INDIAN INSTITUTE OF TECHNOLOGY MADRAS – DEAKIN UNIVERSITY RESEARCH ACADEMY

Research projects

March 2024

Research tackling global challenges in science, engineering and technology

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PROJECT 01

Realising zero-trust security in emerging energy infrastructure

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The collaboration between Deakin University and the Indian Institute of Technology Madras (IITM) will focus on the concept of zero-trust energy systems, and holds immense promise for the future. This partnership signifies a strategic alignment of academic expertise and technological strengths aimed at fortifying the security of critical energy infrastructures for Australia and India.

Zero-trust energy systems represent a paradigm shift in cybersecurity, challenging the traditional notion of trusting entities within a network by default. Instead, this approach advocates verifying and authenticating every user and device, irrespective of their location or network access privileges. This becomes particularly pertinent in the context of energy systems, where the consequences of cyber threats could be catastrophic due to the convergence of Information Technologies with the Operational Technologies.

The collaboration between Deakin University and IITM will likely delve into cutting-edge research to develop robust security frameworks tailored for energy systems. This may involve the integration of advanced multi-factor continuous authentication techniques, artificial intelligence and machine learning driven security verification for continuous monitoring towards an adaptive and evolving cyber defence system. The research would also explore the application of blockchain technology to enhance the integrity and transparency of energy transactions within the system. Moreover, the partnership is likely to extend beyond theoretical research, incorporating practical implementations and testing in real-world scenarios.

Beyond academic contributions, in future, the project aims to establish a durable collaboration between universities and participants in Australia and India. This collaboration will create a network of researchers and organizations, strengthening future partnerships through shared knowledge and discoveries, including, joint workshops, student supervision, India-Australia DST research funding applications, e.g., The Australia-India Strategic Research Fund (AISRF). Such collaborations have the potential to yield long-term benefits for both countries, extending beyond the scope of this specific project.

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PROJECT 03

Remediation of soil and water, black soldier fly larvae

Sustainable Remediation of water, soil and management of waste are huge challenges facing the world. Enabling these with recovery of valuable resources will have multiple benefits in terms of green house gas emissions and economics of the scaled up process. Field work coupled with lab analysis and life cycle assessment will provide the students holistic training in environmental management and sustainability.

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PROJECT 05

Mycelium and fibre waste derived sustainable biocomposites

Fossil fuel based synthetic foams are widely used in packaging and insulation applications. These were lauded as breakthrough inventions once but gradually evolved as materials of major concern due to their non-biodegradable nature and large carbon footprints from entire life cycle with significant impact on climate. For example, an estimated 44,000 tonnes and 340,000 tonnes of expanded polystyrene are consumed in Australia and India, respectively each year. Importantly, one quarter to one third of this ends up in landfill annually resulting in devastating impact on environment.

Mycelium-based foams, produced by root-like networks from mushroom called hyphae are emerging as a potential substitute for plastic-based foams. Current strategy is to employ a waste-to-value strategy by using agricultural waste/textile waste as a growing media for the mycelium. We plan to identify the efficacious strain of mycelium and identify a corresponding combination from various fibrous materials and understand the fundamental of interaction and bonding between textile derived fibres and mycelium fibres. Thereby, develop a strategy to improve the mechanical properties because a key drawback of the currently produce mycelium foams.

While to an extent the foams meet secondary packing requirements, these foams cannot meet the requirements of primary packaging and insulation products like insulation boards. Thus, we plan to understand the role of agro-fibre waste components like cellulose, lignin, and hemicellulose from fibres like coir, hemp, cotton, and animal fibres like wool will be examined.

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PROJECT 06

4D printed hybrid multi-responsive soft actuators

4D printing is the field of additive manufacturing where the systems are 3D printed, and the printed component deforms when exposed to a specific stimulus, making time the fourth dimension of 4D printing. The underlying material used for 4D printing is stimuli-responsive. Hydrogels are well-known solvent-responsive materials that are excellent candidates for various soft sensors and actuators. Light-responsive liquid crystal polymers are a special class of materials with inherent anisotropy that can be engineered to obtain complex shape changes.

This project aims to develop light/solvent-responsive hybrid soft actuators to exploit both systems' advantages. One of the main challenges of 4D printing is the development of inks with appropriate rheological properties for better printability. In addition, in the case of hybrid actuators, the surface functionalization of liquid crystal surface (hydrophobic) must be ensured for integration with hydrogel layers. The project's primary objectives are:

1. develop suitable inks for concurrent 4D printing of hydrogels and liquid crystals with an appropriate interface engineering for inter-layer integrity
2. optimize the process parameters for the efficient use of the material and actuation characteristics
3. develop continuum models (finite element) to simulate the complex deformations in the printed components upon exposure to the stimulus
4. demonstrate applications of the 4D printed actuators in biomedical and microfluidics domains.

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PROJECT 07

Autonomous navigation in human-centric environments

Mobile robots are being used extensively in human centric environments including warehouses and factories. Effective navigation in human centric environments require robotic systems to estimate the intent of humans occupying the space. It is also important for the robotic system to communicate its intent effectively to improve human-robot collaboration.

This project will explore novel techniques to address the above challenge as well as validate the same in simulated and realworld settings.

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PROJECT 08

Computer vision for sports

This project is dedicated to the development of advanced deep learning techniques, seamlessly integrating knowledge about objects' relations and their interactions in the visual domain, more so from the perspective of sports analytics and self-driving cars as these involve firm understanding of intricate spatial dynamics and interactions for decision-making and extracting novel insights.

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PROJECT 12

Optimal energy transfers in DC/AC microgrids

The emerging grid is increasingly becoming dependent on power electronics for various conversions. The efficiencies of different converters are operating point dependent. Further, different sources have different economics of operation and the entry of hydrogen has added another interesting dimension to the system.

A typical system operator will have to contend with solar plant, grid, battery storage and hydrogen generation along with its own economics of storage and usage. It is quite likely that hydrogen could be used to absorb seasonal variations in power produced to find usage for power production in seasons of lean renewable power.

This proposal is to construct a typical microgrid model and explore possible optimised strategies of operation. The work will take into account typical converter topologies and their varying efficiencies based on converter losses. Any prototypes developed at Deakin/IITM will be used for calibrating these efficiencies. Suitable electrolyser models would also enable efficiency of hydrogen production. Deakin has a microgrid installed, while IITM is putting one in place. The grid structures can be used to develop suitably detailed models to enable correct estimates in optimisation studies. The study could suggest proper energy management to explore operation for better economics or better carbon footprint, or simply least grid power drawn.

The work is expected to give insights into the manner of operating a microgrid in the future hydrogen dominated economy.

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PROJECT 14

Learning-based control of delayed robotic networks subject to disturbances

One of the main objectives of the research is to enable formation control in general robotic networks, which can model physical systems with higher-order robot dynamics in the presence of delays and disturbances. Such delays and disturbances are common in robotic systems and can occur either due to time lost during sensing or communication between neighboring agents, or due to local agent dynamics, as well as the interaction between the agents and the working environment.

Learning-based control that intelligently harnesses information about the delays and disturbances is proposed to maintain stability in higher-order delayed and disturbed agents. This informs the subsequent proposed objectives of improving cooperative transport of objects using distributed robotic networks.

This research project has applications in warehouse automation and flexible manufacturing using robots for material handling operations.

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PROJECT 18

Engineering thermoelectric materials for waste heat harvesting and energy sustainability

Energy sustainability is one of the major key technological challenges in this 21st century. In recent years, growing awareness and alarming concern for the environment and renewable energy supplies have revitalized advances in materials engineering and technologies for energy conversion.

Thermoelectric (TE) devices, with their potential to reversibly convert waste heat into useful electricity, propound the likelihood of an all-solid-state technology for power generation, refrigeration, temperature stability, and control. The TE material's performance is evaluated in terms of a dimensionless figure of merit, zT. Boosting the electrical transport properties and suppressing the thermal transport is critical to realizing a high zT. However, these transport properties are interlocked and confront a bigger challenge in improving the thermoelectric energy conversion efficiency. Recent advances in this field of TE offer unprecedented opportunities for designing and fabricating increasingly complex material systems with tunable transport properties (zT > 1).

The present project is concerned with applying novel strategies and principles to designing and creating novel material systems, especially on chalcogenide-based materials with enhanced TE properties.

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PROJECT 21

Energy transition and sustainability in power distribution networks

Energy System Sustainability (ESS) is the challenge faced by the futuristic power grids. Energy transition is an increasingly important area which encompasses different forms of energies like electrical, mechanical, thermal, and chemical creating an energy hub. Energy storage is an important constituent which decides the resilient nature of the grid energy storage technologies and implementation are an integral part of this proposal. Renewable energy is an important component and role in the ESS of the future. Similarly, smart grids using information and communication technologies define the grids of the future.

Application of new concepts, methodologies and techniques for enhancing the energy system sustainability of power and energy systems are the key tasks of the proposal.

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PROJECT 22

Coordinated control and task allocation for autonomous mobile robots in warehouses using multi-objective multi-agent reinforcement learning

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With increasing efficiency needs in warehouses, this research proposes the use of multi-objective multi-agent reinforcement learning (MO-MARL) strategies to develop coordination and task allocation algorithms for autonomous mobile robots in warehouse environments. The use of MO-MARL is motivated by the existence of competing objectives in warehouse operations, such as time, energy and safety. One of the challenges is the presence of uncertainties in the consumer demand, which may lead to changes in desired optimal placement of the inventory, which needs to be accommodated in the algorithms. Another challenge is the non-uniformity in the requirements of warehouses, especially in MSMEs across the industries. Therefore, the learning mechanism in the proposed approach can facilitate generalization in the developed algorithms.

The proposed project can lead to improved operational efficiency in a variety of warehouse management problems with coordinated control of autonomous mobile robots.

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PROJECT 23

Photoreduction of CO_2 into renewable fuels through novel catalytic membrane reactor

Energy crisis and climate change associated with carbon emissions are two of the most critical global challenges facing humanity. Solar powered reduction of CO_2 into green and valuable chemicals and/or fuels is a sustainable approach to simultaneously address these two critical challenges.

This project aims to develop high-performance photocatalysts through surface engineering and integrate them into novel membrane reactors for photoreduction of CO_2 into renewable fuels. In the project, Professor Somnath Chanda Roy's team at IITM will develop surface engineered high-performance photocatalysts through computational design and experimental fabrication. The prepared photocatalysts expect to boost CO_2 reduction capabilities by over 75% by surface engineering, such as surface hydrophobicity tailoring. Dr Shuaifei Zhao's team at Deakin University will integrate the prepared photocatalysts into porous membranes to construct novel catalytic membrane reactors.

The innovative catalyst integration and reactor design will further improve the product yields, enhance the desirable fuel conversion and production, and allow easy separation of the product from the membrane reactor.

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PROJECT 26

Real-time zero-day attack intrusion prevention system for streaming data

Deploying layered security controls including firewalls, IPS/IDS, and other data-centre security controls as well as endpoint security controls are effective approaches to detect and mitigate zero-day attacks. However, the existing approaches are unable to perform effectively to detect zero-day attacks on streaming data; this is a critical and challenging problem which this project aims to address. Further, the proposed solution is expected to lead to low computational cost and highly scalable and maintains end-to-end latency.

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PROJECT 27

Designing and testing field experiments that enable pro-environmental behavior

Encouraging pro-environmental behavior presents a pressing challenge in contemporary society. Behavioral economics offers valuable insights into designing interventions that effectively promote such behaviors.

This study explores the design and testing of field experiments aimed at fostering pro-environmental behavior (e.g., energy/water conservation by citizens, farmers etc.) through the lens of experimental and behavioral economics.

The proposed field experiments will employ a combination of randomized controlled trials (RCTs) and behavioral interventions such as nudges and social norms framing. RCTs will enable rigorous evaluation of the effectiveness of various interventions in influencing pro-environmental behavior. Behavioral interventions will leverage principles such as loss aversion, social proof, and default bias to encourage sustainable choices. Additionally, incorporating elements of gamification and incentives will enhance engagement and long-term embracement of desired behaviors. The empirical analysis will employ econometric methods.

It is anticipated that the field experiments will yield valuable insights into the efficacy of different behavioral interventions in promoting pro-environmental behavior. By systematically testing various strategies grounded in behavioral economics, this research aims to identify the most effective approaches for fostering sustainable actions in real-world settings.

Ultimately, the findings of these experiments can inform policy interventions and corporate initiatives aimed at addressing environmental challenges and promoting a more sustainable future.

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PROJECT 29

Estimation, prediction and enhancement of grid resilience

Electrical power grids are complex dynamic systems which change state very frequently based on the operating scenario, based on the power balance and energy balance between generation and loads. Frequent network changes and disturbances create system instability leading to collapse which needs to be avoided at any cost.

Grid resilience of disturbances is the main objective of the proposal. Self-healing networks are an important concept in grid resilience. The important tasks in this project are:

1. prediction of the power system network operating state
2. estimation of the parameters influencing the operation states
3. identification of the control task required
4. implementation of the control tasks identified.

Grid resilience and self-healing in smart grids are based on the concept of complex networks. The work aims at developing techniques that would resist the failure and rapidly recover from breakdown or collapse. Methods and techniques to improve the grid immunity and resilience are the concepts which will be introduced and implemented in this proposal.

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PROJECT 30

Design, control and energy management of renewable based cyber secure microrgid with electric vehicle and battery energy storage

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Microgrids play a crucial role in promoting energy resilience, sustainability, and grid flexibility, making them suitable for a variety of applications, including remote communities, industrial complexes, military bases, and critical infrastructure. They contribute to a more decentralized and adaptable energy infrastructure. Microgrid control is a crucial aspect of managing a distributed energy system, enabling efficient and reliable operation. The control system of a microgrid is responsible for coordinating the various components within the microgrid, optimizing energy flows, and ensuring stability. Designing, controlling, and managing the energy of a renewable-based microgrid with electric vehicle (EV) integration and battery energy storage (BESS) involves several key components and considerations.

This project aims to conduct research on several areas including:

1. system design: renewable energy sources, microgrid architecture, power converter and control
2. control strategy: grid forming control, power management, voltage/frequency regulation
3. energy management: battery/supercapacitor energy storage, EV integration, demand management
4. integration with the power grid- grid interconnection, grid services
5. regulation and policy – regulatory framework, policy support
6. security framework.

By addressing these aspects comprehensively, we can design, control, and manage a renewable-based grid-forming microgrid with EV and BESS integration effectively, optimizing energy utilisation, enhancing grid resilience, and contributing to the transition towards a more sustainable energy future. By incorporating these cybersecurity measures into the design, control, and energy management of the renewable-based microgrid with EV and BESS integration, you can enhance the overall resilience of the system against cyber threats and contribute to the secure and reliable operation of the microgrid.

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PROJECT 32

An effective framework for extraction and utilisation of recycled materials in road infrastructure

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Road pavements are the one of the most natural resource-consuming infrastructures. Typically, the construction of 1 km of a typical 4-lane road highway requires around 36,000 tonnes of stones and sand which are derived from cutting mountains and mining rivers. Current methods of utilising natural resources for road infrastructure is not a sustainable practice, leading to several socio-economic-environmental challenges. Much research on the use of outdated road materials for new road construction have been carried out. However, they were fragmented attempts and there is still no framework for assessing and guiding the extraction and utilisation of recycled materials for future road infrastructure.

The current proposal aims to develop strategies for extracting high-quality materials from the existing road infrastructure and utilising them again for the new structure without the use of pristine materials. This will be achieved systematically via three following phases:

1. experimental phase consisting of understanding the issues with recycled road materials and their addressal by developing cost-effective and sustainable techniques
2. semi-experimental phase wherein the positive and negative effect of the recycle materials on the strength and durability performance of road/pavement layers will be understood through laboratory experiments followed by numerical simulations for in-situ loading condition assessment
3. theoretical phase to develop frameworks for effective utilisation of road wastes.

It is expected that the outcomes from this project will provide a framework for the extraction of sustainable materials for future road infrastructure.

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PROJECT 35

Secure aggregation protocols for federated learning: ensuring privacy and integrity in decentralised model updates

Federated learning, a promising approach for training machine learning (ML) models on decentralised devices while preserving data privacy, faces challenges in secure model aggregation. This proposal aims to develop novel cryptographic techniques for secure aggregation, ensuring both privacy and integrity.

Federated learning relies on aggregating model updates from numerous decentralised devices, each containing sensitive data. Existing aggregation methods risk exposing individual updates, risking privacy breaches. Additionally, malicious participants may attempt to manipulate the process, compromising model integrity. Secure aggregation protocols are necessary to protect data privacy and ensure model integrity.

This research aims to develop cryptographic protocols for secure model update aggregation in federated learning, ensuring privacy and integrity. It involves designing mechanisms to protect individual update privacy, verify model integrity, and evaluating protocol performance in real-world scenarios. To achieve this, we will investigate cryptographic techniques such as SMPC, homomorphic encryption, and differential privacy for their suitability in federated learning. Subsequently, we will develop tailored cryptographic protocols, considering factors such as communication overhead, computational complexity, and privacy guarantees. The implementation of these protocols will be done using compatible frameworks, ensuring seamless integration with existing federated learning systems.

Expected outcomes include the development of novel secure aggregation protocols, empirical evidence of their effectiveness, and insights into the trade-offs involved in federated learning. The significance of this project is in its potential to enable privacy-preserving, trustworthy federated learning systems, enhancing data privacy, and promoting collaboration while safeguarding sensitive information.

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PROJECT 38

Integration of SWOT and GRACE satellite data for hydro-climatic analysis using advanced machine learning techniques

Rapid advancements in multisource satellite remote sensing, including missions like GRACE (Gravity Recovery and Climate Experiment) and SWOT (Surface Water Ocean Topography), present unprecedented opportunities to enhance observations and predictive capabilities for various hydrologic processes. SWOT monitors surface water bodies such as oceans, rivers, and lakes, offering precise measurements of water levels and flow dynamics, while GRACE tracks changes in Earth's gravity field to monitor terrestrial water storage variations, encompassing groundwater depletion and ice mass loss. However, the integration of multiple satellite data products, particularly SWOT and GRACE, remains relatively unexplored in addressing hydrologic challenges, representing an emerging frontier in both hydrological research and satellite remote sensing.

By assimilating SWOT and GRACE datasets, we aim to provide accurate assessments of different hydrologic extremes (e.g., floods, droughts), water availability, and distribution, providing valuable insights for water resource management and climate change adaptation strategies. This could be achieved by harnessing the advantages of advanced machine and deep learning techniques such as transformer-based models. These architectures can effectively capture the spatial and temporal dependencies in multi-source satellite data, extracting relevant features and making accurate predictions about future hydrological conditions.

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PROJECT 39

IPO valuation, diminishing promoter ownership and stock market crash risk

The study examines how varying levels of promoter ownership influence the Initial Public Offering (IPO) pre- and post-valuation, examining factors 'objective of issue' governance characteristics and alignment of interests. We find firms in India are not having promoters- we propose to examine risks associated with firms lacking a distinct promoter category (highly increasing in India), analysing governance challenges and their implications for investors.

The findings of this research are expected to offer valuable insights for investors, policymakers, and practitioners involved in the financial market.

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PROJECT 40

Materials data extraction using large language models from scientific literature

The key idea here is to explore how Large Language Models (LLMs) can be used to accurately extract materials data (e.g. chemical composition, mechanical properties, etc.) from journal publications to create a materials data repository. Preliminary results show that even Chat GPT 4.0 (used in a rudimentary way) results in poor accuracy, and thus modifications (prompt engineering, RAG, fine tuning) are necessary to improve performance.

Our group is working on developing an LLM pipeline that could be used to extract materials knowledge buried in literature and a store in an easily accessible relational database format.

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PROJECT 41

Development of green self-compacting geopolymer concrete using recycled waste and implementing circular economy principal

We have developed self-compacting geopolymer concrete using alternative cementitious materials (fly ash and slag) using waste glass particles as partial replacement of fine aggregate. In the next phase, we are thinking of replacing sand entirely. In addition, we are aiming to relace coarse aggregares using construction and demolition waste. This use of this waste can also ensure the circular economy principal where the developed mix design can be used as construction and demolition waste in its second life cycle.

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PROJECT 42

Biodegradable nanomotors for targeted drug delivery to cancer cells

Bioinspired autonomous nanomachines are a new way of approaching and solving problems. Unlike current passive diffusion-based nanosystems, these nanomachines can target cells in biological systems to deliver cargo and drugs. The unique fabricated systems can achieve autonomous navigation that can be highly controlled to execute tasks “on-demand” in response to tumour microenvironment.

This project aims to design, fabricate and investigate biodegradable nanomotors for targeted drug delivery to cancer cells and understand their behaviour using lab-on-a-chip approach. Innovative advanced technology will be utilised to engineer the nanomotors for biomedical applications.

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PROJECT 46

Metamaterial-based acoustic analogues of quantum phenomena

Intriguing quantum phenomena such as the existence of 'dirac cones' in dispersion relations are at the heart of the characteristics that give materials such as graphene, Weyl semi-metals, etc. their unique properties. Such phenomena need to be studied in detail to design and develop materials that yield quantum properties. For example, there has been much interest recently in studying 'twistronics' that emerges from juxtaposing multiple layers of 2D materials, such as graphene. However, studying such phenomena in the original materials can be challenging given the scale at which they exist and the stringent requirements on temperature, etc. Fascinating recent investigations show that we can achieve acoustic analogues of exotic quantum phenomena using metamaterials that are easy to fabricate and test under normal room-temperature conditions. Dirac Cones, the Quantum Hall Effect, etc. have been studied in their acoustic analogues.

This project seeks to develop in these directions and establish a testbed for the simulation of quantum effects using acoustic metamaterials and phononic crystals. The goal is to study and list the quantum phenomena of interest and then design acoustic metamaterials that can best mimic such effects before fabricating them. Attention will be given to concepts that are amenable to 3D and 4D printing techniques. A campaign of trials and tests will be developed to study computational acoustics, quantum acoustics, and quantum materials. The results will lead to novel and scalable devices for applications in sensing and computation.

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PROJECT 47

On the provable security of block ciphers and its impact on data-driven cryptanalysis

Block ciphers serve as foundational components in numerous cryptographic constructions, including authenticated encryption schemes and hash functions. Established paradigms for block cipher designs encompass the generalised Feistel network, substitution-permutation network, and add-rotate-XOR (ARX) constructions. In the past, researchers have investigated the provable security guarantees provided by these classical design paradigms. Recently, significant attention has turned toward machine or deep learning-based cryptanalysis of block ciphers, aiming to train models capable of distinguishing between a cipher's output and that of a random function. Several of these approaches have outperformed classical cryptanalysis methods.

This project investigates the relationship between a block cipher's provable security, particularly in terms of its indifferentiability from an ideal cipher, and its resilience against data-driven distinguishing attacks. The findings will contribute to a deeper understanding of these attacks, which are predominantly perceived as black box methodologies.

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PROJECT 49

Advanced forming of engineered Al/Mg sheets with varying strain paths

Semi-solid state processing is a new generation manufacturing process where casting and forming happens together for shaping of materials.

The present work will focus on developing high performance thermally stable engineered Aluminium-Magnesium (Al/Mg) alloy sheets and establish the scientific knowhow of their formability with respect to varying strain paths.

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PROJECT 50

Additive manufacturing of energy generation and storage devices

The project combines IITM's expertise and resources in developing energy generation and storage devices with Deakin's expertise and resources in additive manufacturing of advanced materials. It will explore the 3D printing of multi-level porosity silicon and carbon-based anodes, cathodes, and electrolytes for batteries and electrolysers. 3D printing provides exciting opportunities to design and develop novel, high-performance, and customised components for such electrochemical systems. However, their use in electrochemistry has been limited due to the lack of suitable print materials and resolution. Dr Gupta (Deakin) has recently developed new materials and methods for high-resolution 3D printing of silicon, carbon, and metal composites, which provide the required material properties and print resolution for different electrochemical applications. Moreover, the developed method allows fine control over the pore size and their distribution (1 nm and above) and the integration of multiple such materials into a monolithic body. The developed capability will be amalgamated with Professor Kothandaraman's (IITM) expertise in designing and developing high-performance batteries and electrolysers to explore the next generation of energy generation and storage systems.

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PROJECT 54

Natural language processing (NLP)-based quantitative risk assessment in workplace health and safety

Despite being a priority industry for injury prevention, the construction sector consistently lags behind in occupational health and safety (OH&S) performance globally. Traditional safety strategies have been exhausted, necessitating evidence-based safety innovations. One such solution is leveraging digital technology to analyse historical injury data. However, a significant amount of construction site data remains untapped.

This project aims to develop tools using machine learning (ML), text mining, and large language models (LLMs) to analyse injury and accident reports, focusing on improving health and safety performance in the construction sector. Specifically, the project will implement LLM to analyze injury/fatality reports, establish causal links between accident precursors, and develop a quantitative risk-assessment model. This model will quantify the impact of precursors on injury type and severity, enabling timely extraction of critical information for designing efficient injury prevention strategies.

We are seeking a PhD candidate with a passion for solving complex global problems and the persistence to work in a multicultural, collaborative academic environment. While a basic understanding of OH&S issues is welcome, a background in ML and LLM technology will be advantageous for the candidate's selection.

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PROJECT 55

Assessment of mental fatigue using multi-modal feature fusion

Fatigue is one of the significant occupational hazards in different sectors such as construction and transport. Fatigue can result in serious short- and long-term health and safety issues. In the short term, fatigue prevents people from functioning safely and within normal boundaries which results in injuries and accidents. In the longer-term, fatigue may also result in body stress, diabetes, gastrointestinal disorders, mental health issues, cardiovascular disease and work-related musculoskeletal disorders which account for more than 70% of workers' compensation claims. The emerging field of objective fatigue monitoring aims to use physiological sensing and computer vision to monitor fatigue continuously and address the issue of bias associated with the traditional fatigue self-reporting processes. Despite significant innovations in objective fatigue monitoring, there are significant challenges for implementing the technology in the real work environment that need to be addressed.

This project aims to propose a multi-modal feature fusion approach with the capability of measuring mental fatigue for both workers and operators. The proposed method will combine facial parameters, physiological, and contextual information (e.g., age, experience, light) to assess the level of mental fatigue more accurately and has the potential to be used in different sectors such as transport and construction in real-world environments. As part of the project, a situational awareness system will also be developed to give real-time feedback on the level of fatigue to make farsighted and informed decisions in ongoing operations.

The outcomes of this project will provide an efficient tool for real-time monitoring of mental fatigue in different sectors such as construction, transport, and mining and will aid in minimising the injuries and accidents arising from fatigue.

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PROJECT 58

AI-powered resilience: big data solutions for basin-scale water management in a changing climate

Basin-scale water resource management confronts unprecedented challenges due to the accelerating impacts of climate change. Disruptions to historical precipitation patterns, compounded by shifting land-use and increasing water demand, expose the limitations of traditional models and decision-making tools. Climate change introduces significant uncertainty, increasing the risk of both water scarcity and extreme events like floods and droughts. Yet, within this challenge lies a transformative opportunity. The confluence of vast datasets and cutting-edge artificial intelligence (AI) techniques offers the potential to revolutionize water management. Artificial intelligence and machine learning can unlock patterns within complex systems, enhance predictive capabilities, and facilitate adaptive, climate-resilient planning.

This project aims to harness these opportunities, developing new AI-driven models for basin-scale water management that directly address the challenges posed by climate change. The outcome will be improved water security, supporting both human needs and ecosystem health in a rapidly changing world.

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PROJECT 59

Non-contact monitoring of neonatal health in ICU

The project aims to develop methods for reliable assessment of health and vital parameters using non-contact methods in a neonatal intensive care unit (ICU) environment.

The research challenge is effective fusion of video streams from multiple visible light and IR cameras, and continuous identification of the optimal region of interest on the neonatal skin surface for reliable assessment of skin perfusion changes for heart rate estimation, chest motion patterns for respiratory health estimation, and breath patterns for respiration rate estimation etc. Efficient data fusion is needed to improve signal reliability and ensure good spatio temporal coverage of the unobtrusively estimated vitals; a problem that is as yet uncracked. Moreover, the project will also explore AI based pose detetion and behavioral assessment methods to give an overall state of health of the infant which goes beyond just the essential vital signs..

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PROJECT 64

Benchmarking quantum computers

Developments in areas of quantum artificial intelligence (such as quantum Generative Adversarial Networks) require the development of suitable benchmarks before they can be effectively compared across multiple hardware.

This project aims to identify, solve and contribute to the larger community of quantum AI researchers.

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PROJECT 65

Reconfigurable optical access for future wireless networks

Reconfigurable optical access is increasingly seen as a crucial component to support future wireless networks to offer flexibility and adaptability to accommodate evolving network requirements and technologies.

This project aims to investigate mechanisms that can support dynamic allocation of resources, wavelength switching, and traffic grooming, enabling efficient utilisation of network resources and adaptation to changing traffic patterns and service demands in reconfigurable networks.

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PROJECT 66

Data integrity verification in heterogeneous edge environments

Recent advances in edge computing have pushed cloud-based data caching services to edge by motivating app vendors to cache multiple data replicas on geographically distributed edge servers. However, such emerging edge storage comes with a challenging and unique edge data integrity verification problem which coordinates multiple participants (e.g., edge servers and app vendors) to inspect whether data cached on edge is authentic.

By leveraging cutting-edge distributed ledger technologies, machine learning algorithms, and cryptographic techniques, this project aims to devise robust and efficient mechanisms for detecting tampering, data corruption, and unauthorised modifications.

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PROJECT 67

Advanced alloy design using machine learning

This PhD project aims to leverage the power of applied machine learning and natural language processing techniques to revolutionise materials design. By using advanced algorithms and models, the project seeks to automate and optimise various stages of materials analysis, and then, discovery.

Through the analysis of vast datasets, experimental results and material properties, novel predictive models will be constructed to accelerate the identification of materials with desired properties. Additionally, the project will explore innovative methods for extracting knowledge from unstructured data sources to inform and guide the materials design process. Specifically, the project will focus on metallic alloys (which may include high entropy alloys, steels, or light-alloys), and there will be opportunities to interact with industry partners in this project- to provide pathways for direct impact and experience.

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PROJECT 69

Blockchain for secure energy trading in Internet of Grids (IoG)

The term “Internet of Grids” (IoG) refers to a network where various elements of the electrical grid are interconnected through the Internet of Things (IoT). This involves the integration of sensors, smart devices, and advanced communication technologies within the grid infrastructure to enhance monitoring, control, and efficiency.

This project aims to design and develop a secure energy trading architecture for the Internet of Grids (IoG) using blockchain networks under uncertainty. One significant challenge for the IoG is the need for security, including, access control solutions, that are designed to meet the characteristics of these systems. In a novel approach, blockchain technology and the IoG will be integrated to develop a flexible, scalable, and decentralized delegation model, providing a new access control model, that will not depend upon concrete identity of an entity. Such a model will improve security in large- scale IoG systems while providing for safe and fine-grained policy-management.

This project will:

1. examine innovative methods to access blockchain networks for IoG access control and delegation
2. develop technology for handing secure and flexible access right delegation without the need for a trusted third-party involvement, and strengthen security for IoG while addressing the large-scale nature of such systems.

This will be a major step forward and highlights the importance for handling the particular nature of the IoG.

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PROJECT 71

Graph neural networks for solving combinatorial optimization problems

Combinatorial optimisation problems arise in different disciplines of engineering and science. Mixed-integer linear programming problems (MILP) are solved for developing context-specific metabolic models in biotechnology and for determining operation strategies in water distribution networks in engineering. The MILP problems have to be solved periodically to find optimal solutions. However, large-scale MILP problems are difficult to solve and intractable in practice. Recently, graph neural networks (GNN) based approaches have shown potential promises in exploiting solution patterns for solving these problems.

This project will develop novel and efficient GNN-based approach for solving MILP problems. It will combine the complementary skills of Dr David Tay in graph signal processing and Dr Nirav Bhatt and Professor Sridharakumar Narasiman in solving MILPs for biology and infrastructure networks.

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PROJECT 75

Decentralized cohesive control for connected autonomous vehicles

This research aims to develop cohesive control technologies for connected autonomous vehicles.

Cohesive network control is essential for connected vehicles, where loss of cohesive response during state transitions such as changing velocity of leader vehicle can lead to large errors in inter-vehicle spacing affecting the safety and performance of the system. For instance, closely spaced connected vehicle platoons have been proposed in the trucking industry to reduce the fuel consumption from reduced air drag.

This collaborative research will investigate potential control and communication network technologies in achieving this goal.

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PROJECT 76

Simulation of additive friction stir deposition using material point method

The Material Point Method (MPM) is a meshless technique well adapted to the simulation of solids under large deformation. Currently, we aim to develop the MPM to simulate Additive Friction Stir Deposition (AFSD). This 3D printing technology has the potential to be used for metal recycling. Yet, the current physical understanding of this process is limited and simulations are needed to describe it. Full-scale models of the AFSD are currently limited by the high computational cost of the MPM.

This project aims to employ the MPM to simulate AFSD and in addition improve the computational efficiency of the MPM without degrading its accuracy to achieve near-real-time simulation capabilities. This method could then be used to learn what is the temperature, strain and stress path taken by a portion of metal being printed, and eventually to understand how to tune the process to enable scrap metal recycling.

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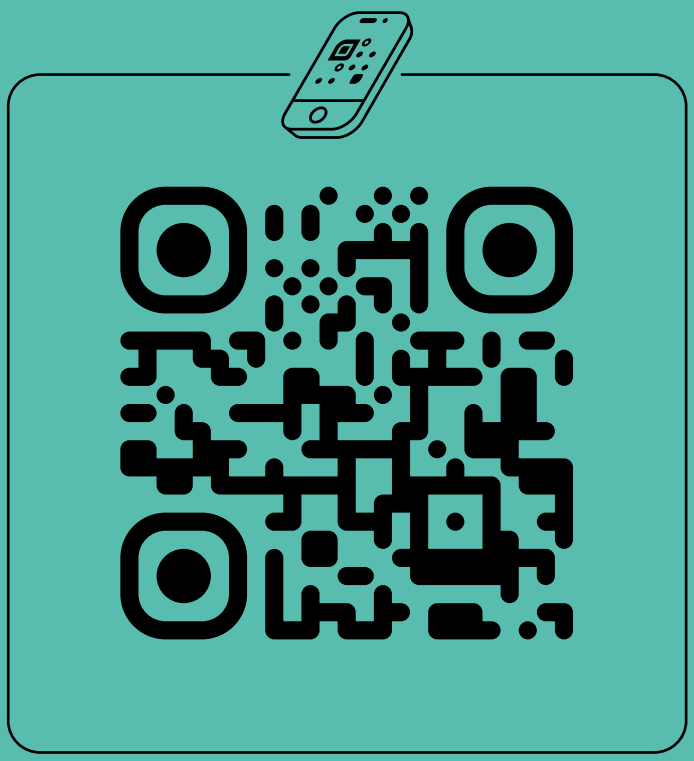

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