List of projects:

**Title: Automated Segmentation of Cancer Tissue Images**

**Supervisor: Beth Jelfs**

School: Engineering

Description: The aim of this project is to develop a method for identifying regions of cancerous tissue from microscopy images. The student will be part of an international team of engineers, scientists and pathologists developing a system for automated diagnosis and prognosis of prostate cancer. The team have developed a new biomarker for cancer which is used to stain the prostate tissue before imaging with a confocal microscope. The goal of the project will be to use the colour intensity of the images to identify regions of cancer while ignoring any artefacts caused by creasing in the tissue, knife marks etc.

**Title: Clustering Rotating Radar Measurements for Robot Navigation**

**Supervisor: Christopher Gilliam**

School: Electronic, Electrical and Systems Engineering

Description: The goal of this project is to develop an algorithm that intelligently clusters measurements from a radar sensor that is mounted to a robot. This project will form part of a system for simultaneous localization and mapping (SLAM) using a new rotating radar sensor. The student will work with both the team in Birmingham and engineers in Australia and China who are working on other aspects of the system. In this project, the student will develop a method to cluster the radar measurements for the purpose of aiding the navigation of the robot. As the robot moves, the radar obtains distance and directional measurements from the objects in the surrounding environment and the student will work on identifying which object each of these measurements belong to and clustering them into groups.

**Title: Identifying Best Practice in Global Climate Vulnerability and Adaptation Planning**

**Supervisor: Daniel Donaldson & Andrew Quinn**

School: Electronic, Electrical and Systems Engineering

Description: Changing climate has increased infrastructure exposure to hazards such as extreme heat, drought, wildfires, flooding and sea level rise around the world. As a result, a variety of forward-thinking infrastructure owners have developed methodologies and plans to assess the risk, impact, mitigation, and adaptation necessary to ensure the resilience of the critical infrastructure that they manage. However, such plans are often developed in isolation from similar work in other sectors or regions and driven by different understandings or requirements of their local context. This summer internship will aim to collect, categorise, review, and aim to synthesise these planning efforts from around the world. The resulting report will provide foundational knowledge to support UoB’s Resilient Systems and Climate Action research. The intern will develop valuable skills and experience on structured literature searching and systematic review methods which are key to a research project. They will also gain an understanding of the current status of climate preparedness of critical infrastructure in a variety of sectors such as electrical power, water and transport networks.

**Title: Problems in Connectivity theory**

**Supervisor: Johannes Carmesin**

School: Mathematics

Description: Classical connectivity theory studies methods to cut graphs along small separating sets into "highly connected structures" (for example cliques or grids). This approach allows for the following proof strategy: firstly, prove your conjecture for highly connected graphs. Then secondly apply the decomposition theorems from graph connectivity to stick these partial solutions together to obtain global solutions. A program quite a few people in my team are working on is concerned with extending classical connectivity theory to allow for vertex sets that do not separate globally but just locally. We have quite a few "easy to state, hard to solve" problems in this area. Quite often even finding the right conjecture is an exciting highly nontrivial problem, and as this is a new area of research there will be lots of opportunities for this as well.

**Title: Extremal graph theory**

**Supervisor: Allan Lo**

School: Mathematics

Description: Here are some questions that I like to study:

A) Minimum degree:

 What minimum degree conditions in a graph ensure the existence of

* Hamilton cycles; or
* a set of vertex-disjoint triangles covering all vertices; or
* a set of edge-disjoint triangles covering all edges?

B) Edge-coloured graphs: Given an edge-coloured graph, how long is the longest monochromatic/properly-coloured/rainbow cycle?

Feel free to replace graph with directed graph, oriented graph, regular graph, random graph or hypergraph.

**Title: Questions in geometry using techniques from algebra and combinatorics**

**Supervisor: Qaasim Shafi**

School: Mathematics

Description: The precise topic and focus of the project are negotiable, but the general theme will be probing questions in geometry using techniques from algebra and combinatorics, for example, tropical geometry.

**Title: Quantum technology**

**Supervisor: Cyril Closset**

School: Mathematics

Description: The precise topic and focus of the project are negotiable, depending on the student's interest, but the general theme will be related to questions of geometry that arise in string theory. For a student with knowledge of quantum mechanics, a related project is to study the relation between supersymmetric quantum mechanics and Morse theory.

**Title: Systems biology**

**Supervisor: Yin Hoon Chew**

School: Mathematics

Description: Living cells have the ability to sense and respond to their environment by changing behaviours such as growth and movement. This ability is executed through networks of interactions among molecules in cells. Mathematical models and/or computer simulations that represent such networks could provide insights and potentially make useful predictions for guiding medical therapies. The precise topic and focus of the project are negotiable depending on student skills and interests.

**Title: Evolution and promotion of cooperation**

**Supervisor: Hong Duong**

School: Mathematics

Description: How cooperation can emerge and persist within populations of self-regarding individuals (according to Darwinian theory of natural selection) has been a challenging question in ecology, biology, and social sciences. The aim of the project is to study the evolution and promotion of cooperation using mathematical models for finite populations.

**Title: Healthcare Technology**

**Supervisor: Fabian Spill**

School: Mathematics

Description: The precise topic and focus of the project are negotiable, but the general theme will be related to

1. Physics-informed machine learning.
2. Mechanical models of Cancer.

**Title: How does weather influence Acute Care Hospitals, Emergency Department admissions and ICU admissions in England?**

**Supervisor: Hui Li**

School: Mathematics

Description: This project is an application to medical statistics. Season and weather are associated with many health outcomes, which can influence hospital admission rates. The project aims to examine associations between the admissions in Acute Care Hospitals, Emergency departments and ICU and local meteorological parameters in England. The results from the project could support hospital planning and preparation for the impacts of climate change. Necessary skills for taking this project include data management: hospital admissions data is available to use. The meteorological database is available to use but it needs to be downloaded and merged with the hospital admission data in England. Various modelling methods are the key part of the project.

**Title: Survey on the effect of COVID-19 on Chinese customers’ choice of shopping channels for daily necessaries**

**Supervisor: Jia Shao**

School: Mathematics

Description: This project requires you to use survey to collect data and examines the factors that influence consumers’ choices, using both offline and online channels as the main channels for purchasing daily necessities.

**Title: Mapping Violence Against Women and Girls**

**Supervisor: Rowland Seymour**

School: Mathematics

Description: This project will focus on trying to identify where and why women and girls are at risk of violence, forced marriage and female genital mutilation in particular. Using a statistical method called comparative judgement, you will develop generalised linear models to begin to understand why these crimes happen.

**Title: New, Green and Sustainable Synthesis of Materials for Light-Harvesting Applications**

**Supervisor: Tomislav Friščić**

School: Chemistry

Description: The proposed research opportunity will establish the first use of a recently emerged mechanochemical[1] methodology for synthesis, known as Resonant Acoustic Mixing (RAM),[2] for the generation of hybrid perovskite materials of high potential for use in solar cells. The RAM technology permits conducting synthesis of molecules and materials without using toxic solvents, and at the same time provides unprecedented advantages in energy- and materials-efficiency, as well as scale-up. It is the recent addition to the toolbox of mechanically-driven, environmentally-friendly synthetic approaches, that have in 2019 been deemed by the International Union for Pure and Applied Chemistry among the top 10 technologies that could change the world. The project will be highly innovative, introduce a new and greener technology to make important materials for future solar harvesting, and overall be a significant contribution to development of a more sustainable chemistry. The project will provide the candidate with extensive and unique experience in mechanochemical techniques, that are of high interest for pharmaceutical and specially chemical industries, along with experience in advanced materials synthesis and characterisation, including powder and single crystal X-ray diffraction, nuclear magnetic resonance spectroscopy, as well as Raman and fluorescence emission spectroscopy. Overall, the experience gained will be suitable for future career development, in either academic or industrial paths.

 The candidate will be working with a team of experienced researchers, including a senior PhD student, a post-doctoral fellow, and be directly supervised by Prof. Friščić. The work is anticipated to lead to valuable results, providing the candidate an opportunity to present their work at conferences and/or publication(s). Our group highly supports an inclusive, diverse environment, and we believe that interaction and collaborations of enthusiastic researchers with different backgrounds and experiences is invaluable for scientific and technological progress.

References:

[1] T. Friščić, C. Mottillo and H. M. Titi "Mechanochemistry for Synthesis" *Angew. Chem. Int. Ed.* 2020, 59, 1018.

[2] H. M. Titi, J.-L. Do, A. J. Howarth, K. Nagapudi, and T. Friščić "Simple, scalable mechanosynthesis of metal–organic frameworks using liquid-assisted resonant acoustic mixing (LA-RAM)" *Chem. Sci.* 2020, 11, 7578.

**Title: Simulated Mechanochemical Mixing of Molecular Solids at High-Energy Interfaces**

**Supervisor: Tomislav Friščić**

School: Chemistry

Description: The proposed research opportunity will contribute to the development of computational approaches that work towards the understanding of mechanochemical processes. Mechanochemistry[1] has emerged as a green and sustainable technique to enable chemical transformations, and, in 2019, has been identified by the International Union for Pure and Applied Chemistry as one of the top 10 technologies that could change the world. Recent developments in computational strategies have provided atomistic insights into the underlying energetics and dynamics of mechanochemical processes which allow for the further development of the field.[2,3] A key area of interest is the inter-molecular interactions between solid materials at interfaces, as the principal site of mixing to occur. The project will provide the candidate with in-depth training on the implementation of force field molecular dynamics simulations that will be complemented with in introduction to periodic density functional theory calculations. More specifically, the candidate will perform dynamic simulations to mechanically disrupt the pristine surfaces of crystalline molecular organic solids under varying degrees of stress. Initially, the project will focus on the effects of mechanical disruption on the materials surface energy before shifting towards the simulated mixing of materials between different solid materials.

 The candidate will be working with a team of experienced researchers, including a senior post-doctoral fellow, and be directly supervised by Prof. Friščić. The work is anticipated to lead to valuable results, providing the candidate an opportunity to present their work at conferences and/or publication(s). Our group highly supports an inclusive, diverse environment, and we believe that interaction and collaborations of enthusiastic researchers with different backgrounds and experiences is invaluable for scientific and technological progress.

References:

[1] T. Friščić, C. Mottillo and H. M. Titi "Mechanochemistry for Synthesis" Angew. Chem. Int. Ed. 2020, 59, 1018.

[2] M. Arhangelskis, A. D. Katsenis, A. J. Morris, and T. Friščić “Compuational evaluation of metal-pentazolate frameworks: inorganic analogues of azolate metal-organic frameworks” 2018, 9, 3367-3375.

[3] M. Ferguson, M. S. Moyano, G. A. Tribello, D. E. Crawford, E. M. Bringa, S. L. James, J. Kohanoff, and M. G Del Pópolo “Insights into mechanochemical reactions at the molecular level: simulated indentations of aspirin and meloxicam crystals” Chem. Sci., 2019, 10, 2924-2929.

**Title: Using the mathematics of plant growth to revolutionise engineering design for 3D printing**

**Supervisor: Galane Luo & Lauren Thomas-Seale**

School: Mechanical Engineering

Description: 3D computer aided design (CAD) software was originally developed to model shapes that can be manufactured by subtractive technology. As such, most solid modelling techniques are focussed on the principles of extruding shapes and then subtracting material. This contrasts with the growth of structures in nature, which for example in plants, have an organic form. The school of engineering and school of mathematics, have co-created a novel design approach to model geometries which can be formed using additive manufacturing (AM), also know as 3D printing (3DP). The approach is based on equations, more commonly associated with modelling the growth of plant roots. This approach will enable more efficient and more creative design for AM (DfAM) in many applications areas. The purpose of this project is to generalise the design software, by building more sophisticated mathematical toolkits to be incorporated into the source-code. The student(s) will work with the piece MATLAB source-code containing all the existing functions for design and analysis. The aim is to first understand the code and then to extend it. The generalised end-product should gain the ability to vary the spatial limits of the geometry, with respect to the 3DP material and parameters.

**Title: Design and 3D printing of cardiovascular geometry powered by mathematical biology**

**Supervisor: Galane Luo & Lauren Thomas-Seale**

School: Mechanical Engineering

Description: 3D computer aided design (CAD) software was originally developed to model shapes that can be manufactured by subtractive technology. As such, most solid modelling techniques are focussed on the principles of extruding shapes and then subtracting material. This contrasts with the growth of structures in nature, which for example in plants, have an organic form. The school of engineering and school of mathematics, have co-created a novel design approach to model geometries which can be formed using additive manufacturing (AM), also know as 3D printing (3DP). The approach is based on equations, more commonly associated with modelling the growth of plant roots. This approach will enable more efficient and more creative design for AM (DfAM) in many applications area, including but not limited to, healthcare technology. The purpose of this project is to explore the geometric capabilities of the technique in the context of cardiovascular grafts; a term used to encompass constructs which replace a portion of vascular tissue, for example an artery. The student will require undergraduate level engineering knowledge of CAD and mathematics. The student will be able to enhance their wider knowledge of mathematics, 3DP and bioengineering.

**Title: Detection of plant pathogens using physical chemistry techniques**

**Supervisor: Julia Lehmann**

School: Chemistry

Description: This internship opportunity will be based on the use of mass spectrometry and laser spectroscopic techniques in the analysis of Volatile Organic Compounds (VOCs) emitted by plant species. This opportunity will provide the student with experience of working in a physical chemistry laboratory under the supervision of postdoctoral researcher. The student will gain experience of data collection and analysis using gas-phase mass spectrometry and infrared laser spectroscopy. The internship may be of particular interest to students interested in atmospheric chemistry and applications of physical chemistry in agriculture.

**Title: Understanding the kinetics of PET-RAFT polymerization in biologically relevant media**

**Supervisor: Maria Chiara Arno**

School: Chemistry

Description: Photo-induced electron/energy transfer-reversible addition-fragmentation chain transfer (PET-RAFT) polymerisation has emerged as a powerful tool for polymer synthesis under environmentally friendly conditions, affording predictable polymer molecular weights and architectures in water and cell culture media. Although the kinetics of PET-RAFT have been investigated in DMSO and water using cytocompatible catalysts, little is known with regards to their behaviour in biologically relevant buffers. This project will investigate the influence of solution pH as well as the presence and concentration of PBS species on monomer conversion, using a range of photocatalysts and excitation wavelengths as well as a wide range of vinyl monomers. Conversion will be investigated through NMR spectroscopy, while size-exclusion chromatography will be used to monitor how the polymer molecular weight increases with conversion. This study will generate a deeper understanding of the kinetics of PET-RAFT polymerizations in PBS, opening new insights in the design of photocatalysts for cytocompatible PET-RAFT.

**Title: 3D-printed smart fibres and textiles for self-powered wearable devices for energy harvesting**

**Supervisor: Omid Doustdar**

School: Mechanical Engineering

Description: Triboelectric generators have great potential as self-powered wearable devices for energy harvesting and recording human activity. For this purpose, 3D printers play a key role due to their flexibility in the manufacturing process. 3D printing method to prepare stretchable elastic fibres with an optimised structure containing conductive and insulative sheath by adding graphene and PTFE (or any recycled filaments) particles could manipulate the rheological behaviour of PDMS prepolymer and make it suitable for 3D printing of core-sheath coaxial stretchable fibres. Overall, this work focuses on the conductive and functional materials for 3D printing and encourages using 3D-printed triboelectric devices for self-powered sensing applications in sports and health applications.

**Title: 2023 Summer Placement in Staring Radar**

**Supervisor: Mohammed Jahangir**

School: Electronic, Electrical and Systems Engineering

Description: 4-week placement, starting Jun/Jul/Aug 2022, for students interested in radar machine learning

• World class radar facility at Birmingham campus

• Research transforming radar performance for difficult to

spot targets

• Show casing technology for counter-drone surveillance

and bird monitoring

• Work will involve variety of tasks, including:

• Participation in live radar trials with drones and birds

• Assisting with field observations and data gathering

• Processing and analysing target signatures

• Refining and validating simulation models

• Evaluating machine learning techniques for discriminating

drone from non-drone targets

• Basic MATLAB experience recommended

• Watch video to learn more about our work

<https://www.youtube.com/watch?v=aG4E3fSBAKY>

**Title: Numerical modelling of particulate systems – toward sustainable industrial processing**

**Supervisor: Richard Williams**

School: Chemical Engineering

Description: Particulate media are involved at some point in the production of more than 50% of all commercial products, from cocoa powder and coffee beans in the food industry, to pharmaceutical powders and tablets. However, compared to “conventional” solids, liquids and gases, these materials remain rather poorly understood, making their behaviours hard to model and predict, and thus their processing complex and inefficient.

The discrete element method (DEM) is a numerical simulation technique which allows the dynamics of diverse industry-relevant systems to be numerically modelled, and thus the efficiency of such systems to be greatly increased in a time- and cost effective manner. DEM is thus increasingly being adapted in industry, in particular those industries with a focus on improving sustainability, where DEM’s energy-saving capabilities can prove highly valuable.

This project will provide the opportunity for the successful candidate to learn DEM modelling alongside experts in the field, and apply the method to real industrial systems. DEM is used in a number of active research projects in the School of Chemical Engineering’s Centre for Doctoral Training in Formulation Engineering, including in collaborative projects with industrial partners such as AstraZeneca, Johnson Matthey, Mondelez, and the Ministry of Defence, enabling the student to perform work of direct relevance to these partners.

The student will also get the opportunity to attend a training course on Responsible Research and Innovation, as well as the CDT Formulation Engineering’s Annual Conference, where they will have the chance to meet current PhD and EngD students, as well as a variety of Industry representatives, providing valuable networking opportunities.

**Title: Positron Imaging and Numerical Modelling of Biofuel Production Systems**

**Supervisor: Kit Windows-Yule**

School: Chemical Engineering

Description: The climate crisis is arguably the greatest contemporary challenge facing society. A major focus in the current fight against climate change is the shift away from the use of fossil fuels, and a major part of this fight is the development of clean and commercially viable alternative fuels. This project offers the successful applicant a chance to become directly involved in this mission.

The student will work alongside both the project supervisor, Dr Kit Windows-Yule, and several PhD students working on or adjunct to this project, as well as with industrial partners IFPEN, who are actively working toward the commercialisation and real-world implementation of the systems being studied in the project.

The student will get the chance to learn new, transferrable skills such as CFD modelling, as well as the opportunity to use truly unique techniques and facilities, such as the University’s Positron Emission Particle Tracking (PEPT) centre – the only such facility in Europe.

The project itself focuses the modelling and optimisation of a stirred-tank bioreactor representative of those under development at IFPEN. The student will have the opportunity to image the system using PEPT, and use the data acquired to create and validate CFD simulations of the system. For both of these activities, the students will be trained by world experts in the application of these techniques, based both in Birmingham and Toulouse.

The student will also get the opportunity to attend a training course on Responsible Research and Innovation, as well as the CDT Formulation Engineering’s Annual Conference, where they will have the chance to meet current PhD and EngD students, as well as a variety of Industry representatives, providing valuable networking opportunities. The CDT has kindly offered to cover the costs associated with these activities.

Please note that this project can accommodate more than one student if necessary.

**Title: Design, modelling and optimisation of a novel system for the mixing of industrial powders and fluids**

**Supervisor: Kit Windows-Yule**

School: Chemical Engineering

Description: The dispersion and mixing of powders in fluids is central to diverse processes in the chemical, food, pharmaceutical, and diverse other sectors. Equipment currently used in industry for such mixing processes is widely accepted to be sub-optimal for such tasks, yet they continue to be used due to the lack of a viable alternative. The goal of this project is to work toward developing such an alternative.

Recent work by the supervisor, Dr Kit Windows-Yule, and collaborators at world-leading chemical company Johnson Matthey have taken the first steps to developing a novel system which they term a “cusp feeder”. The system uses two rotating rollers designed to set up flow patterns within a fluid expected to be conducive to the dispersion and mixing of powders fed through said rollers. Such systems have been described mathematically in the literature, but never used in practice for mixing processes. The successful student will get to play a role in the development, modelling, and optimisation of a world-first prototype for this system.

As a part of the project the student will be taught a number of valuable, industry-relevant and highly-transferrable skills, including the use of discrete element method (DEM) and computational fluid dynamics (CFD) modelling to simulate the system of interest, as well as various machine learning and AI techniques, notably evolutionary algorithms, to optimise the design of the system using unique software developed in the supervisors group.

The student will get to work closely with Dr Darren Gobby, the Manufacturing Research Engineering Lead at JM’s Stockton site, who is leading the development of the cusp feeder system.

The student will also get the opportunity to attend a training course on Responsible Research and Innovation, as well as the CDT Formulation Engineering’s Annual Conference, where they will have the chance to meet current PhD and EngD students, as well as a variety of Industry representatives, providing valuable networking opportunities. The CDT has kindly offered to cover the costs associated with these activities.

Please note that this project can accommodate more than one student if necessary.

**Title: Developing a fluid mixing system for testing zero-carbon combustion/aftertreatment systems**

**Supervisor: Soheil Zeraati Rezaei**

School: Mechanical Engineering

Description: In line with the net-zero agenda, utilisation of zero-carbon energy carriers (e.g. hydrogen and ammonia) to help decarbonise various sectors (e.g. transportation and power generation) is on a promising path. The aim of this project is to design and manufacture a fluid mixing system to be used for testing zero-carbon combustion/propulsion systems and/or their exhaust aftertreatment systems. An ideal candidate for this position would have interest in zero-carbon energy carriers, their use in combustion/propulsion systems, and abatement of environmental pollutants. The candidate should have knowledge of thermodynamics and fluid dynamics. In addition, the candidate should have knowledge of (or interest in learning) Computer Aided Design (CAD) to help design the mixing system, Computational Fluid dynamics (CFD) to help investigate its performance, and workshop activities. The student will benefit from improving their knowledge and skills in the relevant scientific/technical areas, accessing state-of-the-art experimental laboratories, and computing facilities at the University of Birmingham during this project.