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UNIVERSITY OF BIRMINGHAM
School of Mathematics

Summer Research Projects Scheme: 2023
List of Possible Projects & Supervisors

The following members of staff from the School have indicated they are able to supervise projects over a six-week period, which might be different for each member of staff, during Summer 2023. Before submitting an application for a School of Mathematics Summer Research Bursary you must make contact with the member of staff you are seeking to work with.

1. **Jamie Alcock (j.t.alcock@bham.ac.uk)**
   The precise topic and focus of the project are negotiable, but the general theme will be related to financial mathematics.

2. **Matthew Butler (m.butler.3@bham.ac.uk)**
   The precise topic and focus of the project are negotiable, but the general theme will be related to modelling hydrogel mechanics.

3. **Yin Hoon Chew (y.h.chew@bham.ac.uk)**
   Area: Systems biology
   Project 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.

4. **Johannes Carmesin (j.carmesin@bham.ac.uk)**
   Area: Problems in Connectivity theory
   Project 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.

5. **Cyril Closset (c.closset@bham.ac.uk)**
   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.

6. **Hong Duong (H.Duong@bham.ac.uk)**
   Project Title: Evolution and promotion of cooperation.
   Abstract: 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.

7. **Aravind Kumar Kamaraj (a.k.kamaraj@bham.ac.uk)**
   Project Title: Oscillator with an asymmetric bistable potential.
   Abstract: Bistability is found in a lot of systems, from the simple flickering of a switch to the states of quiscence and firing in neurons. Often, the effort required to go from state A to B may not be the same as that required to go from B to A. Mathematically, such systems can be characterized in terms of an asymmetric bistable potential function. This project involves deducing the critical excitation required for making a transition from A to B or vice versa in such systems using tools from dynamical systems theory. I am also open to supervising projects that fall within the ambit of dynamical systems.

8. **Pradeep Keshavanarayana (p.keshavanarayana@bham.ac.uk)**
   The exact topic will be decided upon discussion, but it will be related to evaluation of forces within blood vessels due to flow, in healthy and diseased states.

9. **Omar Kidwai (o.kidwai@bham.ac.uk)**
   The precise topic and focus of the project is negotiable, but the general theme will be "topological recursion in geometry and mathematical physics”

10. **Hui Li (H.Li.4@bham.ac.uk)**
    Title: How does weather influence Acute Care Hospitals, Emergency Department admissions and ICU admissions in England?

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.

11. Allan Lo (S.A.Lo@bham.ac.uk)

Research area: Extremal graph theory

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.

12. Galane Luo (J.Luo.5@bham.ac.uk)

Proposed Project: How do people – or more generally, any type of self-governing agents – achieve consensus among the whole population, if every individual is only able to communicate with their local social network? This kind of behaviour can be observed in various contexts, from political elections to bird flocks, and mathematical modelling has something uniquely insightful to say about it. In this project, you will explore the emerging field of "opinion dynamics", where the evolution of opinions in a population is captured through a high-dimensional dynamical system. You will dissect and reproduce a recent model of consensus formation, and, time permitting, extend the model. You will ideally already have some familiarity with differential equations and linear algebra.

13. Chris Parker (C.W.Parker@bham.ac.uk)

The precise topic and focus of the project is negotiable but the general theme will be related to Algebra.

14. Andrei Savinov (avs296@student.bham.ac.uk)

Project: Approximation of orthogonal matrices in 5G wireless networks.
Project description: Suppose that our signal transmission model for single carrier system is y = HWx + n, where

y – vector of received signal;
x – vector of transmitted signal;
H – is channel matrix;
W – is signal preconditioner (precoder), rank(W) <= rank(H);
n – noise

The task is given H, x, y on the receiver side to construct W and send it back to the transmitter for further transmission. All simulations can be performed via matlab or matlab/python.

The quality of proposed method can be assessed via bit error rate (correctly recovered number of bits) and block error rate (number of successfully decoded codewords).
More challenging problems:

1) Suppose that we have multi carrier system (H_1, H_2, …. H_n) but we are able to report only one W. What is the optimal W in this case?
2) Our H varies in time. How to use information about former H for performance enhancement?

15. Xiaocheng Shang (X.Shang.1@bham.ac.uk)

The precise topic and focus of the project are negotiable but the general theme will be related to the optimal design of numerical algorithms for (stochastic) dynamical systems, potentially with the help of machine learning/neural networks.

16. Jia Shao (j.shao.1@bham.ac.uk)

Project: Survey on the effect of COVID-19 on Chinese customers' choice of shopping channels for daily necessaries.
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.

17. Rowland Seymour (r.g.seymour@bham.ac.uk)

Project: Mapping Violence Against Women and Girls.
Project 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.

18. Fabian Spill (f.spill@bham.ac.uk)

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.

19. **Qaasim Shafi (m.q.shafi@bham.ac.uk)**
    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.

20. **Sergey Shpectorov (S.Shpectorov@bham.ac.uk)**
    The precise topic and focus of the project are negotiable.
    Possible project areas: algebra, number theory, combinatorics, and geometry.

21. **Yuzhao Wang (y.wang.14@bham.ac.uk)**
    The precise topic and focus of the project are negotiable but the general theme will be related to (stochastic) partial differential equations.