Accuracy of 2D images to predict foot size – proposed use in a mass customisation pipeline for the production of orthotic devices

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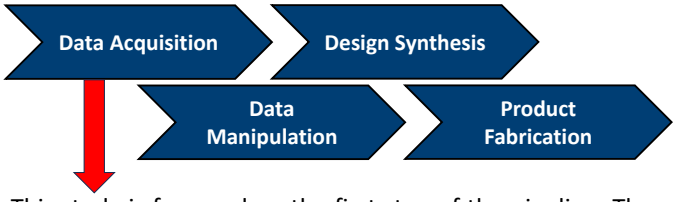
BACKGROUND

Mass customisation (MC) combines the flexibility and personalisation of customised products with the low unit costs associated with mass production. Product customisation in healthcare has been shown to produce improved patient outcomes, comfort, and satisfaction – especially in the orthotics sector. Additionally, the global foot orthotic market size is $4.22 billion in 2024 and so shows a good potential of benefitting from MC inclusion.

Mass customisation pipeline – Data acquisition

This research aims to investigate the potential of applying MC to the orthotics sector of the healthcare industry.
- Standardised MC pipeline:

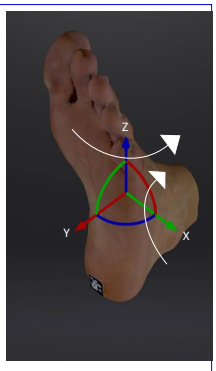


This study is focussed on the first step of the pipeline. The aim is to identify the accuracy and sensitivity of the chosen lowest fidelity data acquisition method for the MC pipeline – 2D RGB imaging.

METHODS

Data capture and 2D image generation:

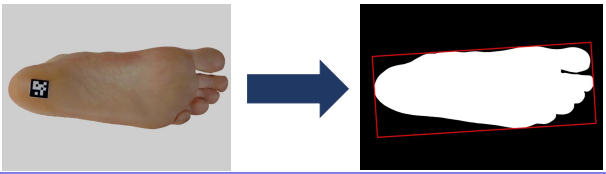
3D texture scans of participant's feet with an attached marker were captured using a 3D scanner and run through a blender programme to create synthetic 2D RGB image data sets.



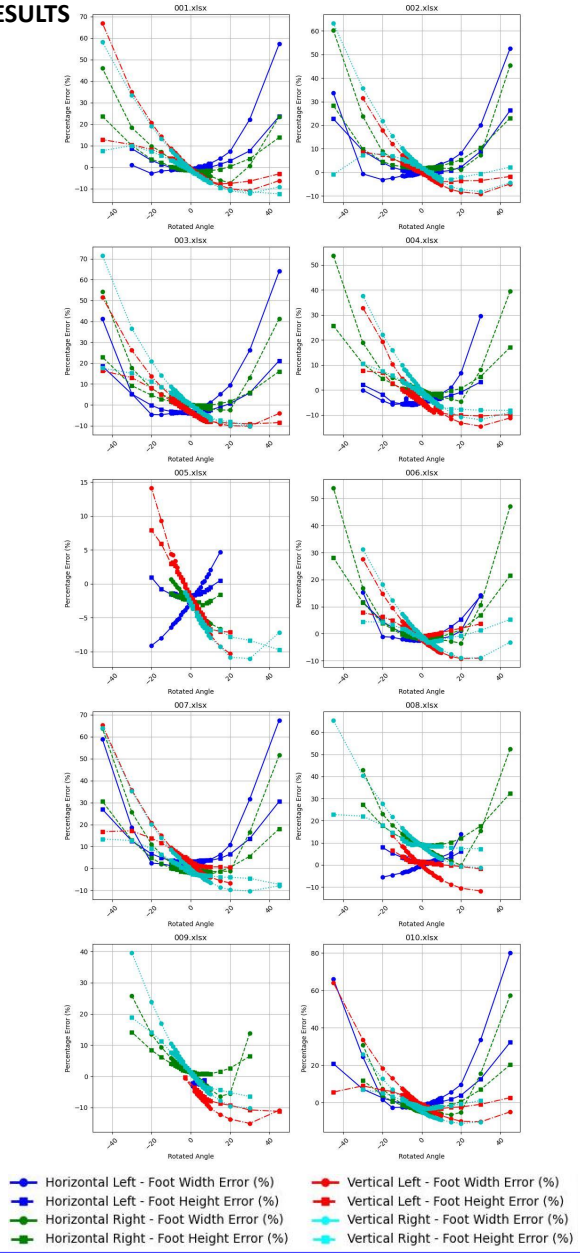
For each participant, the programme generated images of their captured scan rotated about the X and Z axes at known angles: ±0°, 1°-10°, 15°, 20°, 30°, and 45°

Sensitivity testing:

Each of the images in the data sets were segmented and sized using AI-based algorithms to determine the foot's height and width. These were then compared to their measured size to calculate the accuracy of the given angle.



RESULTS



CONCLUSIONS

- Lowest fidelity data acquisition method is suitable
- Similar trends noted for each of the scans across the rotated angles
- %error for each of the scan's plateaus between +10° to -10°
- Average %error at 0° for all scans is -1.02%

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Aircrew Head Injury Protection

Alasdair Mackay
Mazdak Ghajari

> “ Developing **novel** impact tests and brain injury thresholds to aid the development of **safer** helmets ”

Introduction

The necessarily violent nature of an aircraft ejection means there is a significant risk of injury, particularly to the head. At present, aircrew mitigate this head injury risk with helmets designed and tested to a motorcycle derived impact standard from the 1980s.
This research looks to identify the historic risk of head injury faced by aircrew, the biomechanics of aircrew head impact and the common brain pathologies seen. Helmet impact testing, computational modelling and the development of appropriate injury risk functions has been carried out to inform future aircrew helmet impact standards.

Methods

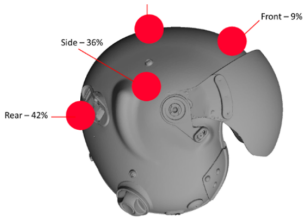
1. Historic injury risk
A review of RAF Centre of Aerospace Medicine accident database archive of all UK ejections between 1972 to 2023 was carried out. Statistical analysis was used to identify the relationships and interactions between ejection speed, aircraft type and the head injury pathologies sustained. Multibody modelling and sled test ejection seat data were used to collect information on head impact kinematics.

2. Improving helmet testing methodology
The historic head injury analysis was used to inform impact conditions for helmet impact testing, including impact surface, location and angle.
A series of impact tests were carried out using a modern ‘biofidelic’ test headform on an unconstrained drop tower. 6 d.o.f. accelerometers were used to capture head kinematics during impact tests of representative helmet impacts.

3. Injury risk function development
Kinematic data from NFL head impacts was used to generate a loss of conciousness (LOC) risk function. An FEM TBI model of the brain is currently being used to collect information on strain and strain rate in the brain for representative impact conditions. Loading conditions from sled test and helmet drop tower data were used to load the FEM model.

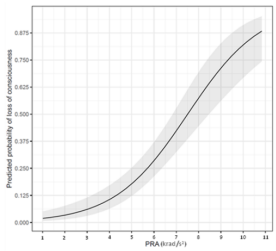
Results

1. Historic injury risk
Loss of consciousness (LOC) was found to be the dominant brain injury sustained in 26 of 33 head injuries resulting from 276 ejections.
The rear and side of the helmet were the most commonly impacted zones.
Helmets were more likely to impact flat and edged shaped objects.



2. Improving helmet testing methodology
Head kinematic data was collected using the biofidelic testing methodology. A range of helmets were tested against impact conditions seen in real life ejection events. The data generated offers improved headform kinematics with a low level of variance compared to legacy aircrew helmet testing.

3. Injury risk function development
Logistic regression curves for LOC were generated for kinematic measures such as rotational acceleration, rotational velocity and the Brain Injury Criterion (BrIC). Brain strain and strain rate has been calculated for NFL head impacts with known kinematics as well as for ejection sled tests and helmet drop tower tests.



Discussion

There continues to be a risk of head injury in aircrew who eject out of combat aircraft. The most common brain injury seen was a loss of consciousness which is known to be closely associated with rotational kinematics of the brain. At present, aircrew helmets are not required to demonstrate rotational protection. A novel drop test and injury risk function for loss of consciousness has been developed to better assess helmets against this measure.
Further work is underway to update the kinematic injury risk curves with strain and strain rate data from the brain and specific regions of interest such as the brainstem and nuclei known to be involved in consciousness.
The development of a loss of consciousness risk function for helmet testing is likely to have utility in other applications beyond military aviation.

Bio

Alasdair Mackay is a 3rd year PhD student in the HEAD Lab under the supervision of Mazdak Ghajari. He is also a GP and Specialist Registrar in Aviation and Space Medicine for the RAF.

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Tree Proof of Position Algorithms, (T-PoP)

> “ A decentralised, trustless, privacy-preserving algorithm to prove your location. ”

Aida Manzano Kharman, Pietro Ferraro, Homayoun Hamedmoghadam, Robert Shorten.
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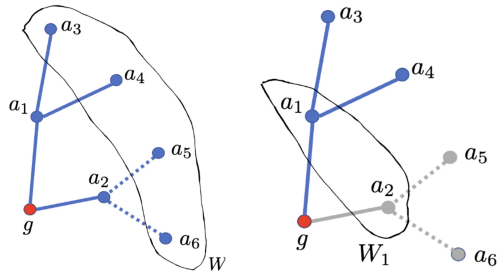
Abstract

We present Tree-Proof-of-Position (T-PoP): a decentralised class of algorithms to prove one's position in a privacy preserving manner. T-PoP is a peer to peer, collaborative algorithm, in which participants may prove they are in a given position without having to publicly disclose it. We make no assumptions of honest behaviour in the system, and consider varying ways in which agents may misbehave. T-PoP is therefore resilient to adversarial scenarios, which makes it suitable for a wide class of applications, namely those where trust in a centralised infrastructure may not be assumed, or high security risk scenarios.

Introduction

The question of proving one's position is trivial to answer when a centralised and trustworthy infrastructure exists. An example such an infrastructure of this could be a network of surveillance cameras that are operated by a trusted government agency. However, this infrastructure does not always exist, or is not always trustworthy. Some real world scenarios where this could happen is in conflict zones or dictatorships.
T-PoP is our approach to provide a truly decentralised solution. Participants can prove they are in a given location without relying on any trust assumptions or centralised infrastructure. Our algorithm is privacy preserving, and highly resilient to adversarial scenarios.



Methods

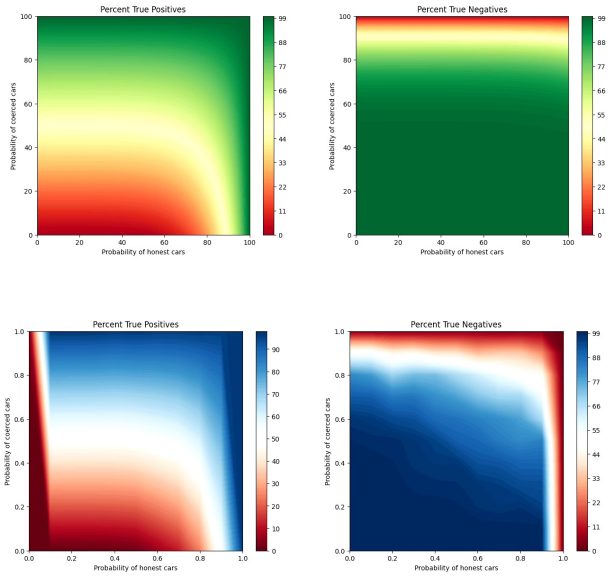
Agents wish to prove that they truly are in the location they claim to be in. We assume agents may lie about their own position, or lie about the position of nearby agents. T-PoP is an algorithm that returns True if the agent is believed to be honest, and False otherwise.
We construct a mathematical model for our algorithm, to provide designers with security and reliability guarantees of our algorithm under varying operating conditions. We then simulate the operation of T-PoP with extensive agent-based simulations. Namely, we construct an environment and instantiate agents in it with varying attributes: some are honest, others dishonest and others are coerced agents (meaning they co-operate with dishonest agents to cover up for their lying behaviour). We then study the performance of T-PoP, namely security and reliability, where security is its ability to detect the dishonest agents (True Negatives), and reliability, its ability to find the honest agents (True Positives).

Results

The results of our mathematical model are in complete agreement with our agent-based simulations, thus showing our mathematical model is valid. T-PoP achieves the highest security in high density scenarios, but the operating conditions of T-PoP can be tuned for varying densities to achieve better security and reliability.

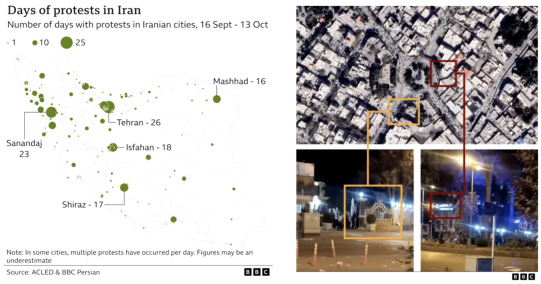
Discussion

The higher the network density, the greater the security and reliability of the algorithm. T-PoP is generally more secure than it is reliable, although its parameters may be adapted to increase reliability at a slight expense of security.



Conclusion

This algorithm can be used in high security risk contexts, where we cannot rely on the veracity and trustworthiness of official or centralised sources. It is collaborative, privacy-preserving and makes no assumptions of honest behaviour. We provide a validated mathematical model for its functioning, and also a mathematical model to probabilistically detect a class of attacks where groups of dishonest agents verify each other and platoon together.



Bio

Aida Manzano Kharman is a PhD student working on fairness, privacy and decentralised systems. Her research interests include algorithms for decentralised systems, distributed ledgers and cryptography. Her work is funded by IOTA Foundation. She received her masters degree at the department of Design Engineering in Imperial College in 2021.

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Bio-Welding Biomaterials to Create Leather Alternatives with Enhanced Material Properties and Smart Functionalities.

"Sustainable bacteria-derived segmented biomaterials."

Abstract

Bio-materials offer an environmentally friendly alternative to synthetic plastic-based materials, but often face challenges in aesthetics and material properties. This project aims to address these limitations by creating segmented materials comprising various bacterial-derived composites. These segments will be bio-welding together, enabling separate manufacturing and subsequent assembly for enhanced manufacturability. Segmented materials can promise improved durability, tailored properties for specific use cases, and potential integration of smart materials with embedded sensors.

In-depth investigation of bio-welding will contribute to enhancing traditional bio-weld strength and developing new manufacturing techniques. Moreover, significant research into PHB-cellulose composites, a potential component of the biowelded composite material, aims to provide a sustainable option for replacing synthetic materials.

This work contributes to the growing knowledge in bio-materials and fosters the connection between research and the manufacturing industry. By exploring innovative approaches to bio-material design and fabrication, this project seeks to advance sustainable material solutions across various applications.

Introduction

Plastics are currently the cheap and reliable backbone of the materials industry; however, their durability means they remain in our environment for thousands of years and generate large amounts of Carbon emissions from cradle to grave. Around 64% of modern materials use plastics such as polyamide, polyester, and nylon, shedding millions of tons of micro-plastics and fibres throughout their lifespan [1-4].

A popular alternative is the use of biomaterials derived from plants, animals, and micro-organisms. Although these materials offer an environmentally friendly option compared to traditional synthetic materials, they are often substantially more expensive and have inferior material properties [5-8].

As a means of survival, some bacterial strains, such as *Komagataeibacter xylinus* (Kx), secrete "pellicles" at the air-water interface. A pellicle is a protective barrier created extracellularly that floats on the water surface. This barrier promotes the transport of oxygen and nutrients, aids in water retention, and prevents desiccation from UV light [9-17]. This pellicle can be harvested and used as a biomaterial due to its exceptional tensile strength, ranging from 200 to 300 MPa [18], and its versatility.

Bacterial nanocellulose (BNC) is produced by acetic acid bacteria through oxidative fermentation, involving enzymes and substrates like glucose. The cellulose forms in a liquid medium and moves to the air-liquid interface to thicken, relying on oxygen. Outside the bacteria cell, protofibrils self-assemble into a complex 3D network, resulting in a highly porous structure that retains about 98% water [19-20].

Aim

The aim of this work is to create a sustainable, eco-friendly fabric material derived from bacteria, segmented into areas with varying localised properties. This allows optimisation for specific use cases with tailored characteristics for different locations. Additionally, the project will explore biowelding between segments, involving design and experimentation with dyecuts and mold designs to ensure economic feasibility and adequate performance compared to synthetic counterparts.

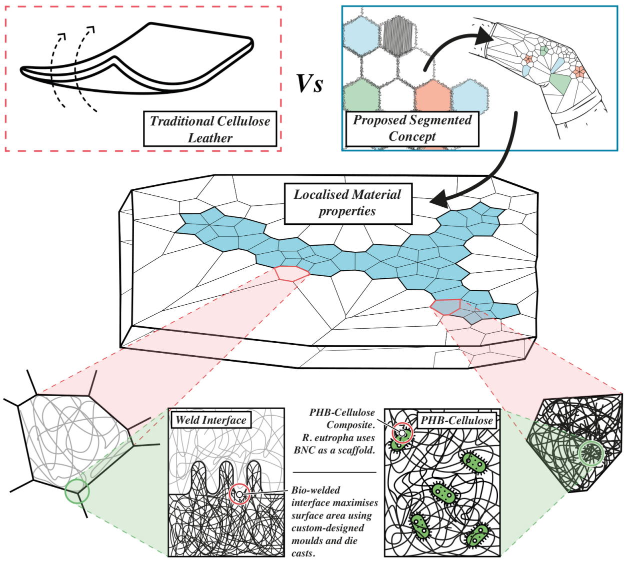

Figure 1 - *The diagram compares traditional BNC materials, characterised by single colour and uniform properties, with the proposed segmented material concept featuring localised material properties. This new material combines different biomaterials bio-welded together to create a single material with varied properties. Some areas contain pellicles from Kx, while others, such as the right side of the diagram, include composite biomaterials optimised for specific use cases, enhancing flexibility, stretchability, rigidity, durability, or integrating smart sensors. The composite on the right uses a cellulose 3D fibre network scaffold with PHB granules synthesised by R. eutropha for reinforcement. On the left, the bio-weld interface between segments is optimised with specially designed moulds and die casts.*

Methods

Initially, a selection of extracellular matrix (ECM) and PHA producing bacteria were cultivated to identify strains that produce usable biomaterials. This involved growing eight strains of bacteria from around the world and experimenting with over 20 ECM/PHA inducing growth mediums.

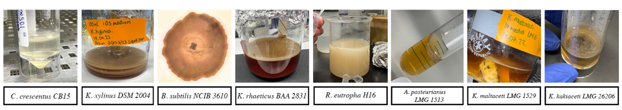

Figure 2 - *Eight strains of bacteria from around the world. Of these strains, Kx, Gr, and Re will be used for experiments in this body of work due to their ability to produce cellulose and PHB, as well as their ease of use.*

Both K. xylinus (Kx) and K. rhaeticus (Kr) were encouraged to synthesise BNC, grown in HS media. These pellicles were then sterilised in 0.1 mol of NaOH and distilled water for one week, followed by washing to remove traces of NaOH. Once sterile, the pellicles were freeze-dried and transferred to SEM and XRD machines. Fiji Fast Fourier Transform image analysis will be used to determine fibre orientation, and XRD data will be visualised using Excel to show crystal characteristics.

Information from SEM and XRD results will be used to understand why BNC has specific material characteristics. Pellicles will be tested using a tensile strength machine. Samples have been prepared and machine inductions are complete, ready for testing.

To connect segments, bio-welding was employed. This involved placing a sterile pellicle at the air-water interface in an active culture of Kx. As each layer of cellulose formed, the culture medium (HS medium) level was increased until the bio-weld reached the height of the original pellicle. This incubation process took around two weeks at a constant temperature of 30 degrees Celsius.

One of the composite segments comprised of PHB grown into the fibre network of BNC. Sterilised BNC, with surface modifications, was added to a growing stirred culture of R. eutropha, where it was allowed to populate the pellicle. After three days, the pellicle was transferred to mineral salt media to encourage the formation of PHB inside the fibre network. This material was then imaged using an SEM and tested with a tensile strength machine.

To study the process of mass BNC manufacturing and apply insights to the bio-welding process, a trip to a cosmetic BNC factory in Vietnam was undertaken. This trip involved observing mass culturing and sterilisation processes, as well as identifying various issues in the industry to help address them.

Results

The majority of tests are currently in progress; however, some results have been collected so far.

After applying surface modifications to BNC pellicles using a micro-needle roller, R. eutropha cells were observed deep inside the pellicle, as seen in the SEM images below. The presence of PHB granules inside these pellicles was confirmed using an optical microscope, UV light, and dye, which caused the PHB granules to fluoresce. Additionally, the liquid media containing the R. eutropha surrounding the pellicles was tested using gas chromatography, showing that 80% of the cell biomass was PHB.

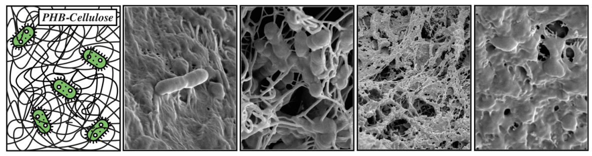

Figure 3 - *The diagram above shows the growth of R. eutropha inside of a BNC fibre network.*

After two weeks of growth in a culture of Kx, the BNC pellicle was removed and bio-welded to a fresh Kx BNC pellicle. Some de-lamination was observed between rows of pellicle sheets; however, bio-welding has occurred and will be examined under an SEM machine. This material has been sterilised with 0.1 mol of NaOH and distilled water and will now be freeze-dried in preparation for imaging.

Discussion

Once Kx and Kr have been analysed using SEM and XRD, as seen in Figure 6, the next step will be to start bio-welding materials together. These initial tests will serve as a baseline for comparing all future composites and materials.

Using an improved method of bio-welding to reduce de-lamination seen in previous tests, segments will be combined. The weld interface will be varied with different mould and dye cut designs, altering surface area, stress concentrators, and weld depth. These will be examined using SEM and tensile strength machines, and the results will be compared to previous findings.

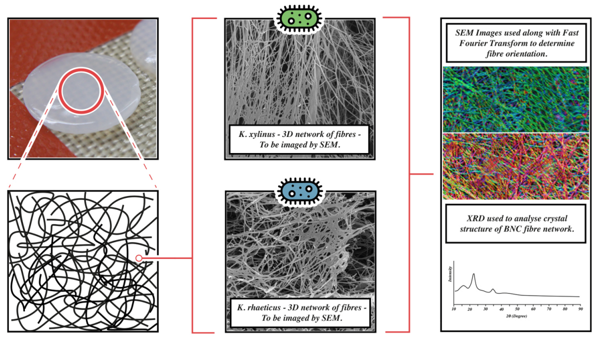

Figure 4 - *The diagram above shows how the BNC from both Kx and Kr will be imaged and analysed using SEM and XRD.*

Research into PHB-Cellulose composites will continue, focusing on verifying previous tensile strength tests, co-culturing the two strains of bacteria (R. eutropha and Kx), and stirred cultivation of BNC with heat pressing. These methods aim to create a strong cellulose mesh network reinforced with PHB granules.

Further experimentation with segments for bio-welding may also include variations of colour, smart sensors embedded in the cellulose, and embedded fibres for reinforcement.

Conclusion

In conclusion, pellicles from both Kx and Kr have been prepared for SEM and XRD analysis. Initial studies of bio-welding with Kx have yielded mixed results, with some observed lamination requiring further examination under the SEM machine. These preliminary findings lay the groundwork for future tests, which will involve experimentation with mould designs, die casts, and options for different material segments, including aesthetics such as colour and integrated electronics. Continued research into PHB-cellulose composites has shown promising progress, although further experimentation is needed to optimise the distribution of PHB throughout the pellicle, potentially through methods like co-cultivation.

Looking ahead, the goal is to collaborate with an external company to develop a segmented composite leather with localised material properties tailored to specific product use cases, aiming to reduce wear in designated areas. This vision underscores the potential of biomaterials to revolutionise product design and manufacturing

Bio

Alfie Mcmeeking - PhD, Dyson School Design Engineering

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Proprioceptive Sensing in a Bio-Inspired Deformable Mobile Robot

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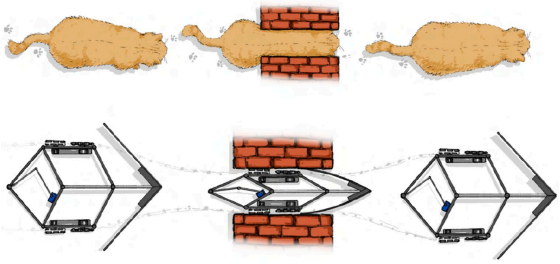
Thrishantha Nanayakkara

> “ Shape-changing capabilities improve mobile robot traversal of obstacles. ”

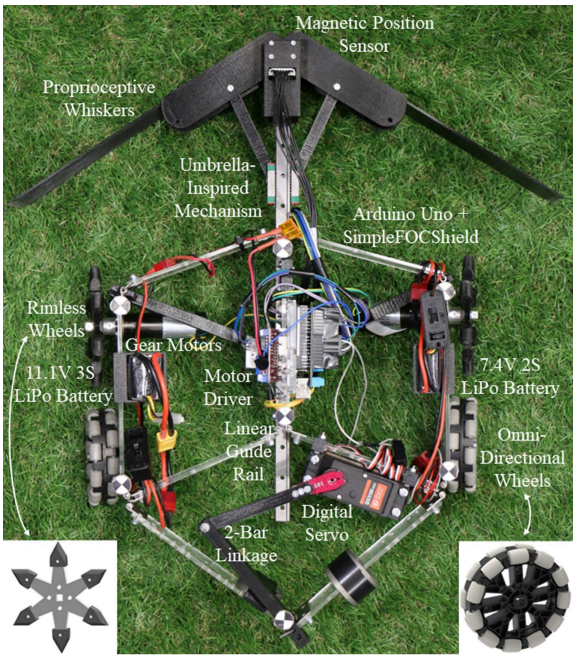
Abstract

- Navigation around compliant obstacles leads to loss of efficiency—and possible mission failure—compared to progression through them.
- We propose the design of DeforMoBot, a deformable mobile robot; it adopts a wider stance for stability or a narrower stance to fit through gaps and traverse obstacles.
- Ability of animals such as cats to morph their shape to traverse small spaces is the bio-inspiration for our design.



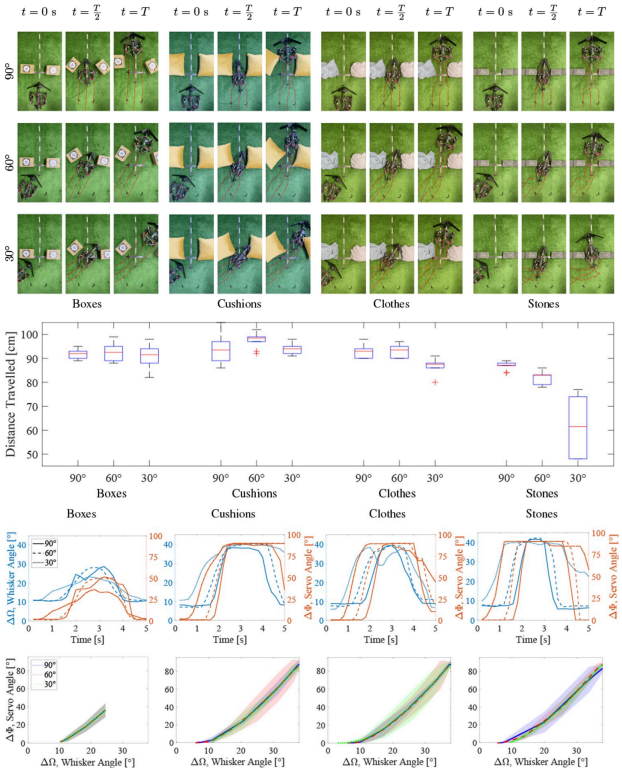
Methods

- DeforMoBot can change shape between regular hexagon and elongated rhombus.
- Spring-loaded “whiskers” match amount of robot’s deformation with compliance level of the obstacles.
- Real-time algorithm uses this whisker feedback to change shape in uncalibrated environments.
- Experiments observe how the robot interacts with obstacles with varied parameters from different approach angles.
- Boxes, cushions, clothes, and stone blocks used as obstacles to cover a range of different physical properties.



Results

- Based on obstacle movability, robot can push these away, narrow body to squeeze through gap, or combine these actions.
- Robot achieved 100% success rate in 11 of the 12 cases: boxes at approach angles of 90°, 60°, and 30°; cushions at 90°, 60°, and 30°; clothes at 90°, 60°, and 30°; and stone blocks at 90° and 60°. 60% success rate in other case, stone blocks at 30°.
- Results show the importance of tuning haptic perception to match the robot’s physical capabilities.



Conclusions

- DeforMoBot changes shape for obstacle traversal, rather than circumnavigation.
- Ability to interpret proprioceptive whisker feedback relative to body shape leads to meaningful obstacle negotiation behaviors.
- Shows importance of co-development of environment perception and physical reaction capabilities for better performance of robots in unstructured environments.

Bio

Barry Mulvey is a PhD student in Morph Lab working on multimodal sensor integration for mobile robots. He received the BSc degree in Electronic Engineering and the ME degree in Electronic and Computer Engineering from University College Dublin. Barry was awarded an EPSRC PhD scholarship for his doctoral work.

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EPSRC Engineering and Physical Sciences Research Council

Design Framework for Circular and Sustainable Packaging Solutions

> “Assist industrial designers to achieve sustainability and circularity targets”

Rizwan Khan, (r.pathan@imperial.ac.uk)
Dr Marco Aurisicchio

Abstract

New European Union (EU) regulations require the Fast Moving Consumer Goods (FMCG) sector to redesign their packaging to meet stricter sustainability standards. However, current packaging design practices prioritise product protection, preservation, handling, and branding as primary requirements, with sustainability considerations often being secondary. This results in packaging that is incompatible with end-of-life infrastructure (e.g., recycling facilities), leading to packaging often ending up in landfills or, worse, leaking into the environment [1].

To address this, we propose a design framework that integrates sustainability and circularity goals into the packaging design process. Our framework aims to support industrial designers in selecting and exploring sustainable and circular packaging options and help attain regulatory targets, ensuring that environmental considerations are prioritised alongside functional requirements

Introduction

Packaging waste is of grave concern in today's world, exacerbated by the current linear economy, which accentuates the problem by prioritising single-use solutions that often end up in landfills [2]. The circular economy offers a promising solution by promoting the reuse, recycling, and reduction of packaging materials[3]. However, based on our current knowledge and literature review there is lack of a holistic framework that comprehensively integrates sustainability and circularity targets with functional requirements. Also, stakeholder requirements are loosely integrated in the design frameworks too. This gap necessitates a new approach to packaging design that ensures environmental considerations are embedded alongside practical and stakeholder requirements.

Our work proposes a design framework that addresses this need, supporting industrial designers in selecting and exploring sustainable and circular packaging options, ensuring that both sustainability goals and functional requirements are met.

Design Framework

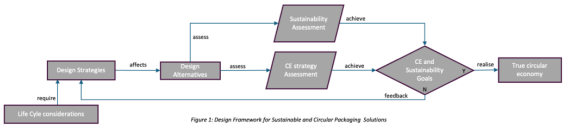
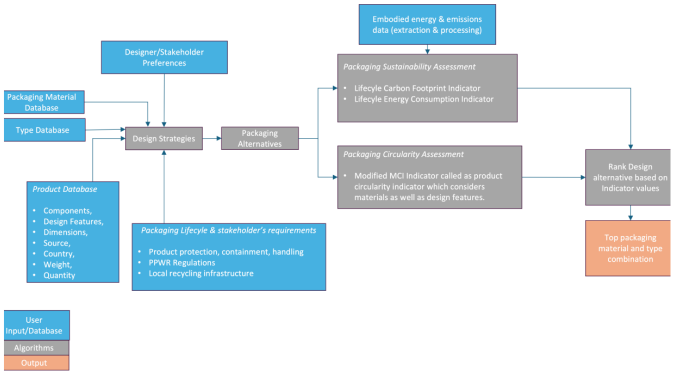
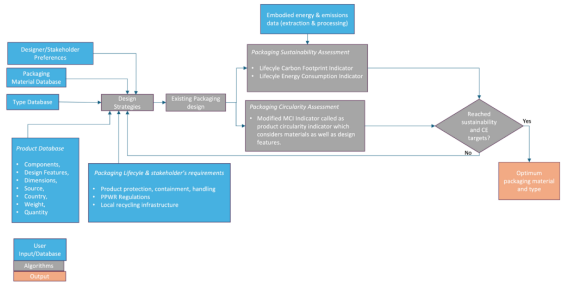


Figure 1: Design Framework for Sustainable and Circular Packaging Solutions

Case study execution workflow : Selection based approach



Case study execution workflow : Target based approach



Bio

Rizwan is a PhD Student whose current project is focusing on sustainable and circular packaging solutions for FMCG industries, which is funded by EPSRC and Procter & Gamble (P&G).
Rizwan received his master's degree in aerospace engineering from IISc Bangalore and has also worked in Tata Consultancy Services Research, Pune.

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3. www.ellenmacarthurfoundation.org

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UAV Mounted Reconfigurable Intelligent Surface for enhancing Communication Coverage

Syed Danish Rizvi (d.rizvi21@imperial.ac.uk)
David Boyle

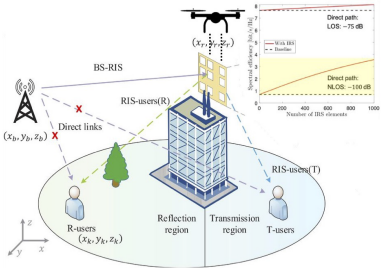
> “ Reconfigurable Mirror on the wall, are you making networks smarter for all? ”

Background

In urban environments, mobile users often experience Non-Line-of-Sight (NLOS) channels, resulting in lower data rates. Reconfigurable Intelligent Surfaces (RISs) are innovative structures with passive reflecting elements that dynamically alter electromagnetic wave phases - thereby improving channel quality. However, conventional wall-mounted RISs are 1) ineffective for users positioned behind the surface 2) creates persistent NLOS pockets because of its stationarity.

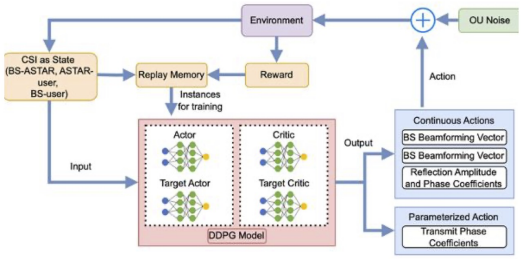
Research Aim

To cater for problems arising from RIS stationarity and to increase the field-of-view to 360° for coverage enhancement, we employ a UAV mounted Aerial Simultaneous Transmitting and Reflecting Reconfigurable Intelligent Surface (A-STAR) with coupled realistic transmit and reflect coefficients (TRC) model. With UAV energy constraints in mind, our goal is to enhance the communication efficiency with respect to power of the A-STAR system by jointly optimizing UAV trajectory, beamforming vectors at base station (BS), and RIS TRCs.



Methods

1. Channel and Sum Rate Estimation between BS, A-STAR and users based on Base station beam forming vectors, RIS TRCs and as dictated by 3GPP specification TR 36.873.
2. UAV power consumption model based on trajectory, STAR elements and UAV size.
3. Machine Learning based optimization
a) Deep Deterministic Policy Gradient (DDPG) model to optimise A-STAR trajectory, BS beam forming vectors and RIS TRCs.
b) DDPG aims to maximise communication efficiency of the system using a Jain's fairness index based reward function to maximize fairness.
c) Action spaces are parameterised to deal with continuous and discrete action spaces occurring due to a practical coupled TR phase shift model.

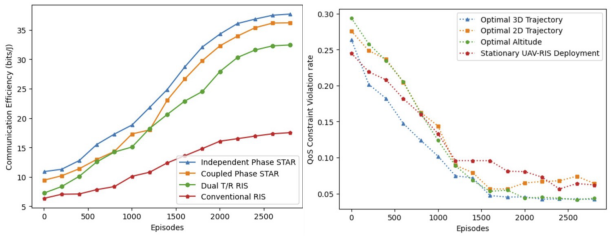


Experiments

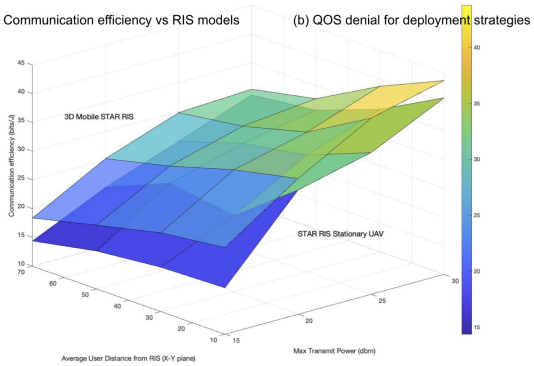
We train the Parameterised DDPG and compare it for optimal stationary, 2D and 3D deployments. We also compare the proposed solution against conventional RIS, dual (joint) T/R RIS and ideal (independent) phase STAR. Communication efficiency of the proposed system is also compared against average user distance and maximum transmit power.

Results and Discussion

Results reveal that the proposed A-STAR shows a 134% improvement against conventional RIS due to 360° coverage and 13% improvement vs dual T/R RIS. Practical coupled TRC phase shift model exhibits at par performance (4% decrement) as compared to an ideal phase shift model. Comparing various deployment strategies for user fairness, optimization of 3D trajectory showed the maximum improvement.



(a) Communication efficiency vs RIS models (b) QOS denial for deployment strategies



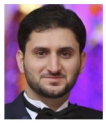
(c) Communication efficiency vs Average user distance vs Max Transmit power

Figure above shows how the average user distance from A-STAR and maximum transmit power changes the communication efficiency for 3D and stationary deployment. It can be noted that at difference of performance between the two deployment schemes was most at lower transmission powers and lower user distances.

Conclusion

The proposed UAV mounted A-STAR can be used to improve both in range and incorporate 360° coverage. By using a DDPG with parameterised action space, we can employ a realistic coupled phase shift STAR model that performs at par with an ideal independent phase shift model.

Bio



Syed Danish Rizvi is a 3rd year PhD Candidate focusing on applications of Reinforcement learning techniques in air-to-ground communications and is funded by Commonwealth Scholarship Commission, UK. Danish Recieved his Master's degree in Avionics from Air University, Islamabad

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Systems and Algorithms Lab

Aligning Conversational AI with Human Values

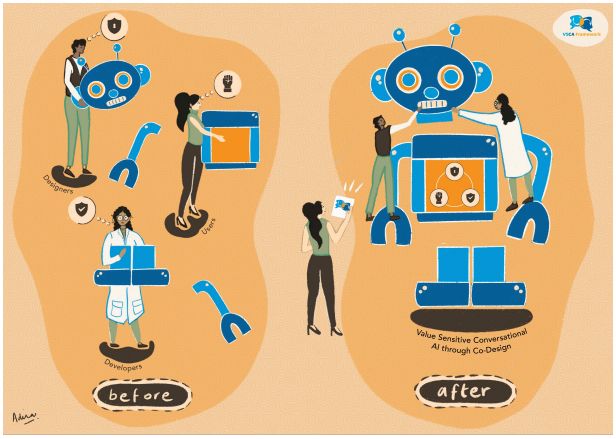
Malak Sadek, m.sadek21@imperial.ac.uk
Dr. Céline Mougenot, Prof. Rafael A. Calvo

> “Correcting the misalignment between conversational agents and stakeholders’ values through collaborative design practices”

Abstract

Conversational agents (CAs) such as chatbots, smart home speakers, and voice assistants are infiltrating an increasing number of critical applications and domains such as healthcare, education, and finance. The recent proliferation of Generative AI and Large Language Models has only sped up the development and adoption of this technology. With this increasing usage comes increasing concerns over which values and whose values are embedded in these systems. As such, this project looks at how collaborative design methods can be leveraged to better align CAs with human values. Using principles from Responsible AI, Value-Sensitive Design and Collaborative Design, the result is a framework and a corresponding toolkit that can allow teams building CAs to do so more collaboratively with different stakeholders in ways that better embody their values.

The project follows a Design Research Methodology format. The first phase of the project consisted of systematic reviews, design workshops and a series of semi-structured interviews with AI/CA practitioners. The aim was to understand (i) the limitations of current design interventions and (ii) the challenges and barriers faced by practitioners when working with human values. The second phase involved developing the framework and the toolkit, as well as creating an evaluation protocol for validating them. The last phase consisted of a mixed-method evaluation study including design workshops, semi-structured interviews, and a comparative analysis through a survey. The outcome of the project is the creation of new knowledge around supporting more collaborative practices for CA design that result in CAs which are better aligned with human values.



Methods

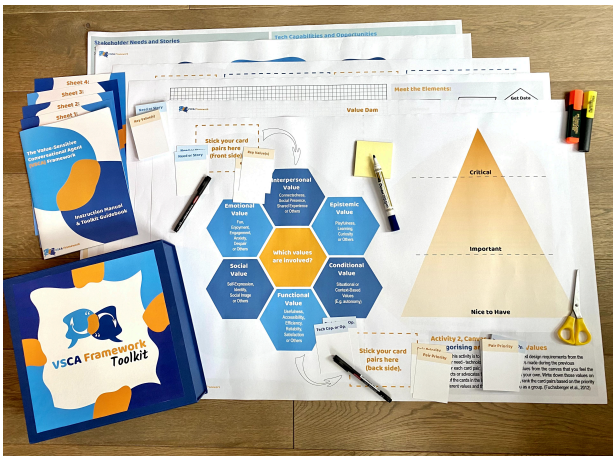
The project involved systematic reviews of 47 CA co-design studies and 7 socio-technical AI design processes, initial design workshops with 12 AI researchers, 30 semi-structured interviews with AI/CA practitioners, a second set of design workshops with 22 industry CA professionals and stakeholders, 13 semi-structured interviews with workshop participants, and a comparative survey with 451 participants.

Results

This work has resulted in a framework and toolkit for achieving value embodiment in CA design. This is facilitated through value elicitation from CA stakeholders and technical utility to CA creators. Design workshops allowed CA practitioners to use the framework and toolkit. Semi-structured interviews found that the process followed allowed for effective value elicitation and resulted in outcomes with high technical utility. A quantitative survey revealed the prototypes to have higher value embodiment, especially with human-centred values, in comparison to control prototypes.

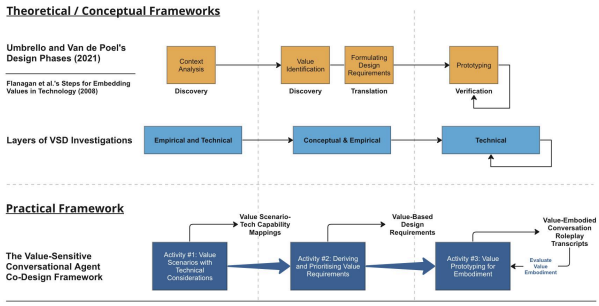
Aside from validating the framework and toolkit, this project has led to the provision of several design recommendations around:

- Supporting value-sensitive design in AI design processes
- Supporting value-sensitive design in CA co-design activities
- Supporting value-sensitive design in Responsible AI toolkits
- Understanding the barriers practitioners face when working with values



Conclusion

This project has identified barriers to creating more value-sensitive CA. A framework and toolkit were created based on design requirements obtained from conceptual and empirical studies. Design workshops, semi-structured interviews and a quantitative survey are used to assess the framework’s process and outcomes. The framework was found to improve value elicitation & technical utility, and lead to more value embodied outcomes.



Bio

Malak is a PhD student at the Dyson School of Design Engineering at Imperial College London and Lead AI Design Researcher at AIxDesign. She is also affiliated with The Leverhulme Centre for the Future of Technology and The Alan Turing Institute. Malak has earned a BSc in Computer Engineering and a MSc in Human-Computer Interaction.

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Fundamental Studies and Simulation of Recycled Carbon Fibre Wet Compression Moulding

Author: Zhengquan Shen
Supervisor: Dr. Nan Li Prof. Jianguo Lin

"Promoting the circular economy."

Abstract

With the rapid development of the composite market and the improvement of environmental awareness, many composite recycling technologies have been developed [1]. However, the applicability and the formability of recycled carbon fibre (rCF) have gradually become a concern . This research is dedicated to understanding and modelling the deformation mechanisms and predicting the formability of wet-laid nonwoven rCF in wet compression moulding, to facilitate medium-volume production of semi-structural rCF reinforced components.

Introduction

The European composite market is set to grow from $17.88 billion in 2019 to $27.54 billion by 2025 [1]. However, high raw material costs, particularly virgin carbon fibre, limit further applications of composites . Meanwhile, recycled carbon fibre, restored through the fluidised-bed process, offers a more affordable alternative with up to 80% fibre strength retention and lower energy costs at 51.73MJ/kg (198-595MJ/kg for virgin fibres) [2, 3]. Being restored by fluidised-bed processes, the raw materials were collected and prepared as nonwoven fabrics and then formed with resins to become a component to serve for semi-structural or structural applications. When combined with fast-curing resin systems, nonwoven rCF composite components, produced via wet compression moulding, can offer performance similar to mild steels and can achieve short cycle time (t<3 min) compared to composites forming [4].

However, due to the lack of fundamental studies on the mechanical behaviours of wet-laid rCF fabrics [5], there are no effective simulation tools for the design and manufacturing process es.

This study aims to identify the crucial factors affecting the deformation mechanisms, forming windows, and formed defects by studying the material's mechanical behaviour, inter-ply interactions and thermal-mechanical couplings. By the end of this project an innovative monolithic process simulation tool will be developed.

Methods

The decoupling of in-plane and out-of-plane behaviours of the material was assumed due to the inherent nature of composite textiles [6].

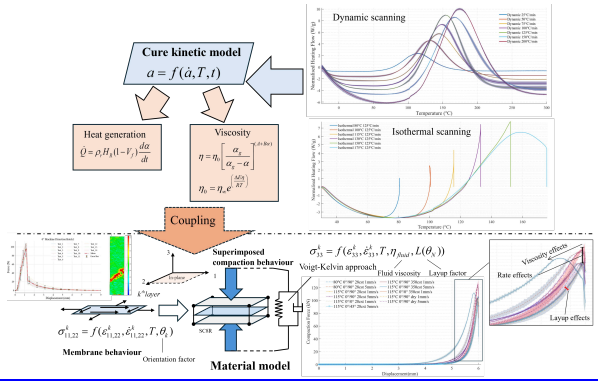
- In-plane properties were tested via tensile tests at elevated temperatures and modelled based on the continuum shell assumption.
- Compaction tests were performed to acquire through-thickness behaviours considering thermal, lay-ups, and infiltrated fluid viscosity factors.
- The cure kinetics of the fast-curing epoxy resins were characterised by performing differential scanning calorimetry (DSC) testing and analysis.

In all the tests, rate-dependent effects were considered.

Results

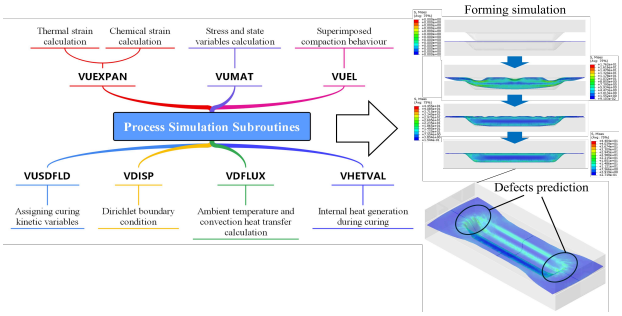
Fundamental studies:

- In-plane tensile behaviours of rCF: The material was tested to obtain stress-strain properties, and considering the effects of orientation, temperature, and load rate. The strength and modulus in the transverse direction are about 50% of those in the machine direction. Thermal (25°C, 60°C, 90°C, 110°C and 130°C) and rate dependency (0.001/s,0.01/s, 0.05/s) were measured and characterised.
- Compaction behaviours of rCF: Compaction tests were performed with the dry and wet (infiltrated with low-viscosity fluids) rCF fabrics. The layups have slight effects on the compaction response while the viscosity of infiltrated fluids contributes to the viscoelastic behaviour of the material.
- Resin cure kinetics: The cure kinetics of the fast-curing resin systems were characterised via DSC analysis (dynamic scanning from -25°C to 275°C at 25°C/min to 200°C/min, and isothermal scanning at 80°C, 100°C, 115°C, 130°C, 150°C and 175°C). The glass transition point was measured to be 102.4°C. The forming window was identified.



Simulation:

- A preliminary thermal-mechanical coupled simulation was proposed via commercial finite element software ABAQUS adopting SCSR reduced integration 8-node continuum shell elements to simulate the in-plane membrane behaviour.
- A preliminary compaction constitutive model was employed by superimposing the through-thickness response of the continuum shell elements via a user-defined element .
- A cure kinetic model of the epoxy resin was proposed, and the viscosity of epoxy resins related to the occurrence of chemical reactions can be introduced in the future.
- As a result, the thermal-mechanical coupling of the simulation was implemented based on VUEXPAN, VUMAT, VUEL, VUSDFLD, VDISP, VDFLUX AND VHETVAL user-defined subroutines as shown in the figure below.



Discussion

Compared to traditional isothermal forming simulations, thermal-mechanical coupling was introduced and the mechanical properties of the materials at forming temperatures were tested. The rate-dependent and fluid viscosity effects were also considered. By using continuum shell elements combining with superimposed user elements, the cost-effectiveness of the model was improved.

However, due to the lack of heating conduction and convection measurements, the heat transfer between fabric and tool as well as fabric plies can hardly be characterised, so further validation of forming temperature distributions are needed to calibrate the model.

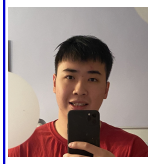
Conclusions and future works

This research proposed a cost-efficient process simulation framework that can support product and process design at an early stage of development. The outcomes can predict the forming defects and understand the applicability of the material. The results at current stage help in understanding the rCF material's mechanical behaviour and can support a monolithic process simulation model in the future.

Future work:

1. Experimental studies and modelling of inter-ply friction behaviour of the material.
2. Forming experiments to evaluate forming defects and validate the process simulation framework.

Bio



Zhengquan Shen
Research Postgraduate Student at Dyson School of Design Engineering

PhD project:
Fundamental Studies on Sustainable Forming of Recycled Carbon Fibre Reinforced Composites for Lightweight Structural Components

Acknowledgment:
This research has been supported by Lightweight Manufacturing Centre (LMC) – National Manufacturing Institute Scotland (NMIS) and WMG, the University of Warwick

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Tribological Behaviours of Additively Manufactured CoCrMo

> “Can the strategic control of porosity in LB-PBF CoCrMo mimic the beneficial effects seen in surface textures?”

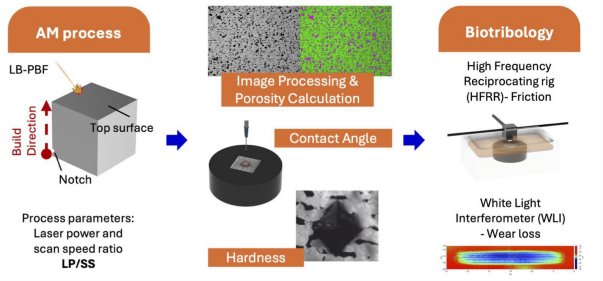
Qingyue Shi (qs20@ic.ac.uk)
Supervisor: Dr Connor Myant

Abstract

This study explores the potential application of controlled porosity in Cobalt Chromium Molybdenum (CoCrMo) alloys fabricated using Laser Beam - Powder Bed Fusion (LB-PBF) to enhance tribological performance in orthopaedic implants.

Introduction

Surface texturing has become a popular method for improved tribological performances in lubricated contacts where surface textures may act as fluid reservoirs that assist with lubrication. Common methods of surface texting normally result in longer manufacturing time and additional cost. However, a carefully controlled porosity may be leveraged to improve the tribological performance of printed metal parts without additional cost.



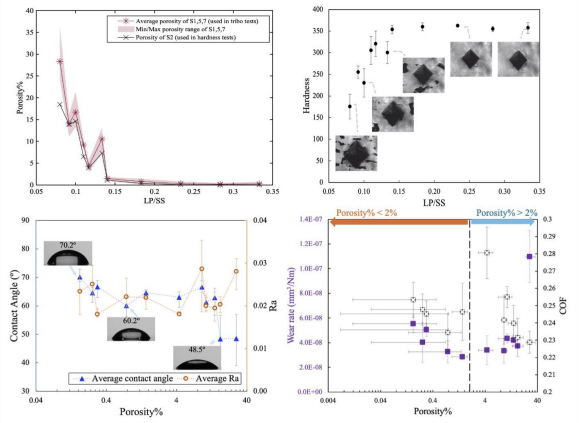
Methods

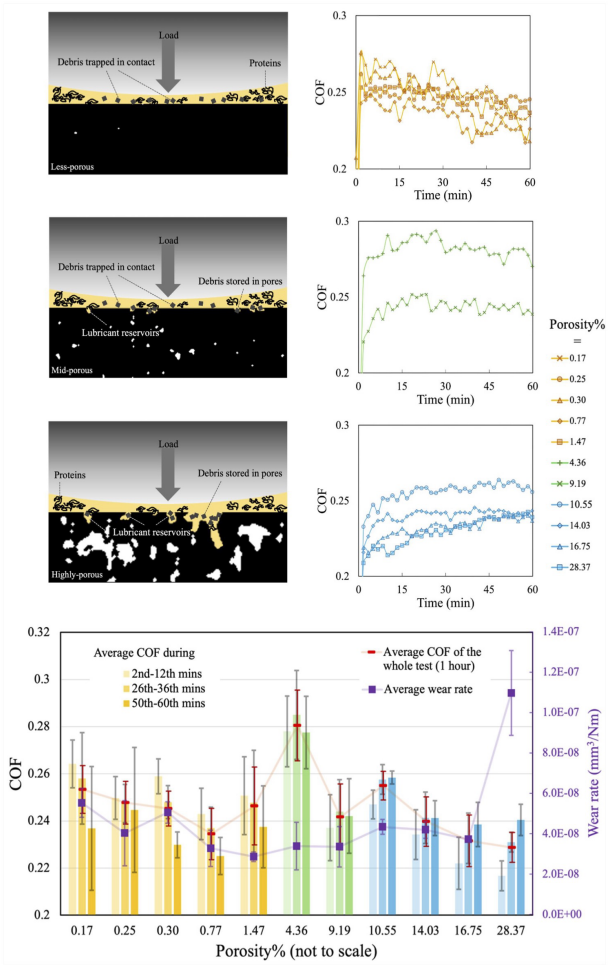
CoCrMo alloy samples were fabricated using LB-PBF with controlled laser parameters to vary porosity. The top surfaces were polished to a mirror finish, and porosity was quantitatively assessed. Hardness and contact angles were measured following standardised methods. Friction and wear were evaluated to investigate the tribological performances of the samples.

Results & Discussion

The results show the presence of pores had a significant impact on the wear and friction characteristics of the LB-PBF CoCrMo alloy.

- LP/SS ratio is an effective way to induce porosity in LB-PBF CoCrMo. As the porosity increases, the hardness decreases.
- LB-PBF CoCrMo with 1.47% porosity resulted in the least amount of worn metal volume.
- Porosity had significant impacts on the friction and wear mechanisms of LB-PBF CoCrMo with ceramic ball sliding in bovine calf serum.





Conclusion

Although porosity is traditionally considered a defect, the results in this study showed that it can be utilised as a design optimisation for tribological performance.

Bio

Qingyue (Esperanza) Shi is a PhD candidate whose current research focus is additively manufactured alloys for join replacement application. She has a Master degree in Materials Science and Engineering from Imperial College London and BSc degree in Nanomaterials.

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Photopolymer Development for Minimally Invasive Spinal Implant for Metastatic Bone Disease

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OncoEng

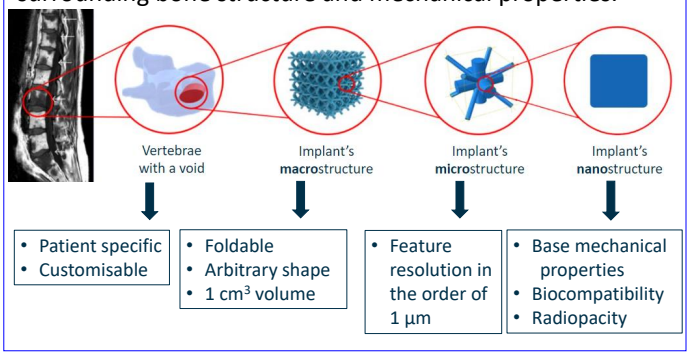
Engineering and Physical Sciences Research Council

BACKGROUND

Metastatic bone disease is a common complication of cancer, particularly affecting the vertebrae and leading to severe symptoms like pain, reduced mobility, and neurological issues, significantly impacting patients' quality of life. The NHS Long Term Plan for Cancer emphasizes new interventions to improve the quality of life for terminally ill patients, highlighting the need for an implant to address spinal lesions.

MATERIAL TARGET PROFILE

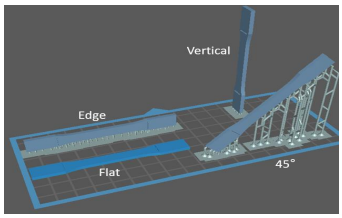
This research focuses on designing and optimizing a biocompatible, radiopaque material that matches surrounding bone structure and mechanical properties.

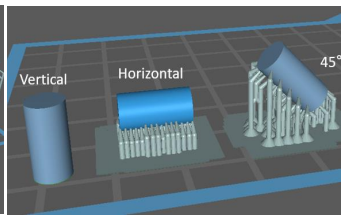


METHODS

Testing for directional weaknesses:
A commercial LCD printer was used to print cylindrical 10x5mm compression samples in three different orientations and three post processing states.

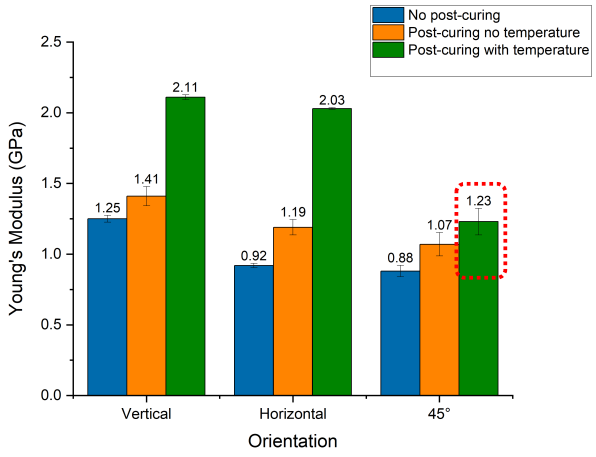
For the tensile tests, dogbone specimens were printed in four different orientations and three post processing states.

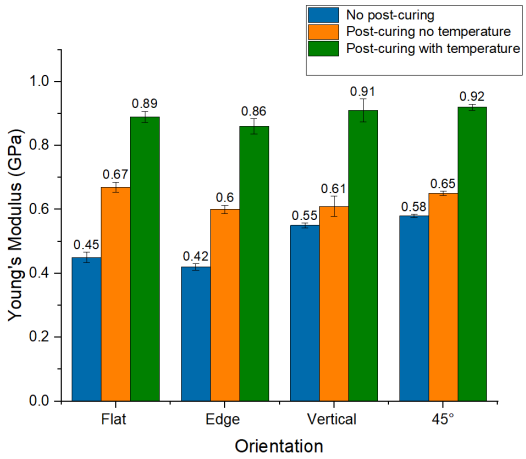




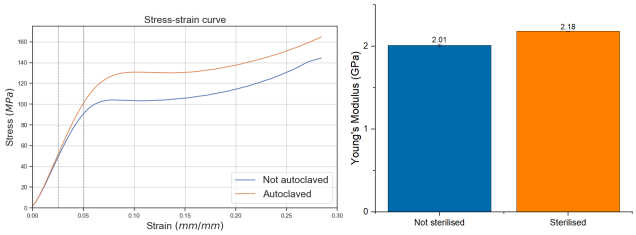
Sterilisation effect: Similar cylindrical specimens were printed and autoclaved to test for the effect of sterilisation on the mechanical properties.

ANISOTROPY EFFECT





STERILISATION EFFECT



CONCLUSIONS

- Post processing with temperature removes the anisotropic effect on the mechanical properties.
- The 45-degree orientation shows directional weaknesses and premature failure.
- Sterilisation increases the Young's Modulus in compression by approximately 10%.

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Designing Digital Behavioural Activation Therapy for Employees in the Chinese Culture

Sijin Sun, s.sun20@imperial.ac.uk
Prof. Rafael A. Calvo

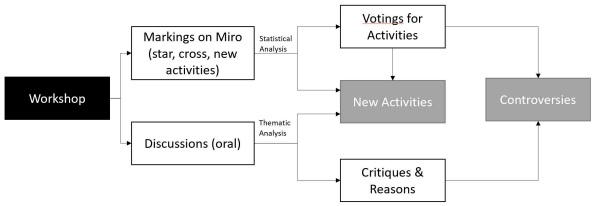
> “ This study highlights the need to **culturally adapt** BAT, considering both traditional values and evolving cultural dynamics. ”

Abstract

Digital interventions based on Behavioral Activation Therapy (BAT) are increasingly common in Western countries. This study explored how BAT can be adapted for Chinese employees through 12 co-design workshops involving 46 participants. Our findings highlight significant cultural differences, particularly in risk avoidance, workplace culture, and close relationships, demonstrating the necessity and value of cultural adaptations.

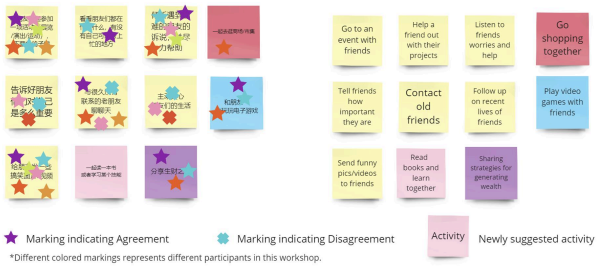
Introduction

Behavioral Activation Therapy (BAT) is a structured therapy that encourages healthier, mood-enhancing behaviors to improve cognition, emotions, and overall well-being [1]. While widely used in Western countries, BAT has also shown effectiveness in Eastern populations, including China, for treating conditions such as social anxiety and depression. However, there is a research gap in culturally adapting digital BAT interventions for Chinese users. This study addresses this gap by exploring Chinese employees' perspectives on positive activities through co-design workshops, using Hofstede's cultural dimensions theory to contextualize the findings. Understanding these cultural nuances is crucial for designing effective, culturally sensitive digital mental health support technologies.



Methods

Twelve online co-design workshops were conducted with 46 Chinese employees, representing a wide age range and diverse educational and professional backgrounds. The participants were introduced to BAT and presented with 201 positive activities designed for Australian employees [2]. Participants voted “likes” and “dislikes” for these activities on an online Miro whiteboard and discussed them. In this mixed-methods study, participants' votes on each activity on the Miro board were recorded and for quantitative analysis. In addition, n inductive thematic analysis of the transcribed text was conducted by a bilingual designer with psychology background and a bilingual psychologist using NVivo. By applying thematic analysis to the conversations, controversial topics emerged, including workplace stress, helping others, charitable acts, and professional mental health support.



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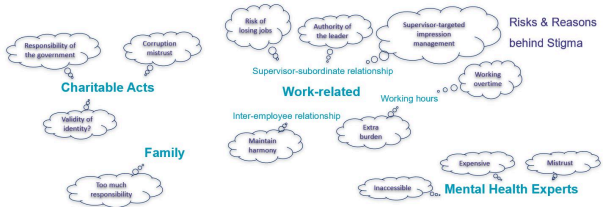
Results

Of the original 201 activities presented to the participants, 28 controversial activities were identified. In addition, 38 new positive activities were proposed in the workshops.
Using Hofstede's cultural dimension theory, we explored how China's hierarchical culture and fierce competition affect BAT activities. Activities like "offering creative advice to leaders" or "negotiating a pay raise" were seen as unrealistic in China due to the high power distance and respect for authority. Younger Chinese generations, however, show more individualistic tendencies and less acceptance of strict hierarchies, suggesting a shift in workplace dynamics.
The traditional concept of family in China is also changing, with younger participants expressing reluctance to visit relatives or maintain regular contact, possibly due to hierarchical dynamics within families. This shift is further influenced by the increasing use of the internet and mobility, leading to looser familial connections.
Participants generally displayed hesitancy towards the activity of "making an appointment with a psychologist/counsellor", citing the immaturity of psychiatric and counselling services in China due to their inaccessibility and high costs. Some participants with prior experience with mental health professionals expressed concerns about their expertise, thereby worrying about the potential risks of exacerbating their conditions through misdiagnosis.
Work-related activities are heavily influenced by cultural differences, with Chinese employees less likely to express dissenting opinions or provide feedback due to fear of losing face. However, some participants demonstrated a proactive attitude by proposing constructive work-related activities, such as “discussing flexible working hours with leaders” - participants argued that after the COVID-19 pandemic, Chinese employer also recognised the benefits of flexible working.



Limitations

The workshops involved 46 Chinese employees, but bias may exist due to the small sample size and urban recruitment, highlighting the need for future studies to include participants from minor cities and rural areas.

Conclusion

This study highlights the need to adapt behavioral activation activities for Chinese employees by considering Confucian influences, socio-cultural transformations, and generational shifts, recommending milder activity suggestions, indirect expression in interpersonal relationships, mental health self-help options, and lighter sports and entertainment activities to effectively align with Chinese cultural norms and reduce additional stress.

Bio

Sijin Sun
PhD in Wellbeing Tech Lab
Interested in interdisciplinary research at the intersection of **computer science**, **design**, and **mental health**.
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QR Code

Studying the effect of morphological features in finger haptics for texture perception

Parvathi Sunilkumar, Morph Lab
Supervisor: Prof. Thrishantha Nanayakkara

Abstract

This study investigates the effects of morphological features of the human fingertip like the fingernail and the distal phalange bone in perceiving different textures. Hall effect sensors are used to understand the texture classification of the fingertip. For understanding the individual effects of these morphological feature four different models of the fingertip are developed. These models are slid on different textures to classify them

Introduction

Tactile perception is integral to the sensory mechanisms that construct our comprehension of the surrounding world. Human hands possess a diverse array of afferent units situated beneath the skin, which can be categorised based on their functional attributes. Various receptors are uniquely attuned to discern discrete stimuli, encompassing mechanical and thermal modalities. The human finger possesses the capability to perceive micro vibrations and force dynamics. This detection is facilitated by four distinct types of mechanoreceptors (fast adapting and slow adapting) located within the skin. These receptors are adept at sensing spatio-temporal deformations of the skin at diverse adaptation rates. When external pressures or vibrations stimulate these mechanoreceptors, they produce electrical impulses, which are then conveyed to the brain through neural pathways.

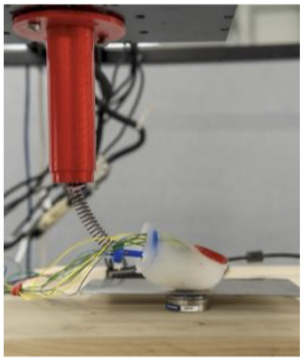

Figure 1: Experimental set-up

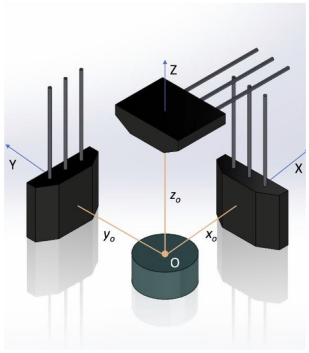

Figure 2: Hall effect sensors and magnet placement

Fingertip Models

Three Hall-effect sensors are placed (as shown in figure 2) in a soft silicone cube, orthogonal to one another. The centres are centred around a neodymium cylindrical magnet of diameter 3 mm. A 3D solid model of an adult's index finger is used to develop the fingertip model using silicone casting. Four distinct fingertip models were developed:
(i) Without both nail and distal phalange bone (F1)
(ii) With nail but without distal phalange bone (F2)
(iii) With distal phalange bone but without the fingernail (F3)
(iv) With both nail and distal phalange bone (F4)
These models are slid against different textures using XY Table at a constant force and velocity

Results and Discussion

For distinguishing various surface textures, the sensor data for each are analysed to determine Frobenius distances. Each texture was represented as covariance matrices to evaluate this. To visualise the sensor data, ellipsoids corresponding to each surface texture are plotted with their centres at the mean of the sensor data readings.

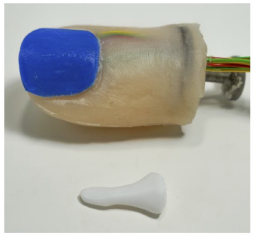

Figure 3: Fingertip Model

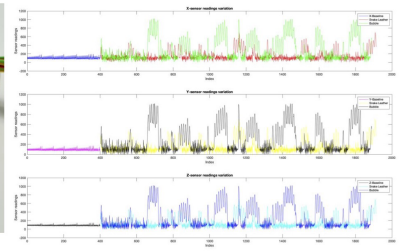

Figure 4: Sensor data variation during the experiment

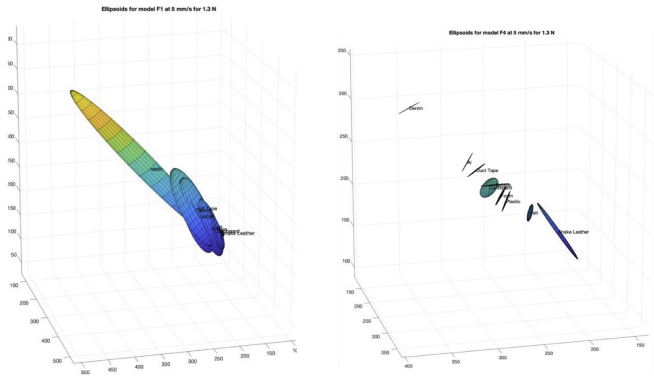

Figure 5: Gaussian Ellipsoids representing the sensor data variation for textures using fingertip models F1 (left) and F4 (right)

Conclusion

From these findings, it can be seen that the fingernail functions effectively channeling the vibrations generated from surface interactions to the sensors. Additionally, the stiffness variations of the finger is done by the distal phalange bone, thereby playing a complementary role in tactile sensation. This novel understanding of human tactile perception is advantageous to a plethora of robotic applications. These include the ergonomic design of everyday use items, which has a significant impact on the detection of irregularities in surface textures and the methodology developments in the rehabilitative healthcare sector. It is also beneficial for the tactile communication tool designing, artificial tactile sensing for prosthetics and other robotic applications.

Bio

Parvathi Sunilkumar is 2nd year PhD Student with her Bachelors in Mechanical Engineering from Government Engineering College Thrissur, India and Masters in Mechanical Engineering (Design) from Indian Institute of Technology (IIT) Palakkad, India.

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Embracing fairness in consumer electricity markets

Student: Shaun Sweeney
Contributors: Pierre Pinson, Robert Shorten, Mark O'Malley, Chris King

What is electricity?

POP QUIZ

(a) A flow of electrons
(b) An economic good to sell to the highest bidder
(c) An input good critical to supporting essential functions in life

Abstract

As consumer flexibility becomes expected, it is important that the market mechanisms which attain that flexibility are perceived as *fair*. We set out fairness issues in energy markets today, and propose a market design to address them.

Introduction

What is fairness?
Fairness is a concept which aims to strike a balance between outcomes for a group (e.g. society) and outcomes for an individual.

Fairness issues in electricity markets today:

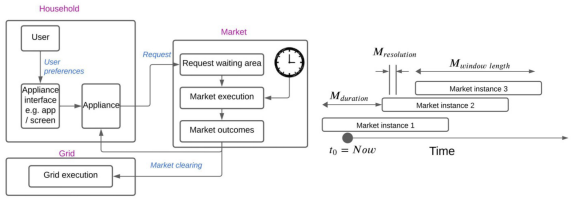
1. Those who impose the most costs on the system do not pay a proportionate share of the costs they impose.
2. Energy bills are made up of increasingly non-controllable costs (standing charge) to support flexibility acquisition to combat intermittency.
3. Time-of-Use tariffs are less effective with less price-sensitive consumers and do not consider whether consumption is for critical needs.

System Description

Consumption characterisation

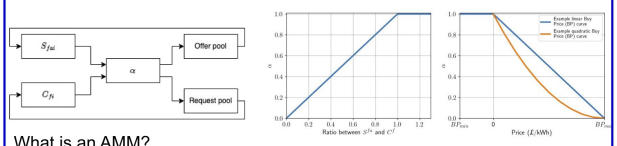
- Consumption is characterised as essential or flexible.
- There are different pricing methodologies and reliability levels for each.
- Flexible consumption must submit *requests* to the market.

Market design - Continuously online, continuously clearing



Pricing strategy

- Automatic Market Maker (AMM) generates energy prices based on instantaneous scarcity rather than marginal cost of production.



What is an AMM?

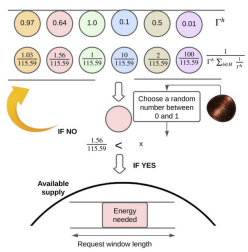
- An AMM determines prices algorithmically and enables transactions to take place automatically when specified criteria is met.
- In our case, prices are determined as a ratio of how much desired consumption can be served.

$$\alpha = \begin{cases} 1 & \text{if } S^{fa} \geq C^{fa} \\ \frac{S^{fa}}{C^{fa}}, & \text{otherwise} \end{cases}$$

Benefits to different groups of using AMM:

- People: Simple interface which requires minimal active participation.
- Economists: Pricing can be designed in line with economic principles.
- Engineers: Acts as a control system to ensure consumption cannot be greater than supply and has a self-corrective effect to procure only enough energy as is needed to meet desired consumption.

Resource allocation methodology



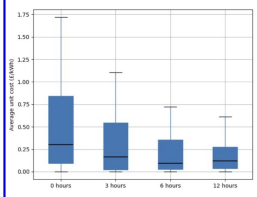
- We propose a dynamic resource allocation algorithm called the *Fair Play* algorithm.
- Fair play allocates the resource stochastically such that those with lower historic request success have a higher chance of success.

$$\min_{x_t^r} \sum_{t\in T} BP_t P^r N^r M_{\text{res}} x_t^r$$
$$\text{s.t.} \quad S_t^b \leq S_t^a \qquad \forall t \in T$$
$$\sum_{t\in T} x_t^r \leq 1$$
$$\sum_{t\in T} BP_t P^r N^r M_{\text{res}} x_t^r \leq C^r$$

Results

Inputs

- Supply: Wind, solar and hydro generation dataset from National Grid
- Consumption: 1 year of consumption data for 101 UK households provided by Moixa (now Lunar Energy).

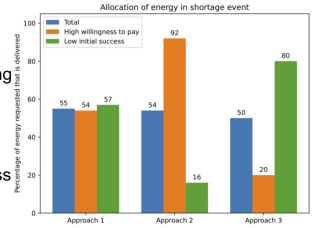


Key result - Pricing

- When a household offers 3 hours of flexibility, there is a 50% reduction in the average unit price for the median household.

We test our system against two benchmarks:

- Approach 1: Volume maximising
- Approach 2: Revenue maximising
- Approach 3: Fair play algorithm



Key result - Resource allocation
Orange: High willingness to pay
Green: Low historic request success
Blue: Orange and green combined

Under Approach 2, 92% of requests from people with high willingness (and ability) to pay are accepted. Under Approach 3, 80% of requests from the group with low historic success are accepted.

Discussion & Conclusion

While the inclusion of variable renewables in the supply-mix brings many technical and economic challenges, it must be remembered that electricity is a critical input good for many essential functions in life. Mechanisms which attain flexibility by unduly inconveniencing people, or which spread the costs in unfair ways put the acceptability of the energy transition at risk.

Bio

Shaun is a 3rd year PhD student with 5 years of work experience in the energy-tech sector. He has a Masters degree in Energy Systems Engineering and a BSc in Electrical & Electronic Engineering from University College Dublin (UCD).

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https://github.com/sweeneys/fair-flexible-energy-market
https://github.com/sweeneys/consumption-characteriser

Testing helmets for trips and falls: towards the development of an industrial helmet rating program

Rachel Tan, *jtan2@imperial.ac.uk*
Xiancheng Yu, Mazdak Ghajari

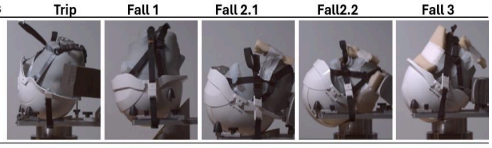
> “ **Comprehensive helmet rating program** to reduce work-related TBIs from trips and falls, aiming to establish **new industrial helmet safety standards** ”

Introduction

Traumatic Brain Injury (TBI) is a common workplace injury, affecting **57 million** people globally each year [1]. Work-related TBIs (Wr-TBIs) make up 17.9% of these cases, with **falls being the leading cause (50-70%)** [2][3]. Current safety helmets meet standards like EN379, which focus on heavy and sharp object impacts, but these account for only 17% of Wr-TBIs.

Our study used human multi-body models to simulate falls and trips, identifying **key head impact conditions** such as location, speed, and angle. We tested industrial helmets under these conditions to assess their effectiveness, providing insights into helmet performance in real-world fall scenarios.

Table 1:The parameters of the impact test condition.

Impact Conditions	Trip	Fall 1	Fall 2.1	Fall2.2	Fall 3
					
Impact speed (m/s)	3.9	3.8	5.5	5.5	5.5
Impact angle (degree)	75	45	75	75	75
Elevation angle (degree)	35	45	40	25	40
Azimuth angle (degree)	45	0	0	0	180

Methods

Five impact conditions are summarised in Table 1. Using the latest biofidelic EN17950 headform equipped with a DTS 6DX PRO sensor package and wireless datalogger, we measured linear accelerations and rotational velocities along three axes for each impact. Data was collected at 20 kHz and filtered per ISO 6487 standards. Peak values of **linear acceleration (PLA), rotational acceleration (PRA), and rotational velocity (PRV)** were extracted as head injury metrics. Each test condition was repeated three times with three different samples.

Results

Figure 3 illustrates the **effects of various impact parameters** on helmet performance, including surface conditions, external helmet design features, and different EPS coverage. These parameters significantly influence safety performance, as shown in both the plotted time history head kinematics and high-speed video snapshots.

Fall 2.1 and Fall 2.2 resulted in high **PLAs exceeding 250g**, highlighting helmet safety performance failure. Fall 2.2, in particular, had impacts closer to the rim, leading to less protection. Fall 2 impacts produced lower rotational motion due to a larger, less oblique impact angle of 75° compared to Fall 1 impacts. Interestingly, Trip conditions produced a higher PLA than Fall 1 despite similar impact speeds.

Discussion

We tested industrial helmets under representative oblique impacts from trips and falls. Current helmets show **poor repeatability** and are not designed for these conditions, leading to **inconsistent protection in real-life scenarios**. A potential limitation of this study is the possibility for some helmets to impact the edge of the anvil, which can affect results for helmets with features like the hump.

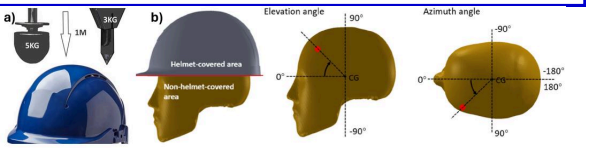


Figure 1: a) EN 397 impact test; b) Elevation and azimuth angle.

Figure 2: Types of hard hats.

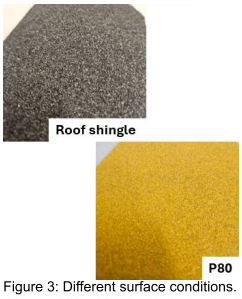


Figure 3: Different surface conditions.

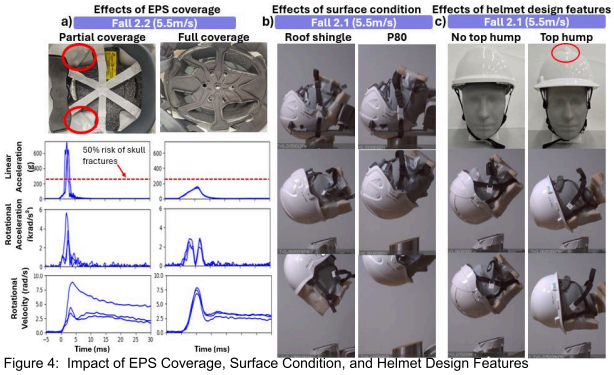


Figure 4: Impact of EPS Coverage, Surface Condition, and Helmet Design Features

Key Findings

EPS Coverage
- Climbing-style helmets with EPS foam generally improve protection but do not completely prevent bottoming out.
- Unlike bicycle helmets, climbing helmets have inconsistent EPS thickness and coverage, leading to varied performance.

Surface Conditions
- Helmets showed greater rotation and similar or lower linear acceleration on the roofing shingle surface.
- All impacts on the P80 surface, except Fall 1, produced significant vertical rebounds.

Helmet Design Features
- External elements like humps on helmets increase rotational velocity.
- These elements cause inconsistent test results, as safety performance varies significantly with small changes in impact location.

Conclusion

Helmet safety performance varies significantly due to design factors such as EPS inclusion, specific features like humps. It is crucial for test protocols to include representative head impact conditions, enabling helmets to be better designed to protect against trips and falls. This study aims to develop a comprehensive rating program for industrial helmets, driving continuous improvement and enhancing safety standards.

Bio

Rachel Tan is a research assistant in the HEAD Lab. Her current research focuses on the safety performance and test protocols of helmets, aiming to better represent real-world impact scenarios, particularly concerning traumatic brain injury.

References

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IMPERIAL Dyson School of Design Engineering

Jacob Thrän, Jakub Mareček,
Robert N. Shorten, Timothy C. Green

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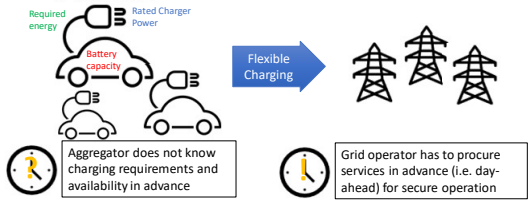
Reserve Provision from Electric Vehicles: Aggregate Boundaries and Stochastic Model Predictive Control

INTRODUCTION

Electric Vehicles (EVs) present both a challenge and an opportunity for future electricity grids. Their comparatively large loads require grid reinforcement or at the least congestion management in distribution grids, but their large energy storage capacity may also enable them to contribute significantly to flexibly run power systems. To get EV owners to agree to service provision from the batteries of their EVs, it is crucial for their driving habits to be unaffected. This in turn means that plug-in times are unknown ahead of time to a potential flexibility provider, an "aggregator", creating a dilemma for the aggregator as the grid operator demands planning security while the flexible resource is uncertain until real-time.



Other uncertain variables, such as residential demand, are similarly uncertain, but this does not pose a problem to the involved stakeholders as these variables can be "aggregated" for several consumers, with aggregate variables being predictable, thanks to the law of large numbers. A similar approach is proposed here for flexible EV charging with aggregate boundaries for the power and energy capacity.

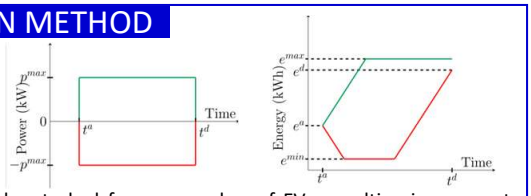
STOCHASTIC MODEL PREDICTIVE CONTROL

Model predictive control (MPC) is a control algorithm that, at each time step, optimises a process over a finite time horizon. Stochastic MPC (SMPC) adds robustness to this approach by ensuring the optimisation probabilistically considers a range of potential scenarios. The scenarios are derived from the predictions of a multiple linear regression model as well as the error distribution in its training set.

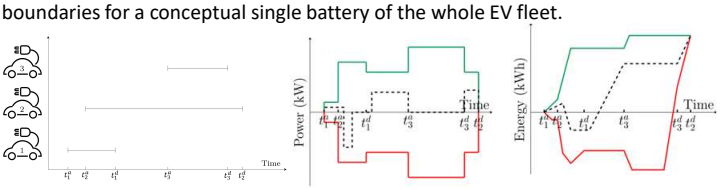
The SMPC builds on a two-stage stochastic optimisation where the first stage decides day-ahead reserve provision while the second stage solely manages real-time charging decisions. The first stage occurs every day at 2pm (for the day-ahead reserve service auction) while the second stage optimisation is carried out in all settlement periods. At each settlement, the SMPC algorithm considers the future scenarios for each of the boundaries with the first-stage optimisation considering the whole next day (66 settlements ahead) while the second stage only considers 18 settlements.

AGGREGATION METHOD

Building on previous work, energy and power potential are constrained by three boundaries.

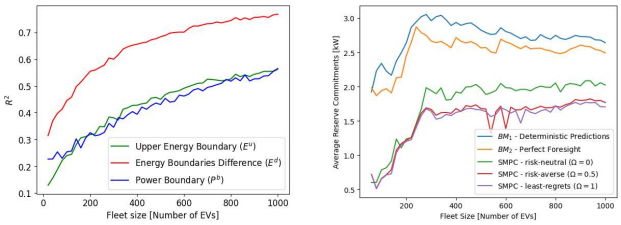


These boundaries can be stacked for any number of EVs, resulting in aggregate boundaries for a conceptual single battery of the whole EV fleet.

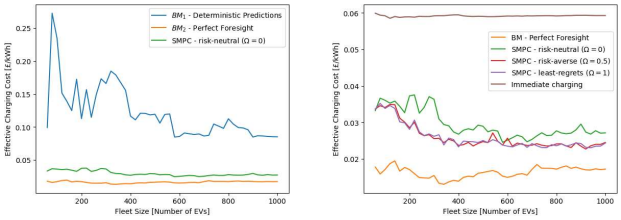


RESULTS

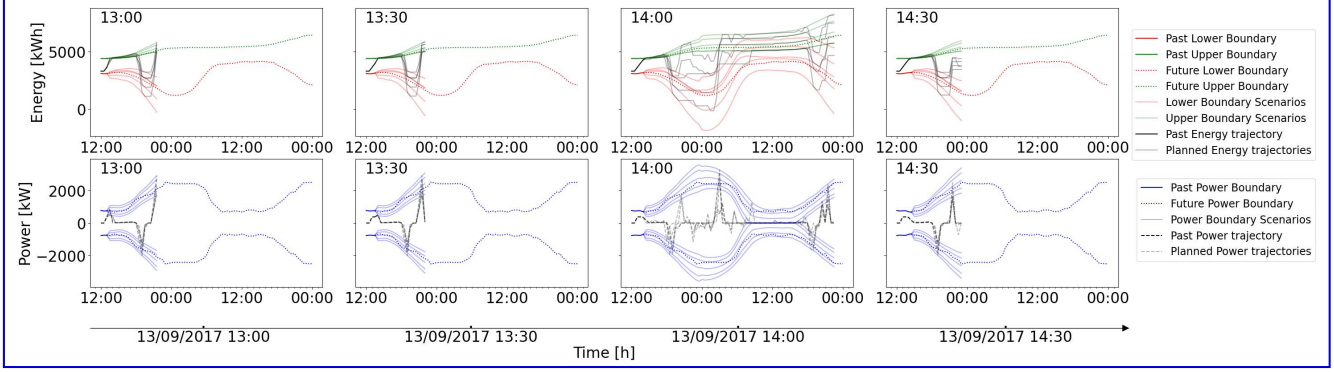
The proposed algorithm exploits the fact that charging behaviour becomes easier to predict as the number of included chargers increases. The size of the EV fleet that the aggregator controls thus also has a profound impact on the financial performance of the scheduling algorithm as increased certainty allows the aggregator to commit to more reserve service provision.



The proposed SMPC is compared against two benchmark algorithms: one which naively uses a deterministic version of our model and makes a single-scenario prediction (BM1) and one that, unrealistically, has perfect future knowledge (BM2).



The effect of fleet size levels off above 400 EVs with SMPC reducing costs by 60% here, close to the 70% that are possible with perfect foresight.



“We Actually Don’t Know How To Collaborate” : Challenges That Interdisciplinary Teams Face In Healthcare Design

Echo Wan, Dr Celine Mougenot

> “How and why **interdisciplinary healthcare design teams** have **(un)helpful collaborations**.”

Background

Putting experts from different disciplines on a team does not guarantee the use of their expertise. Carlisle (2004) posits that for an interdisciplinary team to be successful, knowledge transformation is imperative to harness this diversity. This transformation can be accomplished by navigating the three levels of knowledge boundaries as shown on the right.

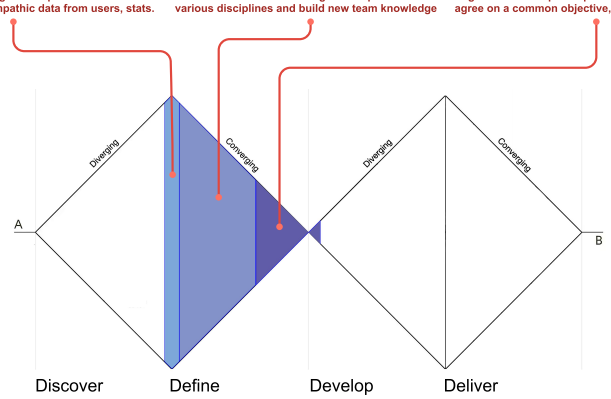
Knowledge Boundaries

Image by vectorjuice on Freepik

Make existing knowledge of the problem accessible. i.e. tacit knowledge, empathic data from users, stats.

Create shared understandings of the problem from various disciplines and build new team knowledge

Negotiate on discipline-specific interests and goals to agree on a common objective, which informs ideation



Research Aim

To understand challenges that teams face with experts from other disciplines, and inform potential interventions.

Within double diamond design process, the “Define” phase is selected as an application case to examine how teams collaborate to frame a design problem.

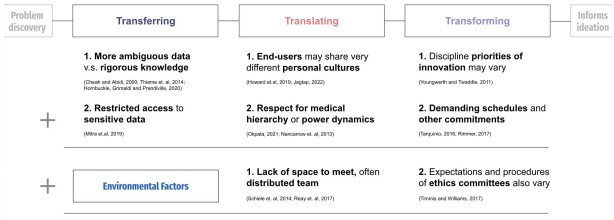
This stage is particularly suitable to be used as a case to study interdisciplinary collaborations in healthcare teams since it includes the transferring, translating, and transforming diverse knowledge of the problem from different disciplines.

Methods + Results

1. Literature Review

The study started with a review of literature on the major challenge in interdisciplinary collaborations in healthcare design through the lens of knowledge boundaries during the “Define” phase of a project.

Results: General Themes for Interview Analysis



2. Semi-structured Interviews

To better understand the collaboration processes and challenges in practice, a thematic analysis is in progress based on 50 interviews with practitioners working on different scales of interdisciplinary healthcare projects.

Preliminary Results

Participants: Designer (n=18); Engineer (n=10); Medic (n=14); Business (n=8)

Bio

I’m a PhD student and a design strategist with experience completing the end-to-end process for product development. My research interest is around co-design tools, healthcare tech, and interdisciplinary teamwork.

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Soft Wearable Robotics:
Innovative Knitting-Integrated Approaches for Pneumatic Actuators Design

" This paper presents an opportunity to bridge soft wearable robotics and textiles, offering **lightweight, flexible, and ergonomic solutions** for human-robot interaction. "

This paper is accepted in ACM DIS 2024 Provocations and Works-in-Progress (PWiP) program

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Yi Zhou, y.zhou20@imperial.ac.uk; Rebecca Stewart, r.stewart@imperial.ac.uk

Abstract

This study focuses on compatible and compact textile architectures to support actuators to be seamlessly integrated, aiming to enhance wearability and interactivity in human-robot interaction. Through a design-driven approach in which various knitting techniques and parameters are used to create sleeves that house silicone air-pocket, it explores principles and variations of textile-based pneumatic actuators design.

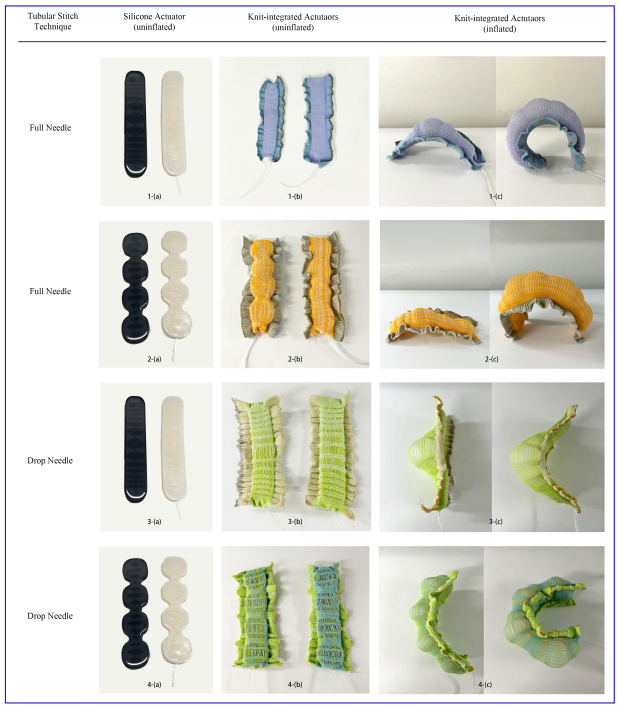
Introduction

Previous research on soft wearable robotics has identified design considerations related to the human wearability of soft robotics, including safety, stability, comfort and portability [1]. Most previous work has adopted a rudimentary strategy of attaching the robotic device to the wearer's body using bulky straps/tubes/bands, resulting in poor interactivity and wearability. The miniaturisation and seamless integration of soft robotic components into wearable forms is a critical gap that requires investigation into how these elements can function cohesively within garments or accessories. The development of lightweight and powerful actuators become a research priority [2]. Therefore, the integration of textile structures should be considered as an essential part of soft wearable robotics [3]. This work explores and discusses innovative integration approaches of knit structure and pneumatic actuators to bridge identified gaps.

Methods

We fabricated a range of knit sleeves to house the silicone actuators integrated with different knitting techniques and varying parameters such as stitch density and knitting tension. Each actuator connected with a manual air pump was then inflated to qualitatively evaluate its mechanical properties and compare bending stiffness, shape-changing and relationships between actuators and knitting structure.

Table 1: Experimental Parameters



- A gauge 7 Dubied double bed knitting machine (7 needles per inch)
- Knitted sample size: width of 112 rows and height of 75 needles
- Two types of tubular stitch techniques: full needle & drop stitch
- Two shapes of silicone actuators
- Eight prototypes in four comparison experimental groups

Results & Discussion

(1.) Figure 1 shows that actuators with equal tension on both sides (10) exhibit less deformation, while those with differing tensions (15-20 front, 7-8 back) show greater deformation. This demonstrates that larger tension differences in double-layer knitting produce more significant actuator deformation.

Figure 1: Actuator performance under different knit tensions.

Figure 2: Comparison between full-needle (left) and drop- needle (right) knit layer.

(2.) Figure 2 demonstrates that the drop-needle technique utilizes the knit structure's pressure to achieve the desired deformation and functionality. The results show that adjusting needle numbers and layouts with tubular knitting enhances the actuator's inflation effect. Figure 3 indicates that aligning the drop-needle arrangement with the actuator's airbag density improves collaboration between the knit structure and the actuator.

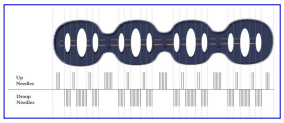


Figure 3: Silicone mold graphic (above) and the drop-needle layout diagram (below).

Conclusion

Soft wearable robotics is not only an extension of traditional robotics applied to the human body but also a new technological paradigm of multidisciplinary innovation. Future plans can include experimenting with various actuator materials (figure 4), shapes to fit ergonomic interaction (figure 5) and a varieties of knitting techniques (figure 6). Quantitative methods,such as applying precise control will further evaluate the mechanical relationship and performance of knitted pneumatic actuators.

Figure 4,5 & 6: Silicone molding process (left), ergonomic interaction (middle) and knit design variations (right).

Bio

Mingke Wang, a first-year PhD student at Dyson School of Design Engineering. Gained previous academic and industrial experiences in fashion, she now focuses on interdisciplinary research in E-textiles and HCI.

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Designing **Trustworthy Autonomous Systems** using **Formal Methods** for **Interpretability**

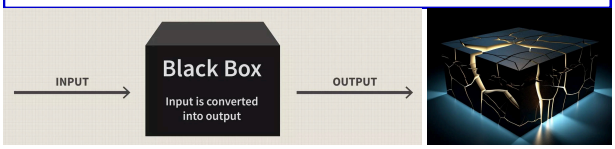
> “ Why not be curious about the intrinsic mechanisms behind AI's decision-making process? ”

Yanran Wang (yanran.wang20@imperial.ac.uk)
David Boyle

Research Background

Reinforcement learning (RL) offers effective reasoning for ***sequential decision-making problems*** with variable dynamics. Nevertheless, such reasoning poses an ongoing challenge to create ***a convincing interpretation*** of the sequential decisions.

This challenge in comprehension poses a significant barrier to real-world RL's implementation in ***safety-critical domains***, such as advanced manufacturing, autonomous navigation and financial trading.



Key Challenges in Interpretability

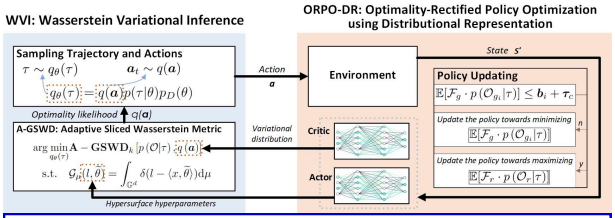
The research surrounding interpretability in the context of RL aims to be conceptualized through three distinct phases:

a. Guarantee of convergence ensures that an RL framework converges towards an optimal policy, e.g., in an asymptotic manner.

b. Transparency in training convergence emphasizes the identification of the underlying convergence process during an RL training.
An instance is the convergence rate. Based on a given training iterations, this rate enables the prediction of the expected level of convergence, with a certain degree of confidence.

c. Interpretation of decisions seeks to explain why these specific sequential decisions were made within a given state and environment. Specifically, this interpretation involves clarifying the quantitative impact of latent factors on these sequential decisions.

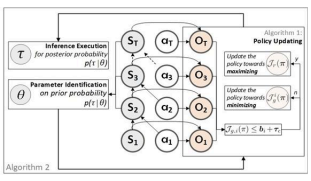
Methods

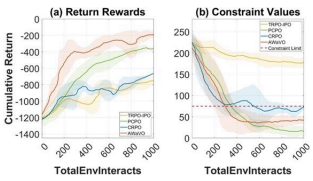


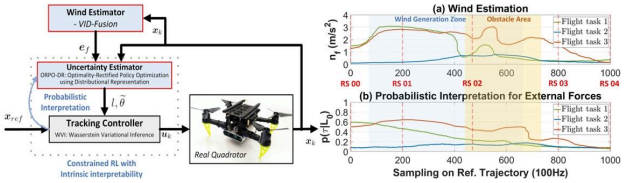
Specifically, we reframe constrained RL as Wasserstein variational optimization, leveraging an enhanced foundational inference framework known as augmented Probabilistic Graphical Models (PGMs):

Optimality-Rectified Policy Optimization using Distributional Representation (ORPO-DR): ORPO is conducted to dynamically adapt to uncertainties; and DR provides an entire distribution of the action-value function, contributing to heightened transparency in the convergence. Consequently, this efficiently tackles a significant portion of the deficiencies outlined in ***Research Aims a and b.***

Wasserstein Variational Inference (WVI): WVI is subsequently performed to achieve the probabilistic interpretation of decisions, thereby tackling ***Research Aims c***.





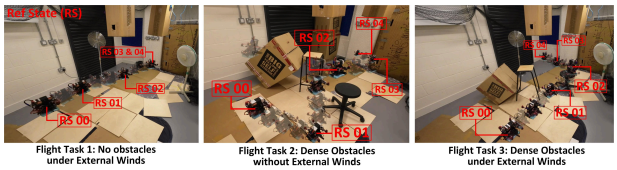


Results and Discussion

To our best knowledge, we present the first intrinsically interpretable constrained RL framework through the lens of probabilistic inference.

Formal methods are employed to demonstrate theoretical comprehension on the *convergence guarantee*, *transparency of training convergence*, and *probabilistic interpretation of decisions*.

Empirical demonstration verifies the guaranteed interpretability with ***a global convergence rate Θ(1/ √ T)*** in simulation. We also showcase the effectiveness of our work by practical implementation in ***a physical autonomous navigation process*** - i.e., real quadrotor flight tasks.



Flight Task 1: No obstacles under External Winds | Flight Task 2: Dense Obstacles without External Winds | Flight Task 3: Dense Obstacles under External Winds

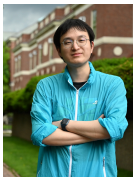
Conclusion

Enthusiasm towards the possible applications of ***autonomous navigation*** is growing worldwide. The insufficient ability to interpret agent actions and policy optimizations, however, poses a significant hurdle in deploying learning-based methods in safety-critical domains.

Representing ***sequential decision-making problems*** as ***probabilistic inference*** can have considerable value, as, in principle, the inference offers diverse and powerful mathematical tools to infer 1) the stochastic dynamics whilst suggesting 2) a probabilistic interpretation of policy optimization.

Empirical results demonstrate that our method balances *a reasonable trade-off* between **high performance** and **quantitative interpretability** in both simulation and **real quadrotor tasks**.

Bio



Yanran Wang is currently a Ph.D. student. His research interest lies in Trustworthy Autonomous System Design, with a focus on achieving Interpretability via Formal Guarantees in reinforcement learning and optimal control theories. Particularly, he is keen on practically implement these theories to intelligent aerial robots via formal verification. He received an M.S. degree in Information and Control at Shanghai Jiao Tong University, China.

Publications

- **Yanran Wang**, Qiuchen Qian, and David Boyle. "Probabilistic Constrained Reinforcement Learning with Formal Interpretability." International Conference on Machine Learning (ICML), 2024.
- **Yanran Wang**, and David Boyle. "Constrained Reinforcement Learning using Distributional Representation for Trustworthy Quadrotor UAV Tracking Control." IEEE Transactions on Automation Science and Engineering, 2024. (Conditionally Accepted)
- **Yanran Wang**, James O'Keeffe, Qiuchen Qian, and David Boyle. "QuaDUE-CCM: Interpretable Distributional Reinforcement Learning using Uncertain Contraction Metrics for Precise Quadrotor Trajectory Tracking." 6th Annual Conference on Robot Learning (CoRL). PMLR, 2023.
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Are bigger batteries better? Tackling EV obesity with data-driven simulation

Felix Wieberneit, Robert Shorten, Emanuele Crisostomi, Homayoun Hamedmoghadam, Anthony Quinn

Abstract

Electric Vehicles (EVs) are increasingly popular, yet convenience issues persist compared to fossil-fuel vehicles. Increasing EV battery capacity has been the main strategy to address these issues, however it remains unclear to what extent this is effective. This study examines the effectiveness of larger batteries in reducing EV inconvenience using a data-driven simulation model. Results demonstrate diminishing returns with larger batteries and emphasize the importance of charging infrastructure. Our simulation model provides insights for optimizing battery sizes and infrastructure planning to enhance EV convenience.

Introduction

- EV Transition: Shift from fossil fuels to electric vehicles is a key component of the broader energy transition.
- EV Obesity: Increasing battery capacities aim to improve convenience but lead to higher costs, vehicle weights, and environmental impacts, stifling adoption and environmental credibility of Evs.
- Objective: Quantify EV inconvenience and examine the impact of battery sizes and charging infrastructure using a city-scale simulation.

EV Inconvenience

- Time cost: Defined in line with prior studies as the total time cost of en route charging events.
- Contribution: Our Simulation model extends literature with previously unaccounted variables (journeys to and from charging stations, competition for charging stations)
- Measurement:

$$EV_{inconvenience} = \sum_{i=0}^{n_{charge}} (search\ time_i + charge\ time_i)$$

Simulation Model

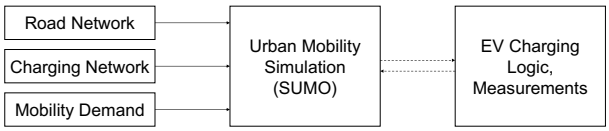


Fig. 1: Simulation Model Overview

- Road Network: Abstract 10x10 lattice network and realistic Central Paris scenario using Open Street Map data.
- Charging Infrastructure: Random distribution for abstract network. Realistic data for Paris from the National Directory of Charging Infrastructure for EVs (IRVE).
- Mobility Demand: Activity-based demand modelling using demographic data from INSEE. Resulting trip distribution is consistent with data from Mobility of people survey.
- Traffic Micro-Simulation: Implemented in SUMO with dynamic interaction via Python.
- Charging logic: Probabilistic Model of EV charging behaviour

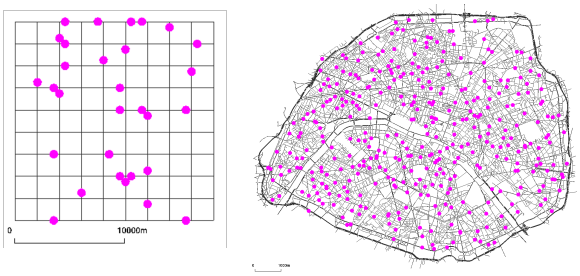
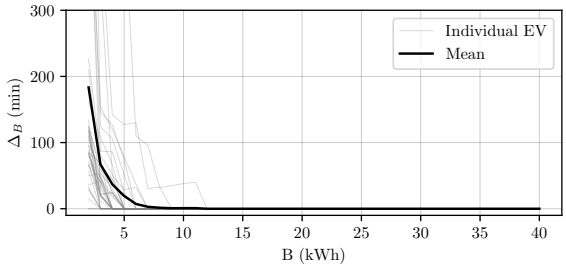


Fig. 2: Abstract road network (left) and realistic road network (right) of central Paris used in this study

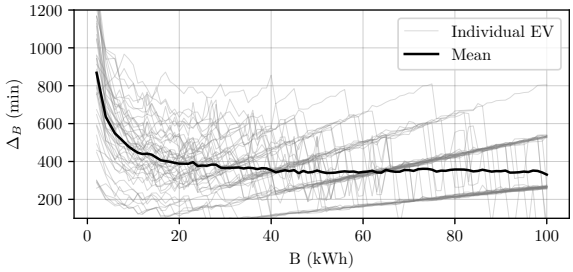
?

Results

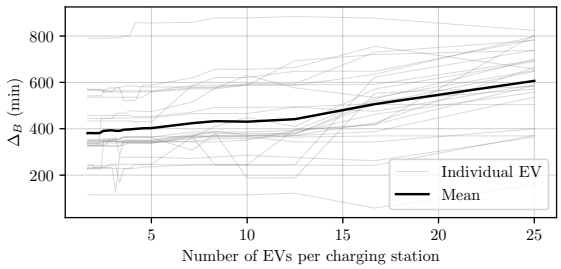
Private Charging: 50 vehicles over 30 days with access to home-charging.



Public Charging: Simulation of 50 vehicles charging publicly over 30 days



Charging Infrastructure: different charging infrastructure densities



Discussion & Conclusion

While increasing EV battery capacity initially reduces inconvenience, the benefits diminish beyond a certain capacity in both private and public charging scenarios. EV inconvenience crucially also depends on the available charging infrastructure (density, location, power output), which can make small battery EVs more convenient. These insights aid optimal design of EV battery capacity and planning of charging infrastructure, and address the EV obesity problem.

Bio

Felix is a 2nd year PhD student.. He holds MSc. and MA. degrees in Design Engineering from Imperial College London and the Royal College of Art. He has two years of professional R&D experience in consultancies and technology startups, working on projects for clients such as Logitech, First Group, Deutsche Bank, BMW, and IHG.

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Novel Heat Stamping for Enhanced Drawability and Reduced Springback in Forming Ti6Al4V

Hao Wu, Famin Tian, Chuankai Tang, Ziang Guo, Nan Li* (n.li09@imperial.ac.uk)

> “Estimations indicate that HS enables the fabrication of Ti6Al4V components with high drawability and shape accuracy, achieving reductions of ~85% in manufacturing costs and ~75% in energy costs compared to conventional processes.”

Abstract

Conventional forming methods for titanium Ti6Al4V, such as hot forming, superplastic forming and hot stamping present several limitations, including prolonged cycle time, high energy and cost consumption, limited formability and severe springback. An innovative rapid Heat Stamping (HS) process was developed as an effective solution to address these issues. This work analysed the advantages of HS by producing two characteristic components: a cup-shaped and a U-shaped component, to assess the ability of HS in improving drawability and controlling springback. Flawless cup-shaped components achieving a high draw ratio of up to 1.8 were successfully produced, and an improvement in post-form hardness indicated superior strength of the fabricated components. U-shaped components demonstrated a significant drop in springback angle from 4.8° to 0.7°, suggesting the potential of HS in achieving high component dimensional accuracy.

Introduction

For titanium alloy Ti6Al4V, the commonly used hot forming and superplastic forming processes are conducted at elevated temperatures between 700 – 900 °C and at slow strain rates ranging from 10^-4 – 10^-1 /s [1][2]. Both methods require prolonged durations (up to hours), high tooling costs (ceramic and nickel-based superalloy), and an inert gas environment, making them high-cost and energy-intensive processes. Hot stamping, as an alternative method, is used to improve production efficiency; however, the formability and dimensional accuracy of the components are typically not satisfactory [3].

A novel Heat Stamping (HS) process, integrating hybrid heating and rapid stamping techniques, has been recently developed [4][5]. Unlike the hot stamping method, where the heating of the feedstock blank material and forming are conducted at the identical temperature, the HS process employs a lower forming temperature achieved through a step quenching operation following heat treatment. This method strategically utilises the favourable microstructures and optimum flow stress characteristics of the material at specific temperatures to maximise formability. The HS process is notably fast with a considerably high forming rate, and is conducted using a cold, low-cost steel toolset, dramatically reducing energy consumption.

Methods

Fig. 1 depicts the computer-aided design and the actual experimental setup of the HS rig used in this work. The air nozzles were mounted on the rig and controlled by a custom-designed air flow system to step quench the blank prior to stamping.

To demonstrate the advantages of the HS method, cup-shaped components with a high draw ratio of up to 1.8 were attempted and U-shaped components were produced using both traditional and new stamping processes with 2.56 mm thick Ti6Al4V sheets. A high forming rate of 200 mm/s was selected for the forming trials. Vickers hardness testing and 3D topological scanning were conducted to evaluate the post-form strength and the springback angles of the cup-shaped and U-shaped components, respectively.

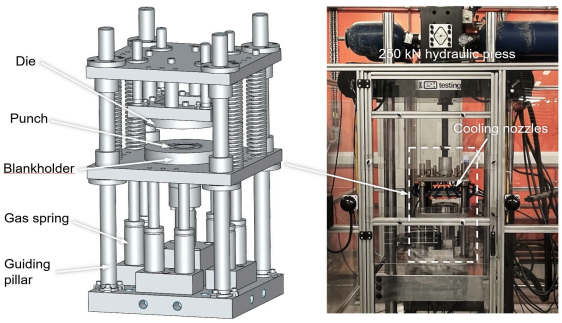

Fig. 1. Left: Computer-aided design of the HS rig. Right: Actual layout of the HS experimental setup, showing the cooling system and forming rig installed on the 250 kN hydraulic press.

Results and Discussion

Fig. 2a compares the cup-shaped Ti6Al4V components produced by hot stamping [3] and the HS method. For hot stamping, the component with a 1.6 draw ratio exhibited wrinkling on the sidewall due to uneven material flow, whilst the one with a 1.7 draw ratio demonstrated near-complete fracturing. In contrast, the HS process successfully formed a defect-free component with a draw ratio of 1.8, and with relatively uniform thickness throughout the entire component. The hardness along the same component (Fig. 2b) shows an increase of ~15% in the hardness compared to the as-received material. This indicates enhanced strength of the post-formed component produced by the HS method.

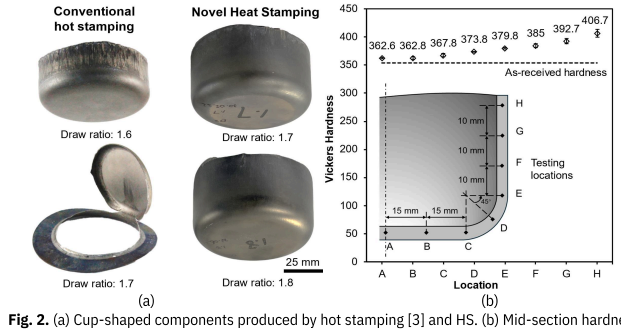

Fig. 2. (a) Cup-shaped components produced by hot stamping [3] and HS. (b) Mid-section hardness profile along the HS component with a draw ratio of 1.8.

Fig. 3a displays the U-shaped components made with hot stamping and HS. A sharp reduction in the springback angle θ, from 4.8° to 0.7°, was achieved with the HS component. Fig. 3b compares the upper component profiles obtained through 3D scanning. Clearly that the surface of the HS component was much closer to the ideal profile, indicating a higher dimensional accuracy was achieved.

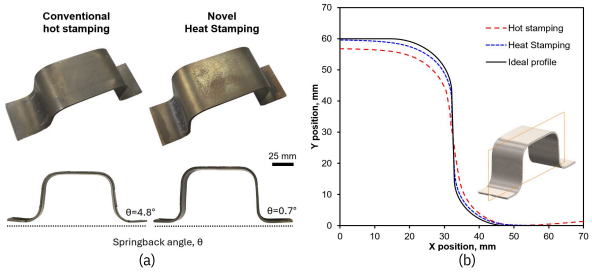

Fig. 3. (a) U-shaped components with springback angles measured. (b) Comparison of the measured and ideal upper component profiles (scanning location indicated).

Conclusion

This study has demonstrated the outstanding advantages of HS in forming titanium alloys, including a rapid process (forming time <1s), significant energy savings, and low tool costs. Estimations indicate that HS enables the fabrication of Ti6Al4V components with high drawability and shape accuracy, achieving reductions of ~85% in manufacturing costs and ~75% in energy costs compared to conventional processes. Future work will focus on boosting industrialisation by upscaling and automating the current in-house manufacturing system.

Bio

Hao works on a range of advanced manufacturing processes, including metal forming, additive manufacturing, friction stir welding, etc. He uses various materials analysis methods for optimising manufacturing, including electron microscopy, micro-CT and digital methods.

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Designing Digital Mental Health Interventions for Healthcare Professionals: Participatory Study

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Supervisor: Rafael A. Calvo, Céline Mougenot

> “Digital interventions that facilitate a temporary escape from the clinical environment were highly valued by healthcare professionals.”

Abstract

Digital mental health interventions (DMHIs) represent a promising line of research as they provide feasible, accessible and cost-effective alternatives to traditional mental health interventions. However, for healthcare professionals (HCPs), the availability of tailored DMHIs is scarce, and engagement levels are found to be low. Therefore, it is crucial to develop DMHIs that are both relevant and engaging to HCPs. This study aims to design and develop an DMHI for HCPs through a two-stage participatory design workshop. Initially, HCPs (N=9) working in a tertiary hospital in China were invited to the ideation workshops. One concept was then selected to be built into a low-fidelity prototype, which was tested and re-designed among a larger group of HCPs (N=15) in subsequent workshops. Eventually, a refined concept was developed, leading to a potentially more effective DMHI tailored specifically for HCPs. Related design implications and strategies were also drawn from participant feedback.

Introduction

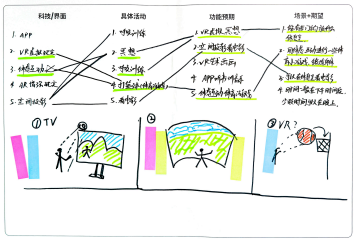
HCPs are one of the most vulnerable groups to occupational stress and burnout, and DMHIs can be a suitable strategy to mitigate their stress and burnout [1]. However, research has shown that there is still a scarcity of DMHIs developed for HCPs [2]. Plus, off-the-shelf mental health tools like mobile apps often suffer from low engagement rates among HCPs [3]. Therefore, research has called for tailored DMHIs for HCPs to maximise engagement rate. Participatory design is a valid method of designing with user involvement and is contributive to designing effective and engaging product.

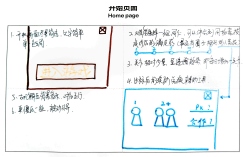
Methods

This study includes a two-phase participatory design workshop to ideate and design DMHIs for HCPs. The first phase focused on idea generation, using tailored “Tech + Action” activities to support generating concepts around DMHIs. HCPs (N=9) collaboratively brainstormed and developed eight initial concepts. The second phase focused on concept refinement, where a low-fidelity prototype is tested with HCPs (N=15) for its acceptability and potential for design iterations. Participants were asked to adopt a “think aloud” approach [4] and were provided interface templates to assist the re-design. Thematic analysis was used to analyse the feedback collected from participants, enabling the research team to extract meaningful insights and guide further development of the intervention.

Results

In the idea generation phase, participants valued DMHIs that allowed them to mentally transport to different settings, as well as the potential to relax statically or through mind-body movement exercises. Key attributes such as flexibility, choice, technical practicality, and an engaging, playful experience were emphasized. Out of eight DMHI concepts proposed, one was selected and developed into a low-fidelity prototype by the research team. The subsequent prototype evaluation workshop demonstrated that the concept was well-received, practical, and meaningful. Design iterations by participants suggested their needs for more choices in content and visual styles, clearer and more concise information, and incorporation of voiceover for psycho-education. Besides, participants demanded clearer meanings of gamification elements like scores and ranking systems, and showed a preference for group experience.





Discussion

This study presented a two-stage participatory design process with tailored activities for designing DMHIs. Specifically, the “Tech+Action” process was found to be useful to support idea generation around DMHIs, particularly among participants who were not tech-savvy and lacked mental health literacy. Overall, participants highly valued the chance to escape to different environments and engage in relaxation through both static and mind-body movement exercises. Preferences emerged for voiceovers and moving image contents, whereas the response to gamification elements was mixed, suggesting that such features should be implemented cautiously.

Conclusion

The study showcased the potential of well-designed DMHIs to reach an ideal acceptance and engagement among HCPs. By incorporating suitable participatory design activities, and design elements like mental transportation, relaxation exercises, personalized content, and psycho-educational content, DMHIs can provide a well-received and engaging alternative to support staff wellbeing.

Bio

Zheyuan Zhang is a PhD student at the Dyson School of Design Engineering. His research interests include design, mental health, wellbeing, participatory research, human-computer interaction, and human motivation. His thesis is on designing and evaluating a digital mental health tool for healthcare staff in China and the UK.

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QR Code

A preliminary study on data-driven simulation of stamp forming using graph neural network

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Graph neural network for spatial-temporal predictions in metal forming processes

Abstract

A Graph Neural Network (GNN) surrogate model was developed to predict spatial-temporal displacement fields of blank material under different simulation settings. This GNN surrogate model was compared with Finite Element (FE) simulation results of cold stamped dome shape component. The GNN model shows promising results of spatial-temporal prediction of displacement fields in various cold stamping simulation setups.

Introduction

The metal stamping process involves the dynamic responses of elastoplastic sheet metal under high-speed tool impacts. These responses are typically analysed using Finite Element Analysis (FEA) to predict nodal accelerations, velocity, and displacements, which is crucial for optimising manufacturing processes and ensuring structural integrity. However, FEA is time-consuming. Graph Neural Networks (GNNs) offer a more efficient alternative by regressing FEA solutions through a data-driven approach, mimicking finite element solvers with neighbouring message aggregation of irregular structured graph input. This preliminary study explored and analyses the GNN training performance across various stamping case studies, ranging from single punch to complex studies involving all stamping tools, with the aim of improve GNN training convergence in cold stamping case studies where all stamping tools are considered.

Methods

- **Dataset Preparation and Pre-processing:**

Three sets of cold stamping simulations were conducted to form a dome-shaped component (**Figure 1**). In each simulation trajectory, results from 20 intermediate timesteps were extracted to construct graph embeddings.

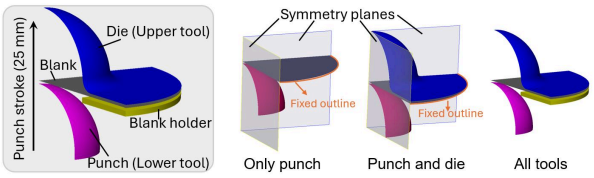

Figure 1. Simulation setups.

- **Graph Construction:**

Input and Output Modelling. (**Table 1**)

Table 1. GNN input and output.

Node input at time t_n	Edge input at time t_n	Node output at time t_n
$\mathbf{u}_i^{t_{n-1}} = \mathbf{x}_i^{t_n} - \mathbf{x}_i^{t_{n-1}}$ $\mathbf{u}_i^{t_{n-2}} = \mathbf{x}_i^{t_{n-1}} - \mathbf{x}_i^{t_{n-2}}$ $\mathbf{u}_i^{t_{n-3}} = \mathbf{x}_i^{t_{n-2}} - \mathbf{x}_i^{t_{n-3}}$ One hot vector $\triangle$ time	$\triangle \mathbf{x}_{rs}^{t_n} = \mathbf{x}_r^{t_n} - \mathbf{x}_s^{t_n}$ $d_{rs}^{t_n} = \| \mathbf{x}_r^{t_n} - \mathbf{x}_s^{t_n} \|$	$\mathbf{u}_i^{t_n}$

- **Model Architecture:**

The GNN architecture is built using multiple Multilayer Perceptron (MLP) units with residual connections. The model is trained on ground truth simulation results at different timesteps during the stamping process. Once sufficiently trained, the model will be tested using roll-out predictions to obtain spatial-temporal results of material deformations during stamping. **(Figure 2)**

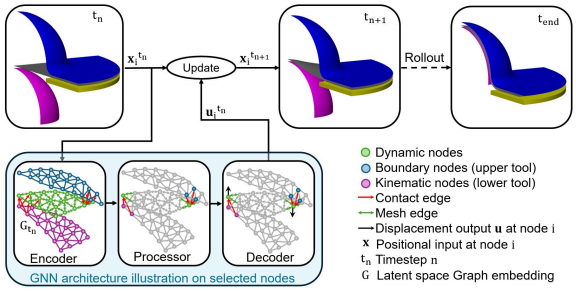

Figure 2. Overall GNN framework illustration.

Results and discussion

- The highest prediction accuracy occurs when only a punch is used to push the blank, with fixed nodes on the blank outline. Adding die and a blank holder reduces prediction accuracy.(**Figure 3**)
- The gap between the blank holder and die allows Z-direction movement of blank, affecting material flow and causing thickening effects in the flat region. This introduces complex non-linear behaviours in blank displacements that the model fails to predict.
- Larger errors are observed in the middle regions distant from boundary conditions due to the model's insufficient message-passing capabilities, which fail to capture long-range dependencies. (**Figure 4**)

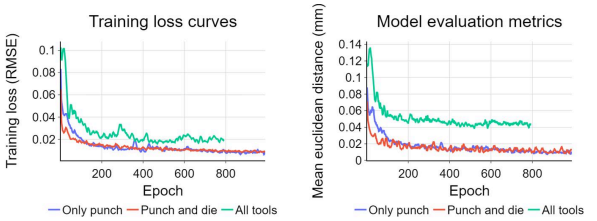

Figure 3. Training loss curves and evaluation metrics.

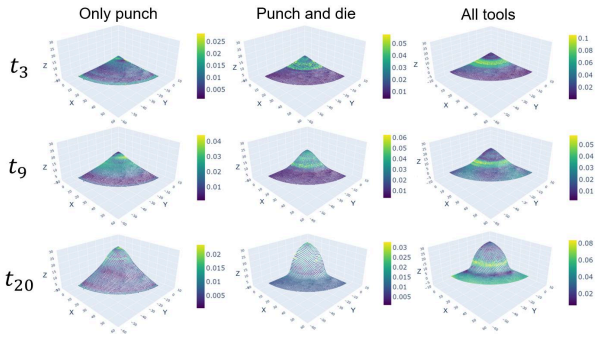

Figure 4. Euclidean distance (mm) between ground truth and prediction results.

Conclusion and future work

- This architecture achieved overall promising training results with mean euclidean distance error of 0.011mm, 0.013 mm, and 0.023mm for the 'only punch', 'punch and die', and 'all tools' case study, respectively.
- Multigraph analysis [2] or down-sampling techniques [3, 4], may be needed to capture long-range dependencies effectively.
- Further expand training set to include more diverse simulation setups. Exploring different material inputs and their effects on training outcome.
- Conduct cross-validation and rollout test.

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Author Bio

Yingxue Zhao is a PhD student researching on the application of graph neural networks for spatio-temporal predictions in metal forming process. Yingxue is dedicated to exploring and developing methods that enhance the accuracy, efficiency, and generalisability of the metal forming predictions using data-driven approaches.

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Humans Mindlessly Treat AI Virtual Agents as Social Beings: Evidence from a Cyberball Experiment

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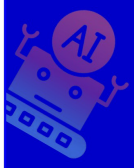
Nejra van Zalk, Talya Porat



Takeaway for Agent Design:

“

Consider social norms

Tailor for age groups

”

Background

Do humans really treat AI virtual agents as social beings? Existing studies have shown conflicting findings about this counter-intuitive human tendency [1]. As an individual's state of mind significantly affects their way of responding [2], we investigated this question by differentiating between mindless and mindful responses in human-agent interaction:

- **Mindless responses** are automatic and intuitive, generated quickly without engaging working memory.
- **Mindful responses** are controlled and reflective, involving deliberate thought [2].

We examined mindless and mindful responses in the context of ostracism and inclusion. Research has confirmed the social norm of inclusion in human-human interaction; people tend to compensate the ostracised target and devalue the ostraciser when observing ostracism in an online ball-tossing game (i.e., the Cyberball paradigm) [3,4,5]. We wanted to see if this tendency would also occur in human-agent interaction.

Research Questions

We thus investigated whether participants would respond similarly to an ostracised AI virtual agent in Cyberball (see Figure 1):

- **RQ1:** How do participants respond when they observe an agent being excluded or treated fairly by another human?
- **RQ2:** Do user characteristics (i.e., demographics, dispositional traits, and agent usage experience) influence these responses?

We treated participants' objective, real-time behaviour during Cyberball as the mindless response, while their subjective, retrospective perceptions after Cyberball as mindful responses, following [6].

Figure 1: Screenshots of Cyberball's cover story (left) and game interface (right)

Methods

We used a 2×2 mixed design, with **Cyberball condition** (exclusion vs. fair play) as the between-subjects factor and **co-player type** (AGENT vs. HUMAN) as the within-subjects factor. Participants (N = 244) were randomly assigned to either the exclusion or fair play conditions and engaged in 36 ball tosses with two co-players. After Cyberball, participants reported their perceptions of the AGENT and HUMAN players. They also completed a series of measures on user characteristics. See Figure 2.

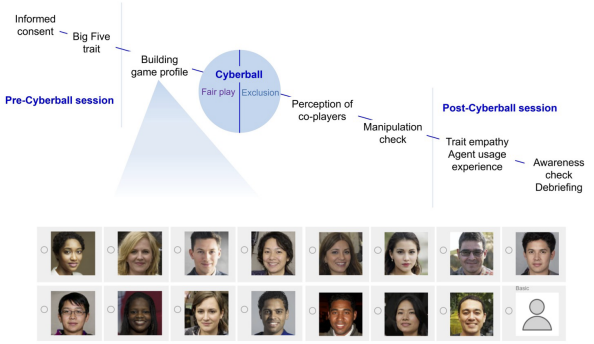


Figure 2: Study procedure (above) and GAN-generated faces for game profile building (below)

Results

Mindless response: Behaviour towards co-players

- **Ball-tossing tendency**: Participants in the exclusion condition had a significantly higher ball-tossing tendency (to the AGENT) than those in fair play, $p < 0.001$. Only age (no other user characteristics) moderated the effect of Cyberball condition, $p = 0.002$; this effect diminishes with younger age and was not significant at age ≤ 23; see Figure 3.

Mindful responses: Perceptions of co-players

- **Sympathy**: Participants generally felt more sympathy for the HUMAN than the AGENT, $p < 0.001$. The interaction between Cyberball condition and co-player type was significant, $p = 0.007$; see Figure 4.
- **Impression**: Participants generally rated the HUMAN more favourably than the AGENT, $p < 0.001$. The interaction between Cyberball condition and co-player type was not significant, $p = 0.282$.

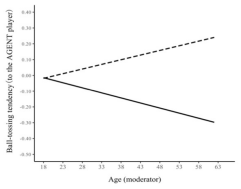


Figure 3: Two-way interaction plot illustrates that the older the participants were, the higher was their ball-tossing tendency (to the AGENT) in the exclusion condition, while their tendency in fair play was lower.

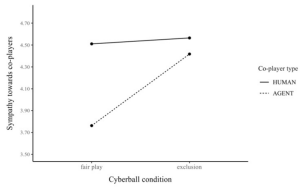


Figure 4: Two-way interaction plot illustrates that participants in the exclusion condition had higher sympathy towards the AGENT than those in fair play; sympathy towards the HUMAN showed no difference between two conditions.

Discussion

We compared results with those from human-human Cyberball research.

- **Individuals tend to mindlessly treat AI virtual agents as social beings:** Participants mindlessly compensated the ostracised AGENT by tossing the ball to them more often, as people would when observing human-human ostracism [3,4].
- **Individuals do not mindfully perceive these agents as comparable to humans:** Participants felt higher sympathy for the ostracised AGENT, as people would for an ostracised human [7]. But they did not devalue the HUMAN ostraciser, indicating they did not equate the agent's experience with that of an ostracised human [4,5].
- **The tendency to mindlessly treat AI virtual agents as social beings diminishes with younger age.** Additionally, we did not find any user characteristics that affected participants' mindful perceptions of agents as less comparable to humans.

Future Research

Cyberball is a kinetic game, whereas human-agent interaction in real-life scenarios typically occurs through written or spoken natural language. We thus will design a voice interaction game to increase the ecological validity in the next study. Please scan the **QR code** below to listen to the voice of our agent, **Paxly** /ˈpæksli/.

Bio

Jianan Zhou is a second-year PhD student at Imperial, researching human interaction with conversational agents. She holds an MSc in Social and Cultural Psychology from the London School of Economics and a BSc in Psychology from Beijing Normal University.

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