (a feature common to β-propeller proteins). Thus, the protein acts as the host and the macrocycle is the guest. Each protein monomer contributes 120-180 Å^2 to the interface area with the calixarene, resulting in a total of 900 Å^2 - the largest protein−calixarene interface observed to date. Solution-state NMR experiments confirm the binding site and suggest a micromolar dissociation constant. Apparently, multivalent interactions are important in this unexpected complex.

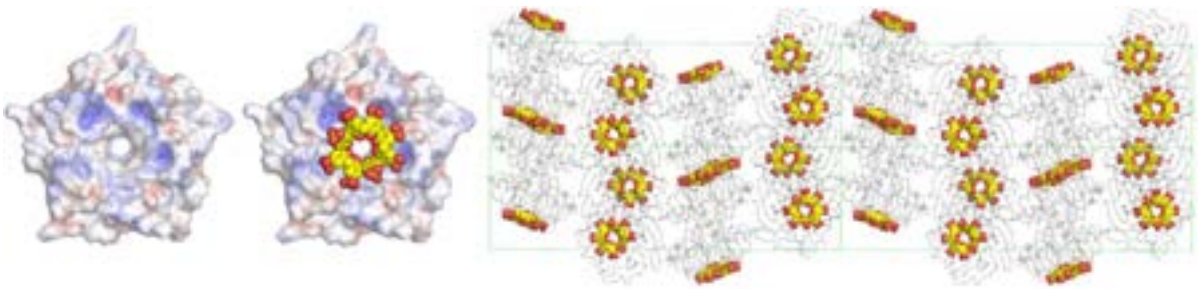

Figure 1: Crystal structures of the pure pentamer (left), the pentamer–**sclx$_8$** complex (middle) and the corresponding crystal packing (right). The protein is shown as a surface coloured by electrostatic potential.

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LncRNA based antigen load enables the classification of patient's survival and immunotherapy outcomes in Melanoma

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INTRODUCTION

ICB (immune checkpoint blockade therapy) is one of the promising treatments for melanoma. However, ICB response varies among patients, emphasizing the importance of identifying genomic biomarkers to predict likely responses in advance of treatment. LncRNAs are previously associated with cancer-specific epitopes. We aim to establish the association of lncRNA based immunogenicity scoring (lnc-IM) with tumor immune microenvironment (TIM), predicting ICB responses and prognostic value in melanoma.

MATERIALS AND METHODS

The data used includes TCGA-SKCM (n=101), and ICB treated melanoma cohorts UCLA (n=25) and MSKCC (n=16). Each patient was assigned a lnc-IM score based on the number of peptides it can present depending on its MHC-I genotype. A logistic regression-based classifier was used to predict ICB responses based on lnc-IM scores.

RESULTS AND DISCUSSION

The survival analysis showed better survival of patients with low lnc-IM counts (HR= 0.39, p=0.009) in the TCGA-SKCM cohort. TIM is an indicator of tumor progression and immunotherapeutical responses. We compared immune cell scores (calculated using xCell algorithm) with lnc-IM scores. Anti-tumor immune cells showed significant differences among low and high lnc-IM groups, while no such association was apparent among pro-tumor group. We further explored if such scoring can help improve the prediction of ICB efficacy. Lnc-IM count (derived in this study) and the neoantigen load (derived as a part of the trial) were used to assign each patient a "combined antigen score" among ICB treated cohorts. We hypothesized that such scoring could help predict ICB outcomes for tumors that are not hypermutated but can benefit from this therapy. We demonstrated that such a classifier improved the predictions, yielding an AUC of 0.71 with an accuracy of 0.5 and recall 1.

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An Integrated Finite Element and Agent-Based Model For Mechanosensitive Tumour Growth

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INTRODUCTION

The mechanical properties of the matrix affect cancer risk and progression. We use finite element analysis (FEA) and agent-based modelling (ABM) to investigate tumour cells response to mechanical forces from the matrix and guide macro-scale growth.

MATERIALS AND METHODS

Ion channels and pumps, actomyosin tension, and cytosolic proteins manipulate the cellular osmolarity and volume *V* [1]. We propose that growth is induced by electro-osmotic ion fluxes and biomass synthesis. Cell growth depends on hydrostatic pressure from cell stress and mechanical loading, and osmotic pressure. A custom graphically accelerated FEA model to investigate cell-matrix interplay was integrated with PhysiCell, an established ABM framework [2]. Processes including cell growth and division are dependent on adhesion, repulsion, and motility forces. Integrating our novel cell growth model, the external pressure to inhibit cell division will be quantified by restricting growth below a critical mitotic volume V_{crit} (Fig 1A).

RESULTS AND DISCUSSION

Compressive loading and increasing matrix stiffness reduces tumour size due to stress-sensitivity. Mean cell pressure reaches a critical value where proliferation is inhibited, and core tumour cells experience higher stress than peripheral cells, supported by excised tumour data [3]. Tumour size reduces with increased matrix stiffness, consistent with recent research [4].

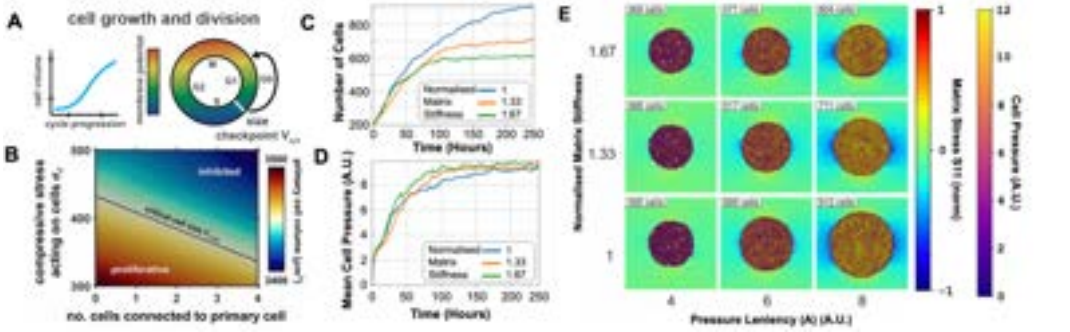

Figure 1: (A) Cell volume increases due to biomass synthesis; (B) Mitosis is limited by stress; (C) Cell proliferation and (D) pressure depend on matrix stiffness over time; (E) Tumor spheroid size decreases with increased matrix stiffness due to mechanosensitive feedback.

Results show that stress-dependent tumour growth emerges from a constraint on osmotically regulated cell growth, whereby cells cannot obtain a critical mitotic volume due to external loading. Simulation of multicellular proliferation using FEA-ABM models provides unique insight into the evolution of macro-scale tissue behaviour and mechanosensitive growth.

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Hydrolysates obtained from fish waste promote growth of gut-friendly bacteria

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INTRODUCTION

The waste produced by seafood industry can be utilized to develop a protein-rich product that has a range of functional properties. Protein content from fish by-products can be effectively recovered by enzymatic hydrolysis. The resultant fish protein hydrolysates (FPH) are functional blends of modified proteins, peptides, and amino acids that can potentially be applied in the food industry. Prebiotics are dietary components that selectively promote the development and/or function of gut-friendly bacteria in the colon. Studies have demonstrated that milk protein hydrolysates can enhance growth of lactic acid bacteria. Our research will investigate the potential of FPHs to promote the development of gut-friendly bacteria *in vitro*.

MATERIALS AND METHODS

Blue whiting fish protein hydrolysates

Prepared protein hydrolysates from Blue Whiting (*Micromesistius poutassou*) were obtained in powder form from Biomarine Ingredients Ireland (BII). Peptide mix A and B were partially hydrolysed and soluble protein fractions respectively.

Microorganisms

The bacteria used in this study were as follows: *Lactobacillus reuterii* (DSM 20016), *Lactobacillus casei* (DSM 20011), *Lactobacillus gallinarum* (NCIMB 13223), *Lactobacillus fermentum* (DSM 20052), *Lactobacillus plantarum* (DSM 20174), *Lactobacillus acidophilus* (DSM 8821) *and Bifidobacterium angulatum* (ATCC 27669).

Growth Assay

The powders were diluted in distilled water at a final concentration of 1% (w/v). Inulin and fructooligosaccharide were used as standards. The bacteria were grown in MRS medium supplemented with 1% hydrolysate for 24 hours at 37 °C in sterile 96-well microtiter plates. The turbidity was evaluated hourly using a spectrophotometer at 595nm as a metric of bacterial density.

RESULTS AND DISCUSSION

The effect of hydrolysates (1% w/v), on bacterial growth is represented in Fig.1.

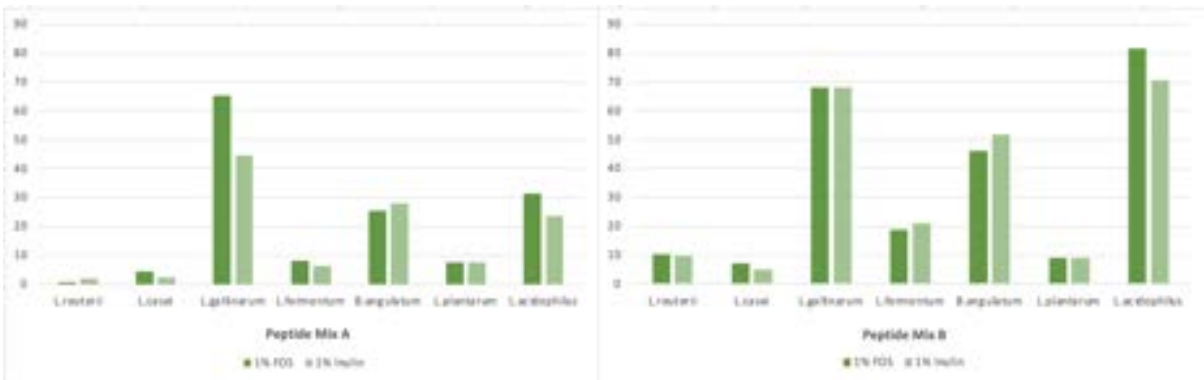

Figure 1: Growth rate (%) of a selection of beneficial bacteria supplemented with 1% (w/v) fish protein hydrolysate compared to other commercial sources (FOS and inulin) at the same concentration. Data are expressed as mean ± SD (n=3).

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2D Digital Laser printing of Kirigami-inspired 3D Strain Sensor

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INTRODUCTION: Flat Polyimide (PI) sheet is processed using two laser inscription regimes from the Femtosecond Laser. First to carbonize strain sensitive tracks, and then to cut around the sensing elements to form a topological shape that encased 3D body parts. Thus, a Kirigami-inspired sensor is created from 2-Dimensional (2D) to sense 3D shapes to demonstrate how a single Femtosecond laser can be used for fabrication of Kirigami-inspired strain sensor, by alternating between two beam parameter regimes.

MATERIALS AND METHODS: Laser carbonization with 1030 nm 550 fs laser at scan speed 2-3 nm, power 0.24-0.28 W, at repetition rate 200 kHz occurs due to heat accumulation which creates the strain-sensitive Laser Induced Graphene (LIG). The temperature due to heat accumulation is calculated from equation 1 :

$$\Delta T = \frac{8\,\eta_{abs}\,\eta_{Heat}(v)E_p\sqrt{f}}{\pi d_s^2}.\frac{1}{\rho C_p\sqrt{4\pi D_T}}.(2\sqrt{ft}\text{ -1.46}) \quad (1)$$

Laser ablation occurs due to multiphoton absorption at 1.72-2.51 W, at f=200 kHz, and scan speed 200-300 mm/s and was used to cut the boundaries of the design.

RESULTS AND DISCUSSION: The Kirigami design showed increased sensitivity to knee bending by placing the sensor under the knee-cap. Figure 1 shows that ilt demonstrated a change in the output voltage of 10.7±1.4% upon knee-bending, compared to 3.0±0.7% in planar sensor due to enhanced stress accumulation (by order~ 10^2 N/m^2) and conformal fitting on body joints.

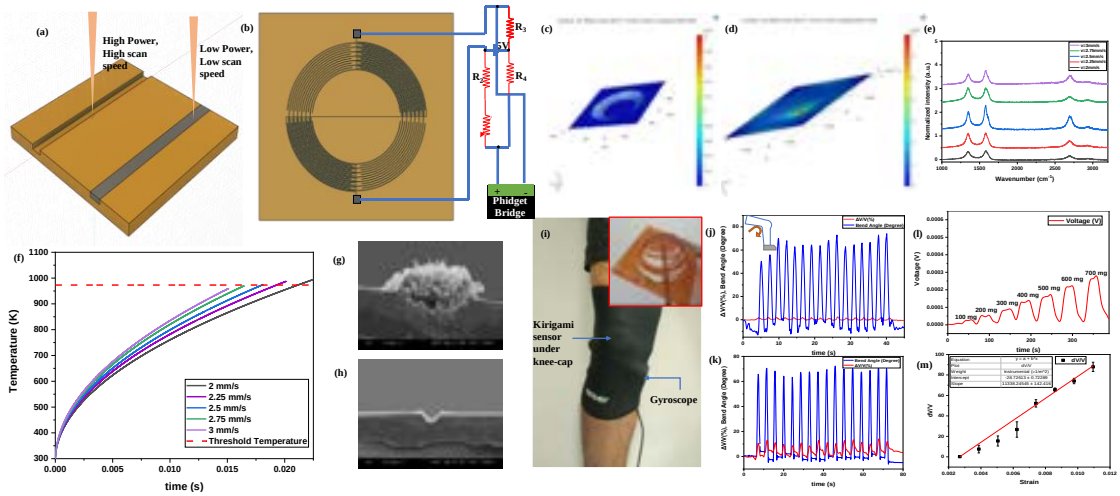

Figure 1: (a) Process conditions of femtosecond laser printing, (b) Kirigami sensor, (c) Stress distribution in Kirigami sensor, and (d) Planar sensor, (e) Raman spectra of LIG, (f) *T* vs *t* from heat accumulation model, (g) Cross-sectional SEM of LIG and (h) laser ablated track, (i) Kirigami sensor under knee-cap, (j) Relative change in voltage in the planar sensor, and (k) and the Kirigami sensor upon bending of knee, (l) Change in PhidgetBridge voltage upon loading of 100-700 mg, (m) *GF* measurement from *ΔV/V* vs strain.

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Dynamics of chromatin factors RSF1, CENPS and CENPX at DNA damage sites

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INTRODUCTION

Chromatin has a major influence on the DNA damage response (DDR). Several chromatin-related factors contribute to specialised DNA packaging during the DDR including CENPS (MHF1) and CENPX (MHF2) histone-fold proteins and the chromatin remodelling factor RSF1.

MATERIALS AND METHODS

To establish the dynamic exchanges of these chromatin components we defined a timeline for MRE11, RSF1, CENPS, and CENPX at DNA double-strand breaks (DSBs) in live HeLa cells by microirradiation using a 405 nm laser and sensitiser.

RESULTS AND DISCUSSION

CENPS, CENPX and RSF1 are recruited with a half-time of ~100 s and removed with a half-time of ~2000 s. Enrichment for cell cycle phase revealed that recruitment occurs in G1, S and G2 phases, but that the half-time is delayed in G2 and recruitment is more abundant. CENPS and CENPX recruitment occurs simultaneously at a time between the regimes of NHEJ and HR that is consistent with published estimates for ATM activation.

The removal of CENPS and CENPX occurs at a similar time to the recruitment of RAD51. This places CENPS and CENPX in the vicinity of DSBs at the time when nucleosomes are being actively remodelled to enable resection, and their increased abundance at DSBs in G2 correlates with extended resection for HR.

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H2AX gene copy number in cancer cell line models

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INTRODUCTION

Breakage of chromosome 11 q arm distal to *CCND1* amplification occurs in breast, ovarian and head and neck squamous cell carcinomas (HNSCCs). Several important DNA damage response (DDR) genes are left as single copies after 11q breakage events including *H2AX, ATM, CHEK1* and *MRE11A.* The implications of how this affects DDR function and H2AX protein incorporation in chromatin are unknown.

MATERIALS AND METHODS

HNSCC cell lines CAL33, TE14, OE21 and PE/CA-PJ34 (clone C12) were selected in the Comprehensive Cell Line Encyclopedia (CCLE2) based on genomic analysis. Each line was passaged for 50-60 cycles with sampling every 2-5 cycles. Karyotypes were analysed by TaqMan-based copy number analysis, metaphase spreads, and Fluorescent In Situ Hybridisation (FISH).

RESULTS AND DISCUSSION

TaqMan copy number analysis relative to *MRPL19* for a panel of genes along 11q in early passages of the cell line indicated differences with predicted chromosome structure for all lines except OE21 based on genomic characterisation in CCLE2. Chromosomal counts of metaphase spreads revealed that ploidy predictions in CCLE2 were inconsistent for CAL33 and TE14. Furthermore, FISH for *MRPL19* revealed that this commonly used reference is not diploid in all cell lines. Late passages of CAL33 showed increased ploidy of CAL33. FISH of cell lines is ongoing.

We find that genomics-based characterisation of cell lines may be affected by inferred ploidy, leading to inaccurate copy number calls in CCLE2. We also observe that cell lines can change ploidy in long-term culture or potentially undergo chromosomal breakages. This enables investigation of the mechanism and effects of 11q arm loss. We plan to use this property to compare DNA damage responsiveness of HNSCC and breast cancer cell lines, and to investigate the effect on H2AX protein abundance in chromatin.

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Fantastic DNA in a Box: A successful example of adapting interactive hands-on science outreach to work remotely online

Presenter: Janic Schulte, Janic.Schulte@universityofgalway.ie

Co-authors of poster: Grenon, Schulte, Carroll et al.

Cell EXPLORERS is an educational outreach programme delivering STEM activities regionally and nationally in Ireland (www.cellexplorers.com). The programme uses hands-on activities on molecular and cellular biology facilitated by local scientists to engage the Irish public in the importance of science in society. The most widely disseminated activity is a session called 'Fantastic DNA', where young people (aged 8-12 years old) are guided by enthusiastic science explainers in their classrooms to individually extract DNA from bananas. For many, this is their first interaction with a real scientist, and a highly appreciated experience to engage in authentic hands-on science. In 2020, in response to social distancing measures implemented due to the COVID-19 pandemic, we adapted the Fantastic DNA session to work remotely – Fantastic DNA in a Box. This was enabled by developing a science kit for teachers ('the box'), which contains both materials and resources for pupils to individually complete the experiment in their classrooms. Teachers have the option to guide their pupils using the complementary teacher resources, or connect with Cell EXPLORERS explainers remotely via Zoom. This poster will present the development of this science kit, evaluation findings, and advice for other practitioners looking to develop their own remotely facilitated science kits.

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Measuring protein-polymer nanoparticle interactions using polarized Excitation Emission Matrix (pEEM) spectroscopy

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INTRODUCTION

Monoclonal antibodies (mAbs) have gained prominence as superior therapeutic agents compared to traditional small molecule drugs. However, the manufacturing process of high purity mAbs is complex and may result in protein aggregation and contamination, which affect critical quality attributes (CQAs) and ultimately drug efficacy and safety. Currently, size exclusion chromatography (SEC-HPLC) is used to measure mAb aggregation quality, but it is complex, expensive, and time-consuming. This study proposes Polarized Excitation Emission Matrix (pEEM) as a reliable alternative to SEC. pEEM is a sensitive, label-free, and non-destructive measurement method that uses the protein's inherent fluorescence to yield a $4D^2$ data system that includes scatter, fluorescence, absorbance, and polarization information. The study hypothesizes that PNIPAm can prevent stirring-induced aggregation of HSA, a model protein, and such interaction was examined using pEEM.

MATERIALS AND METHODS

Different molarity ratios (1:1, 1:10, and 1:100) of HSA and PNIPAm – 40 kDa Mw were employed to induce protein aggregation via stirring at 2,000 rpm for 2 hours. Polarized Aqualog Fluorimeter was used to acquire PEEM, while size information was obtained orthogonally via DLS (Malvern Nano Zs) with 5 measurements per sample at 173°.

RESULTS AND DISCUSSION

Protein samples without PNIPAm showed higher levels of Rayleigh light scattering (286 nm) and lower emission (18%), indicating aggregation and larger particle sizes observed via DLS (450 nm). On the other hand, PNIPAm-containing samples exhibited a well-preserved emission pattern and a relative decrease in scatter, indicating its hydrophobic interactions with HSA, preventing unfolding and subsequent aggregation. In addition, DLS analysis also showed a decrease in particle size. Fluorescence anisotropy measurements taken under four polarizations (VH, VV, HH,

and HV) showed similar values for HSA control and PNIPAm samples, differing only for protein samples devoid of polymer. The method for HPLC-SEC to evaluate is still under development.

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Changing Cell Explorers practices to widen participation in Educational STEM outreach activities

Muriel Grenon, Sarah Carroll, Janic Schulte, Shannon Stubbs, Kristin Anderson, Jennifer DeWitt, Ran Peleg

Cell EXPLORERS is an educational Science outreach programme delivering STEM activities nationally and internationally. The programme objectives are to inform, inspire and involve young people in modern biology and biomedical sciences.
The programme provides authentic interactions between young people and local scientists with the aim to impact young people's perceptions of science and scientists and combat stereotypes that might prevent engagement in science. The programme is unique in the way it generate its own research and evaluation findings to guarantee impact and develop innovative and impactful practices in informal/non formal science education and public engagement (EPE).

During the COVID-19 pandemic, the programme had to reinvent both its public engagement practice and evaluation research, and successfully transitioned to online activities by developing interactive hands on online line session based on the use of classroom- and family- science kit delivered in advance of the session.
Backed with a strong ethos of inclusion and equity and using educational research evidence to guide the programmes practices, Cell Explorers continues to work through collaboration with schools, youth groups or family, to widen participation using novel remote or in person activities, with a recent focus on those from under-served communities. Some of these recent innovations and evidence of impact will be presented.

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Development of advanced in-vitro mineralized models to study osteoporosis

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Introduction

Our in vitro studies have demonstrated that the mechanobiological responses of osteoblasts and osteocytes can be impaired during estrogen deficiency. We have developed three dimensional (3D) multicellular models, which have revealed that estrogen deficiency leads to changes in osteoblast to osteocyte transition, mechanosensation and mineralization. Here we build upon these studies by developing models that are highly mineralised, to mimic the composition and mechanical properties of mature bone tissue more closely.

MATERIALS AND METHODS

Synthetic proxies for healthy and osteoporotic bone mineral were created using platelet-shaped carbonated hydroxyapatite nanoparticles coated with different proportions of hydrated amorphous surface layer (HASL) - 35% (HA1) and 20% (HA2) as proxies for healthy bone mineral and osteoporotic bone mineral, respectively. Osteoblasts (MC3T3-E1) were pre-treated with 17β-Estradiol for 48 hours and then encapsulated in hydrogels with 50/50 gelatin/nHA mass ratio with 1%wt mtgase and cultured for 21 days under continued estrogen or estrogen withdrawal. Biochemical assays (DNA, ALP, and calcium content), micro-CT scanning (µCT100, Scanco), SEM (Hitachi, S2600), mechanical testing (Zwick Roell, Z009), histological staining (DMP1/actin, Von-Kossa staining) were conducted**.**

RESULTS AND DISCUSSION

Micro-CT confirmed a high level of mineralization in HA1 at day 0 (Fig 1 A). SEM analysis revealed nano-sized HA and agglomerated n-HAP particles (Fig 1 A, B). MC3T3- E1 cells at day 0 were spherical (Fig 1C) but formed dendritic cell processes and DMP1 staining was positive by day 21(Fig 1D, 1E)). DNA content increased significantly for all groups at day 21 compared to day 0 (Fig 1F). At day 21, calcium deposition and mechanical properties for HA1 and HA2 groups was higher under EW than E conditions (Fig 1H, 1I). Calcein labeling and Von Kossa staining revealed several mineralized regions (Fig 1J, 1K). Future studies will validate this approach as a model study on osteoporosis.

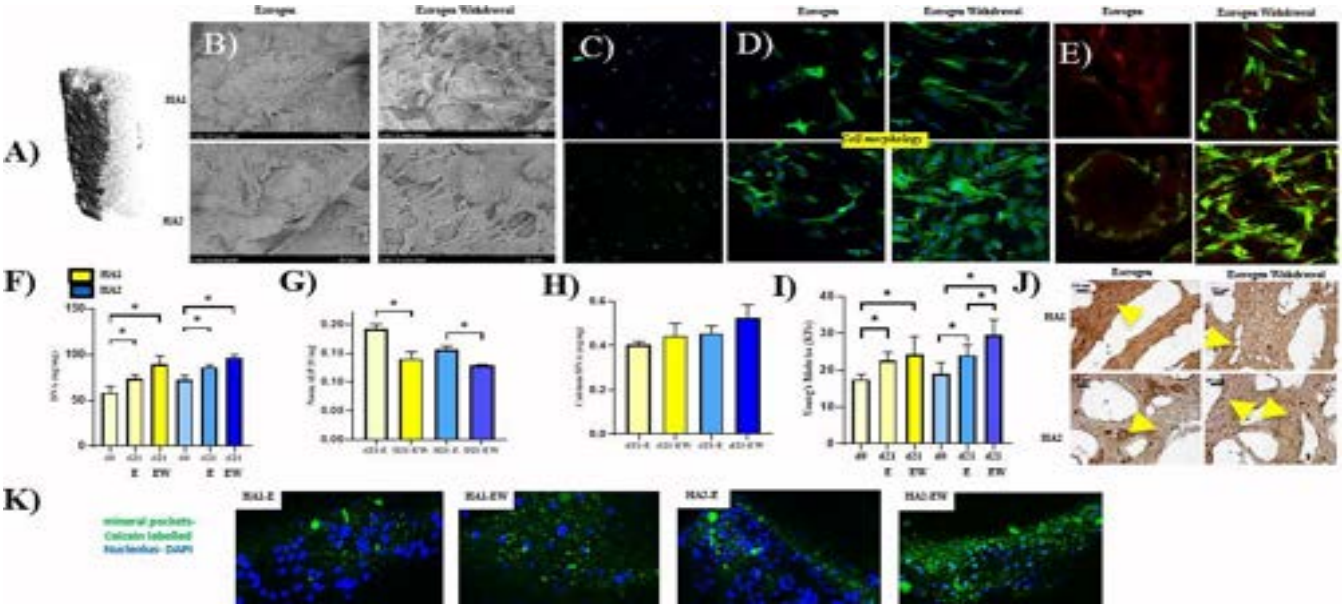

Figure 1: (A) Micro-CT and (B) SEM of HA1-E reveal different HA nano and micro-HA morphologies (pink, yellow arrows) at day 21. (C) Actin staining for HA1 day 0 and (D) E+ HA1, EW HA1, E+ HA2, EW HA2 at day 21, (E) Actin/DMP1 staining for EW HA2 at day 21, (F) DNA content, (G) ALP activity, (H) calcium content, and (I) mechanical properties of cell free constructs (J) Von kossa staining and (K) Calcein labelling.

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A THERMODYNAMIC FRAMEWORK FOR SARCOMERE FORMATION IN CARDIOMYOCYTES SPREAD ON MICRO-PATTERNED SUBSTRATES

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INTRODUCTION

Identification of in-vitro protocols to develop mature cardiomyocytes (CMs) with aligned myofibrils is a challenge in cellular and tissue engineering [1]. We propose a novel thermodynamically based theoretical model for sarcomere and stress fibre (SF) formation within a cell. We simulate cells on square and rectangular adhesive patches and quantitatively compare our model to experimentally measured levels of sarcomere formation.

METHODS

We consider that cytoskeletal proteins can exist in three states within a CM: (i) bound as part of a SF ($\hat{N}_{BF}$), (ii) bound as part of a structured sarcomere ($\hat{N}_{BS}$), or (iii) unbound within the cytoplasm ($\hat{N}_U$). At steady-state conditions the chemical potentials of these three states are in thermodynamic equilibrium, which derives the areal density of sarcomeres within the cell

$$\hat{\eta}_S = \frac{\frac{1}{\hat{n}_S}(\hat{\xi}_1 - \hat{N}_{BF})(\hat{N}_U + \hat{N}_{BF})\exp(\hat{n}_S\Delta\hat{\mu})}{\hat{\xi}_1 + (\hat{N}_U + \hat{N}_{BF})\exp(\hat{n}_S\Delta\hat{\mu})}.$$

We develop a statistical mechanics framework for CM spreading, analysing over two million cell spreads with Monte Carlo Markov Chain walks. Simulations are performed on micro-patterned ligand patches for comparison with in-vitro experiments.

RESULTS AND DISCUSSION

A sample of computed spread cells are shown in Fig. 1 for CMs on rectangular ligand patches. Highly aligned dense sarcomere structures are predicted for cells on 7:1 rectangular patches. In contrast, for a cell on a square patch our model predicts a low-density of sarcomeres. Computed sarcomere formation increases with AR, shown in Fig. 2B, in agreement with experimental measurements [2].

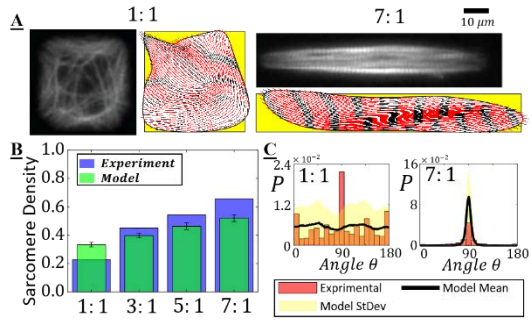

Figure. 1. (A) Predicted CM states on ligand patches, sarcomere orientations red quivers (thickness scales with sarcomere density). Ligand-patch AR on (B) sarcomere density, (C) sarcomere alignment as a function of patch AR, strong agreement with experiments is observed, with elongated CMs exhibiting higher levels of alignment. Experimental results (Ribeiro et al. [2]) for comparison.

Our model uncovers the following mechanism: Gibbs free energy decreases with increased sarcomere density. Sarcomere areal density exponentially increases with in series units, driving elongated cells. This mechanism may guide in-vitro strategies to generate contractile CMs. Optimal dynamic loading regimes promoting sarcomere formation can be identified using our model [3].

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College of Science and Engineering, Inaugural Research and Innovation Day 2023

Investigation of parasite-derived immunomodulatory molecules on T and B lymphocytes

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INTRODUCTION

Fasciola hepatica, a trematode capable of infecting a wide range of mammals, including humans, is an intriguing pathogen due to its unique ability to modulate the host's immune system and persist in the host for up to two decades. One of the molecules released by this parasite, the Helminth Defense Molecules (*Fh*HDM), has been extensively studied for its immunomodulatory properties, particularly on macrophages. However, the effects of *Fh*HDM on T and B lymphocytes remain largely unexplored. Therefore, this study aims to investigate the impact of *Fh*HDM on these critical immune cells.

MATERIALS AND METHODS

In this study, we utilized the BD FACSCelesta™ flow cytometer at Nantes Université to investigate the effects of two FhHDM peptides, FhHDM-1 and FhHDM-C2, on B lymphocytes. Specifically, we tested these peptides against different B lymphocyte sub-populations to observe their effects on proliferation, cell activity, and apoptosis following various stimulations. In addition, we conducted analyses of the peptides on T and B lymphocyte co-cultures to investigate their effects on proliferation and cytotoxicity markers. We performed flow cytometry analysis using FlowJo software, which allowed us to obtain accurate and reliable results.

RESULTS AND DISCUSSION

FhHDM-1 has demonstrated potential immunomodulatory effects on B lymphocytes, particularly in terms of apoptosis and cell activation. Interestingly, the overall performance of FhHDM-1 was better than that of FhHDM-C2. Furthermore, the peptides were found to have effects on CpG stimulus, which is an exciting development, as until recently it was hypothesised these *Fh*HDM effects were only against LPS. However, further proliferation assays with activated B cells are needed with additional peptide concentrations to fully evaluate their effectiveness. Additionally, assays with T cells only would be interesting to perform to gain a better understanding of the peptides' effects on other critical immune cells.

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The outbreak of COVID-19 has led to an increased demand for real-time detection systems that can identify infected individuals. Due to a rapid rise in COVID-19 cases, many countries have experienced a shortage of testing resources and a limited capacity to conduct testing. Early Covid-19 detection is necessary to counter these issues, where coughing is a common symptom of COVID-19. This research paper proposes using different AI-based models such as CNN, ResNet, and Vision Transformer for COVID-19 detection. The study uses publicly available datasets, including CoughVid, COSWARA, and the Cambridge dataset. The proposed models are trained and tested on these datasets to evaluate their effectiveness in detecting coughs and identifying COVID-19 infections. The results show that the proposed AI-based models accurately detect coughs and identify COVID-19 infections. The paper investigates how various deep learning (DL) models perform on a combined dataset of cough samples to identify COVID-19 at an early stage. The results suggest that the existing DL method approach could be valuable for finding new illnesses in the future. This proposed framework can help with early diagnosis, clinical decision-making, and precise prediction in healthcare informatics.

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Eccentric Intradiscal Pressure and High-Stiffness Ligaments Explain Progression of Spinal Deformities: A Finite Element Analysis

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Hypothesis:
Asymmetric intradiscal pressure and increased ligaments stiffness cause eccentric loading of vertebral units in Adolescent Idiopathic Scoliosis (AIS) and therefore lead to differential spinal growth.

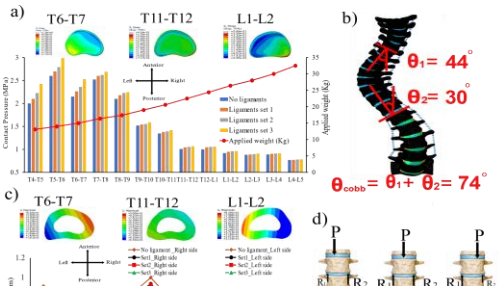
Design:
Finite Element Method (using *Abaqus*)

Introduction:
Although AIS is a mechanical deformity and most therapy plans are based on modifying the spine's mechanical environment, there is no consensus on the mechanical factors that lead to spinal deformities' progression. To determine these factors, we investigate the effects of intradiscal pressure and its connection with the supporting ligamentous structures on the spine's growth.

Methods:
Numerical simulations were performed using a 3D model of a scoliotic spine. The spine's geometry was acquired from DICOM data of an AIS patient. 3 simulations were performed, each consisting of a set (1-3) of ligaments. The sets' stiffnesses follow ascending order (Set1 < Set2 < Set3). Gradually increasing follower loads along the axis of the spine were applied. The pressure levels acting on growth endplates and discs were observed.

Results
Despite the applied loads being lower, the intradiscal pressure was high in the spine's higher-deformity region (T4-T9). Moreover, the effect of ligaments' stiffness correlates directly to intradiscal pressure; the stiffer the ligaments, the higher the intradiscal pressure. Due to geometrical asymmetry, the generated pressure is eccentric towards the concave region of each vertebral unit, thus deforming the nucleus pulposus asymmetrically. As a result, the deformed annulus fibrosus structure generates asymmetric uplift forces in the convex side of each vertebral unit. The eccentric pressure and uplift force are opposite in location and direction.

Conclusion:
High-stiffer the with eccentric intradiscal pressure is associated severe spinal deformities. Moreover, the ligaments, the higher the magnitude of the intradiscal pressure, which leads to severe asymmetric uplift deformations.



a) Intradiscal pressure and applied loads; b) Spine's cobb angle; c) uplift deformation at the highest and lowest regions of annulus fibrosus; d) Illustration of forces acting on the vertebral units.

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