10th- 11th July

2025

British Early Career Mathematicians' Colloquium

{BECMC}^{25}

ABSTRACT BOOKLET

TABLE OF CONTENTS

PLENARY TALKS

CONTRIBUTED TALKS

SESSION 2 - Thursday Afternoon

Lecture Theatre A 12

Albert Nyarko-Agyei, University of Exeter

James Arthur, University of Exeter

Lecture Theatre C 13

Arnaud Dumont, University of Birmingham

Samuel Renforth, University of Birmingham

Room 310 14

Hrit Roy, University of Edinburgh

Joel Summerfield, University of Birmingham

SESSION 3 - Friday Morning

Lecture Theatre A 15

Dmitri Mints, Imperial College London

Néstor Jara, University of Chile

Richard Alasdair Howat, University of Birmingham

Lecture Theatre C 16

Niamh Brereton, University of Birmingham

Jacob Asmat, University of Birmingham

Pouya Partow, University of Birmingham

Room 310 18

Edward Chida, University of Greenwich

Rahma Adbulahi, University of Birmingham

Belinda Lombard, University of Birmingham

SESSION 4 - Friday Afternoon

POSTERS

pp. 25-33

1 - Robin Allen

2 - James Arthur

3 - Feargus Ball

4 - Bim Gustavsson

5 - Niamh Brereton

6 - Pete Gautam

7 - Richard Alasdair Howat

8 - Ali Aziz

9 - Fraser Sanders

10 - Georgina Ryan

11 - Joseph McCusker

12 - Charlotte Satchwell

13 - Qendresa Selimi

14 - Kylie Savoye

15 - Joel Summerfield

16 - Charlotte Norridge

17 - Ibby Sajid

18 - Nayana Unnipillai

19 - Aran Dabbaghichi

20 - Piscopia

MODELLING - LTA

How does a plant grow and respond to its environment? A story across the scales!

Euan Smiters, University of Cambridge

We face many problems in our world, including the effects of climate change. As a result, we need more resilient crops. However, we lack a fundamental understanding of how plants grow and respond to their environment in order to accomplish this goal.
In this talk, I will begin at the cell scale, where we examine how certain plant cell types form intriguing jigsaw-like shapes using a viscoelastic anisotropic vertex element model combined with a system of reaction-diffusion equations interacting with a stochastic cytoskeleton model. I will follow this with an examination at the tissue scale, focusing on the impact of plant cell division and different cell setups on tissue mechanics

ALGEBRA - LTC

Introduction to twisted conjugacy in groups

Gemma Crowe, University of Manchester

Dehn's famous decision problems for finitely presented groups have been studied for over a century by combinatorial and geometric group theorists. In recent years, a variant of one of these classical problems, namely the twisted conjugacy problem, has been studied. The motivation for this work comes from Bogopolski, Martino and Ventura who, in 2009, proved an equivalence between conjugacy in group extensions and twisted conjugacy. In this talk I will give a brief survey of this lesser-known decision problem, and discuss some of the latest results in this area.

FLUID MECHANICS - LTA

Models of cerebrospinal fluid flow and solute transport around the brain

Mariia Dvoriashyna, University of Bath

The human body is composed of approximately 60% fluids, many of which undergo oscillatory motion. From the rhythmic pumping of blood by the heart through the vessels to the cyclical flows of respiration in our lungs and the peristaltic movements in our gut, these oscillations play a crucial role in maintaining bodily functions.
In this talk, I will discuss the oscillatory flow of cerebrospinal fluid (CSF) around the brain during the cardiac cycle, which is relevant for clearing metabolic waste and delivering medicine to the brain. I will present theoretical models of the CSF flow based on lubrication theory (an asymptotic technique valid in long and thin domains). I will also describe how solutes are transported in this oscillatory flow, focusing on different transport regimes.

ANALYSIS - LTC

Quasicrystals, aperiodic order and substitutions

Andrew Mitchell, Open University

The discovery of quasicrystals—naturally occurring crystalline structures that exhibit long-range order but lack translational symmetry—came as a surprise to materials scientists and was awarded the 2011 Nobel Prize in Chemistry. This discovery has stimulated a wealth of research in the field of aperiodic order, the study of mathematical quasicrystals.
The prototypical examples of mathematical quasicrystals are sequences generated by substitutions, symbolic rules that replace each symbol from a finite alphabet by a concatenation of symbols from the same alphabet. For example, the Fibonacci substitution is the rule defined over the alphabet {a,b} by a -> ab, b -> a. A right-infinite sequence can be associated with a given substitution in a natural way and, under a mild assumption on the substitution, this sequence is non-periodic under the shift action.
In this talk, I will provide an introduction to aperiodic order and substitutions, and discuss how techniques from analysis and ergodic theory have contributed to the development of a rich theory. I intend for this talk to be accessible to a general mathematics audience. Therefore, no prior knowledge of quasicrystals or ergodic theory will be assumed.

COMBINATORICS

Double-jump phase transition for the reverse Littlewood-Offord problem

Victor Souza, University of Cambridge

Erdős conjectured in 1945 that for any unit vectors $v_1, \ldots, v_n$ in R^2 and signs $e_1, \ldots, e_n$ taken independently and uniformly in $\{-1,1\}$, the random Rademacher sum $\sigma := e_1 v_1 + \ldots + e_n v_n$ satisfies $|\sigma|_2 \le 1$ with probability $\Omega(1/n)$.
While this conjecture is false for even n, Beck has proved that $|\sigma|_2 \le \sqrt{2}$ always holds with probability $\Omega(1/n)$.
Recently, He, Juškevičius, Narayanan, and Spiro conjectured that the Erdős' conjecture holds when n is odd.
We disprove this conjecture by exhibiting vectors $v_1, \ldots, v_n$ for which $|\sigma|_2 \le 1$ occurs with probability $O(1/n^{3/2})$.
On the other hand, an approximated version of their conjecture holds: we show that we always have $|\sigma|_2 \le 1 + \delta$ with probability $\Omega_\delta(1/n)$, for all $\delta > 0$.
This shows that when n is odd, the minimum probability that $|\sigma|_2 \le r$ exhibits a double-jump phase transition at $r = 1$, as we can also show that $|\sigma|_2 \le 1$ occurs with probability at least 0.525^n.
Joint work with Lawrence Hollom and Julien Portier.

STATISTICS AND DATA SCIENCE

Scale of Harm: Estimating the Prevalence of Trafficking to Facilitate Online Child Sexual Exploitation in the Philippines

Rowland Seymour, University of Birmingham

The Scale of Harm was an international project to estimate the number of children in the Philippines being trafficked to generate online child sexual exploitation. In this talk, I will explain how we developed a method to generate the first national prevalence estimate for this crime. We carried out a survey of over 3,000 Filipino households collecting aggregated relationship data and developed hierarchical Bayesian model to efficiently generate prevalence estimates for local municipalities in the Philippines. The results show that Nearly half a million Filipino children were trafficked to produce new child sexual exploitation material in 2022.

MATHEMATICS EDUCATION - LTA, 1PM

“Somebody needs to tell them...don’t be afraid, nobody will judge you” - My journey into a career in mathematics education

Holly Gilbert, Coventry University

It is not unknown that mathematics is a widely disliked subject. I have repeatedly heard from people that ‘I don’t like maths, I’m not good at it’, and my response is always ‘you are, you just haven’t found a way that works for you’. This is because I truly believe that their opinion has stemmed from their experience. So, what is, and what should be, being done to help combat this disengagement? This talk will take you through my personal and professional journey into mathematics education research and practice, and my contributions to answering that question. Starting with my undergraduate dissertations, designing a new teaching method for statistics and using agent based modelling to test its implementation; progressing on to a multi-phase PhD research project with a central aim of exploring ways to use pandemic learnings to improve university level intervention in mathematics and statistics. To most recently my post-doctorate research, exploring student transitions from A-level to undergraduate level mathematics with a focus on underrepresented groups. I present key methodologies, findings, and personal take-aways from each stage in the aim to inform and inspire those wanting to begin their own journey into a career in mathematics education. Because support can transform fear into confidence.

HISTORY OF MATHEMATICS - LTA, 4PM

On meeting the challenge (or not). English responses to Fermat’s questions on number theory in the later seventeenth-century

Philip Beeley, University of Oxford

While still flushed with the success of their partly joint work on quadratures, published in John Wallis’s Arithmetica infinitorum in 1656, the Savilian professor of geometry at Oxford and his former student, William Brouncker, were soon confronted with a series of challenges in number theory sent from across the Channel by the brilliant French mathematician Pierre Fermat. At first, the two Englishmen Wallis and Brouncker completely misjudged the significance of the problems they had been set, delivering trivial or incorrect solutions, but Wallis eventually went on to devote a considerable amount of time and productive energy in tackling them – and above all the one he called Fermat’s first ‘negative theorem’, now better known as his ‘last theorem’.
The talk will chart the course of these early English responses to questions in number theory, situating them within the broader context of contemporary work in the mathematical sciences, while at the same time showing how their successful solution soon came to be seen in London and Oxford as a task vital to securing national prestige.

SESSION 1 — LECTURE THEATRE A

Character degrees in blocks of symmetric groups

Bim Gustavsson, University of Birmingham

Let p,q be primes, $\mathbbm{k}$ a field of characteristic q and $n\geq p$ a natural number. Let B be a block of $\mathbbm{k}S_n$. We ask whether there exists some irreducible character χ in B have degree divisible by p. For $p=q$, the question follows as a consequence from the Brauer Height Zero Conjecture (proof recently completed by Malle, Navarro, Schaeffer Fry and Tiep in 2024). We ask the same question for when $p\neq q$. Some of the cases for this question have been answered by the work of Giannelli-Malle-Vallejo (2019), Giannelli-Meini (2021) and Giannelli-Mecacci (2024). We will present some new results when $q=2$ and p is an odd prime.

Reductive pairs arising from representations

Shuo Feng, University of Essex

Let G be a reductive algebraic group and V a G-module. We consider the question of when (GL(V), ρ(G)) is a reductive pair of algebraic groups, where ρ is the representation afforded by V. First, we will give some general observations of general G and V. Then I will followed Oliver Goodbourn's paper give an example of SL2. Finally, I will give a brief introduction of my research on other groups.

Commuting Involution Graphs for Finite Simple Groups

Jimmy Bryden, University of Manchester

The structure of a finite simple group is in some sense controlled by its involutions and their centralisers. This inspires the definition of the commuting involution graph. Given a finite group G, and a conjugacy class of involutions $X \subseteq G$ the commuting involution graph of G on X is a graph with vertex set X making distinct elements adjacent if and only if they commute in G. Over the past two decades, a number of results have appeared mainly classifying the diameters and disk sizes of commuting involution graphs for families of finite simple groups. This talk will introduce this subject and the various combinatorial and geometric methods which can be used to study the properties of these graphs.

Eliciting Some generalisations of Dirichlet distributions as priors for Multinomial models

Nayana Unnipillai, Open University

The Dirichlet distribution, arising in the context of probability theory and statistical modelling, is a workhorse, especially for multinomial sampling models. Its strength lies in the way it can simulate proportions across several categories, which is why it is so useful in various disciplines, from biology to information and communication theory. However, as our understanding of complex systems evolves, there arises a need to extend and generalise existing models to better capture the subtleties of real-world phenomena. This has led us to explore beyond the Dirichlet distribution, searching new formulations that can better accommodate diverse scenarios and data structures. To address these limitations, researchers have proposed various generalisations of the Dirichlet distribution, including the Scaled Dirichlet distribution, the Flexible Dirichlet (FD) distribution, and the Extended Flexible Dirichlet (EFD) distribution. These generalisations provide more flexibility in capturing the expert's beliefs and dependencies among the components in the elicitation context. While the elicitation of the standard Dirichlet distribution has been well documented, the elicitation of these more flexible generalisations is a relatively new area of research. We have developed a Shiny R application to facilitate this process, enabling experts to input and visualize their beliefs using these generalisations more accurately. This tool represents a significant step forward in the practical application of these theoretical advancements, offering improved methods for eliciting expert knowledge.

Assessing the Impact of Anti-Seizure Treatments in Network Models of the Brain

Peter Kissack, University of Birmingham

Epilepsy is a common neurological condition characterised by recurrent seizures, the genesis of which has been associated with the interplay between local dynamics and network structures within the brain. By measuring correlations between signals from electroencephalography data, we can derive macro-scale networks representing the brain's functional connectivity. Using techniques from graph theory and dynamical systems, we can quantify aspects of the topology of these networks and model the propagation of seizure activity associated to given network structures. In two recent studies, we have investigated the link between features of brain network topology (i.e. trophic coherence) and long-term changes and robustness, using synthetic dynamic network models and clinical data from people with idiopathic generalised epilepsies. In both projects, we found preliminary evidence of how dynamic network models enables us to quantify the impact of ASMs on seizure-risk.

Mathematical modelling of a mass-conserving electrolytic cell

Georgina Ryan, University of Oxford

The electrochemical processes in electrolytic cells are the basis for modern energy technology such as batteries. Electrolytic cells consist of an electrolyte (an ionic compound in solution), two electrodes, and a battery. The Poisson–Nernst–Planck equations are the simplest mathematical model of steady state ionic transport in an electrolytic cell. These equations are traditionally solved with ionic concentration boundary conditions. We instead find the matched asymptotic solutions for the ionic concentrations and electric potential with mass conservation and known flux boundary conditions. These new boundary conditions are often used in numerical simulations and reflect the electroneutrality of the electrolyte. Unlike ionic concentration boundary conditions, the mass conservation condition necessitates solving for a higher order solution in the outer region. Our results provide insight into the behaviour of an electrochemical system with a known voltage and current, which are both experimentally measurable quantities.

Modeling and simulation of viscoelastic liquid crystal elastomers

Rabin Poudel, Cardiff University

Combining the self-organisation of liquid crystals (LCs) with the flexibility of elastomers results in a special class of stimuli-responsive solid materials called liquid crystal elastomers (LCEs). These materials deform in response to changes in the LC orientation driven by temperature variation, electric, magnetic, or optical fields, and their LC alignment changes when mechanical loads are applied. This coupling makes LCEs a top choice for bioinspired devices and engineering designs.

Experimental evidence further suggests that, under certain conditions, the stress-strain curves of nematic LCEs display strain-rate dependent hysteresis during loading and unloading. A hyperelastic constitutive material has a unique stress-strain relationship, independent of strain rate, whereas the stress-strain response for viscoelastic materials changes with strain rate. Nevertheless, for LCEs, the shape of the nonlinear stress-strain curve is typically invariant with respect to strain rate. In this case, at fixed rate, the macroscopic deformation may be captured by nonlinear hyperelastic models. In addition, appropriate viscoelastic modelling of LCEs must account for dissipation induced by viscous LC rotation coupled with polymer deformation, but the modelling of this coupling remains an open question.

In this study, we devise a mathematical model for viscoelastic LCEs where different contributions are clearly defined and simulated computationally. To develop efficient numerical models for nonlinear viscoelastic deformations of LCEs, the finite element method (FEM) is employed. This is well-suited for capturing complex behaviours and interactions, providing detailed insights into complex mechanical responses under various boundary conditions and internal constraints.

A Novel Mathematical Model of the SLC25A10 Transporter Indicates Operation via a Ping-Pong Mechanism.

Ramin Nashebi, University of Birmingham

The mitochondrial dicarboxylate carrier SLC25A10 exchanges phosphate with dicarboxy-lates such as succinate and malate, playing a key role in metabolic regulation. electroneutrality and compettitive interaction of dicarboxylate at a single site make this antiporter special. Recent Experimental works suggest that this antiporter operateis via ping pong mechanism rather than sequantiaon. Many mathemtical model have beern developed to investigate the kinetic behavior of this transport. However, these model assumed that this transporter operates via sequential kinetic mechanism. Here, we developed a novel kinetic model that captures competitive binding of dicarboxylates within a ping-pong framework, coupled to phosphate exchange. Our model, validated against experimental data, provides a thermodynamically consistent framework for simulating physiological and pathological conditions. It elucidates how metabolic perturbations and enzymatic interactions influence SLC25A10 transporter flux and regulation.

Dynamical models for evaluating long-term epilepsy surgery outcomes

Gwen Harrington, University of Birmingham

Epilepsy is one of the most common neurological disorders affecting more than 70 million people worldwide. Around 30-40% of epilepsy patients find that their symptoms are unaffected by at least two trials of anti-epileptic drugs (AEDs). For these patients, surgical intervention provides a potential avenue for long-term seizure freedom. While many of these surgeries will initially appear successful, the likelihood of a patient remaining seizure free post surgery decreases over time. One explanation for this phenomenon is the role of brain network structure in seizure generation. We generate functional networks from pre-surgical patient EEGs and use a dynamic network model to predict the likelihood of successful surgical outcomes for potential changes in post-surgical brain network topology.

Generalizing vulnerability in estimating Modern Slavery prevalence

Albert Nyarko-Agyei, University of Exeter

Insights from traditional surveying are straightforward when people are easily questioned and reveal their membership in a study's target groups. This approach is not well suited to recording the number of people in stigmatised or marginalised groups. As a solution, we are interested in using a network approach (Sibling Method) to estimate the prevalence of children in situations that are deemed under the term "Modern Slavery". Children with this status typically have a low occurrence in the population so small surveys are prone to bias and if status in these groups can be hidden. Additionally, the more commonly used term of human trafficking is difficult for members of the general public to apply to their networks. Therefore, we suggest using indicators of the status to elicit responses that can be used to estimate prevalence. This talk will outline the proposed approach using ongoing work to estimate the prevalence of Forced Child Begging in Niger and highlight the statistical considerations involved. Previous estimation at the global level has been criticized for its lack of specificity so country specific individual factors are proposed to improve estimation.

A Variational Derivation of Shallow Water Equations with Full Rotation Vector

James Arthur, University of Exeter

In this poster we derive some new shallow water equations from a Lagrangian Mechanics point of view. Following on from the work of Stewart and Dellar we present some new Shallow Water and Green-Nagdi equations for a shallow water system in a rotational box, from here we derive Poisson Brackets that allow entrance into numerical solutions of these systems.

Decomposition Classes

Joel Summerfield, University of Birmingham

Decomposition Classes provide a natural way of partitioning a Lie algebra into finitely many pieces, collecting together adjoint orbits with similar Jordan decompositions. The current literature surrounding these tends to only cover certain cases – such as in characteristic zero, or under the Standard Hypotheses. Building on the prior work of Spaltenstein, Premet-Stewart, Topley-Saunders and Ambrosio, we have adapted many of the useful properties of Decomposition Classes to work in greater generality.
This poster will introduce Decomposition Classes for the Lie algebras of connected reductive algebraic groups – defined over arbitrary algebraically closed fields. We will then present some structure results about Decomposition Classes and their closures, which are called Decomposition Varieties. Finally, examples of the closure order structure will be given via Hasse diagrams for the Decomposition Classes of certain Type A algebraic groups.

Abelian Ideals of Borel Subalgebras of Lie Superalgebras

Samuel Renforth, University of Birmingham

Dale Peterson found a surprising result that the number of abelian ideals of a Borel subalgebra of a semisimple Lie algebra g, is given by 2^(rk(g)), where rk(g) denotes the rank of g. We attempt to generalize this result to Lie superalgebras, which are essentially Lie algebras with a notion of parity. Through some useful diagrams, we explicitly calculate the number of these abelian ideals in the C(n) family of Lie superalgebras and show that Peterson's result does not hold. In particular, we find that the number of abelian ideals depends on the choice of Borel subalgebra.

Tangential convergence and related results for elliptic boundary value problems

Arnaud Dumont, University of Birmingham

A classical result in harmonic analysis states that the Poisson extension of a function $f\in L^{p}(\mathbb{R}^{n})$ is a harmonic function in the upper half-space which converges to f almost everywhere as it approaches the boundary within so-called 'non-tangential' conical regions. In their 1982 paper, Nagel, Stein and Shapiro showed that this a.e. convergence at the boundary could be improved to larger 'tangential' approach regions provided that the boundary data f exhibited higher regularity than mere p-integrability, in a way quantified using Bessel potential spaces.
In this talk we will explain how these results can be generalised to the Dirichlet problem for general divergence form elliptic equations with real coefficients (independent of the tranversal direction to the boundary) in the upper half-space.
We will also describe how the higher regularity of the boundary data provides better convergence properties at the boundary, quantified by estimates on the Hausdorff dimension of the subset of the boundary where convergence fails.
If time permits, we will present similar results for real elliptic equations in bounded Lipschitz domains.

On the convergence of two-dimensional Fourier series

Hrit Roy, Universtiy of Edinburgh

A central question in harmonic analysis is the convergence of Fourier series. While the one-dimensional case is well-understood, the situation in two dimensions is more subtle, due to the variety of natural ways in which the frequencies can be summed. For example, summing over square regions yields convergence, whereas summing over circular regions can lead to divergence. In this talk, we explore the geometric feature that governs this convergence behaviour, and aim to characterise the shapes that ensure the Fourier series converges.

High order homoclinic tangencies and universal dynamics for multidimensional diffeomorphisms

Dmitrii Mints, Imperial College London

Our research is aimed at studying the dynamics of smooth multidimensional diffeomorphisms from Newhouse domain, that is, open regions in the space of maps where systems with homoclinic tangencies are dense. We prove that in the space of smooth and real-analytic multidimensional maps in any neighborhood of a map such that it has a bi-focus periodic orbit whose invariant manifolds are tangent, there exist open regions (which are subdomain of the Newhouse domain) where maps with high order homoclinic tangencies of corank 2 (invariant manifolds forming the tangency have a plane of common tangent vectors) are dense and maps having universal two-dimensional dynamics are residual. This is a joint work with D. Turaev.

Dichotomies respect to growth rates and their spectra

Néstor Jara, University of Chile

We introduce a comparison framework for growth rates that yields a criterion for determining when a given system has an empty dichotomy spectrum. In addition, we establish a duality between the concepts of dichotomy and bounded growth in a generalized setting.

Cut and project schemes in hyperbolic space

Richard Alasdar Howat, University of Birmingham

We study a hyperbolic cut and projection method in relation to cocompact Fuchsian groups. We present a condition on the fundamental domain of the group so that the projection set S is chaotic Delone. We also investigate the distances between the points in S and show that the set of distances is countably infinite. Finally, we apply our results to a cocompact Fuchsian triangle group Γ and show that a chaotic Delone set can be constructed when the fundamental domain of Γ is hexagonal. In contrast, for a quadrilateral fundamental domain, the signature of Γ must contain at least two odd integers.

Challenges Faced by Specialist Mathematics Students at the Transition to University: Insights from across the UK.

Niamh Brereton, University of Birmingham

Whilst there exists a growing body of evidence reporting the challenges faced by specialist mathematics students at the transition to university, much of this research has focussed on the students' perspectives. Through a recent study, we have explored the extent to which staff working in mathematics departments recognise these challenges and investigated whether mathematical sciences departments in higher education institutions across the UK have mechanisms in place to support students within their learning at the transition to university.

In this talk, we present the results of a thematic analysis performed on qualitative survey data from 30 distinct higher education institutions across the UK, which sought to address the following research questions:

- What challenges, if any, do staff believe first-year students face at the transition to studying mathematics at university?
- What interventions, if any, do universities have in place to support first-year mathematics students during this transition?

Our analysis of results offers an interesting insight into the extent of alignment between staff and student views and suggests where departments are currently working to address transitional issues. Significantly, it indicates where further work or research would now be beneficial.

From Individuals to Institutions: Agent-Based Insights into Cooperation and Collective Dynamics

Jacob Asmat, University of Birmingham

Collective actions are needed to solve urgent global challenges, yet promoting cooperation among self-interested agents remains difficult. Sanctions are a widely observed mechanism for discouraging undesirable behaviour, but sanctioning regimes themselves are vulnerable to freeriding - individuals may benefit from increased cooperation without contributing to enforcement. Using agent-based models of public goods games, this talk explores how different sanctioning strategies can emerge and transition through social learning and exploration. We show that peer punishment acts as a catalyst for the development of more complex sanctioning regimes, and that institutions can emerge even when they reduce profitability in the short term. Our results reveal that institutional sanctioning does not require foresight or central planning, but can arise endogenously through asymmetric metastability and strategic coevolution. These findings offer insight into how robust cooperative structures can self-organise from simple interactions, shedding light on the dynamics behind real-world institutional development.

Big-steps in mathematical operational semantics.

Pouya Partow, University of Birmingham

Small-step and big-step are two well-known flavors of operational semantics. The former describes fine-grained steps of reduction, while the latter describes the ultimate result (if it exists) in one atomic step.
One can define equivalence between small-step and big-step specifications when the net result of small-step reductions of a term coincides with the result of the big-step reduction. However, a rigorous mathematical explanation does not exist to describe more about the connection of these two fundamental and similar concepts.
Abstract HO-GSOS is a categorical framework to reason on small-step higher-order operational semantics. It describes a certain higher-order rule format categorically, allowing further abstract inspections.
We have set this framework as our playground, and so far we have worked through crafting a comprehensive method to derive a big-step specification from small-step. We have introduced some constraints on HO-GSOS, namely "Strongly Separated HO-GSOS", and described a transformation to equivalent specifications in our new rule format, "Big-step SOS". The equivalence of the resulting big-step derivation is proved rigorously, and some primitive and frequently needed features of programming languages have been instantiated within the method.

A Vine Copula–Embedded Spatio-Temporal Framework for Stochastic Multisite Precipitation Modelling Across Local and Regional Scales

Edward Chida, University of Greenwich

Multi-site stochastic models provide a robust framework for analysing environmental data and quantifying uncertainty in hydrological systems. We introduce a novel class of time-dependent vine copula-embedded hidden Markov models (HMMs) for multi-site precipitation modelling, addressing key limitations of existing approaches. By integrating pair copula constructions, known for their hierarchical and flexible dependency modelling, into a covariate-driven HMM framework, the model captures temporal dependence, complex, asymmetric spatial dependencies and site-specific interactions across weather station networks. Unlike exchangeable Archimedean copulas, this approach explicitly represents pairwise relationships between sites, allowing for accurate simulation of precipitation characteristics. The model is evaluated at both small and large spatial scales to assess its ability to reproduce key statistical properties, including mean, variance, dry/wet spell dynamics, and spatio-temporal correlations. At local scales, it effectively captures fine-grained rainfall features and short-range dependence, while at regional scales it replicates broader precipitation patterns and long-range correlations. Parameters are estimated using maximum likelihood, and the model is applied to daily rainfall data from four weather stations. Results show that the vine copula-embedded HMM significantly outperforms conventional HMMs, offering enhanced accuracy in simulating precipitation statistics and improved utility for hydrological risk assessment and uncertainty quantification.

Feature selection and parameter inference with sparsely sampled data via an L1-penalty

Rahma Abdulahi, University of Birmingham

Motivated by the challenge of fitting a nonlinear system involving a high number of possible parameters to infrequently sampled data, we apply a LASSO penalty function in conjunction with global optimization. The LASSO penalty allows for the gradual removal of parameters in a model, allowing for a reduction in the number of irrelevant features and the dimensions of the parameter search space.
In this report, we will cover the application of the method on a nonlinear semi-mechanistic model of stain removal developed by Procter & Gamble to aid in the formulation of detergents. Through multicore computing, we obtain consistent global optima across a range of LASSO penalty hyperparameters. The key features in determining detergent performance are then identified through the L-curve criterion and cross validation. We discuss the potential application of the approach in biochemical systems with large numbers of parameters and infrequently sampled time series data.

Data-driven Mathematical Modelling of the HPA Axis in Humans

Belinda Lombard, University of Birmingham

The hypothalamic-pituitary-adrenal (HPA) axis is the endocrine system controlling dynamic responses to stressors. Mathematical modelling and experiments in rodents have shown that negative feedback loops underpin rhythmic activity within this axis, but a human equivalent model is lacking. This talk outlines a data-driven approach to calibrate a model of hormonal rhythms in the human HPA axis. The model is written in terms of Delay Differential Equations (DDEs) and predicts the conditions that lead to pulsatile secretion of cortisol and ACTH hormones with ultradian (<24 hrs) periodicity. Oscillatory solutions arise via a Hopf bifurcation, physiologically determined by a balance between the hypothalamic circadian drive and feedback loop delay.
The model was calibrated using data consisting of cortisol and ACTH plasma hormone profiles measured every 20 minutes over 24 hrs in 10 healthy individuals. Wavelet analysis revealed unique patterns in hormonal rhythms across individuals, including variability quantification. Model fitting yielded specific parameter values for each participant and estimated cohort distributions. Bifurcation analysis determined the conditions needed to sustain ultradian rhythmicity, and the sensitivity of the oscillatory solution to parameter variability. Coupling a model of sleep regulation will help explore the interactions between stressors and sleep disruptions, offering insights into how circadian rhythms affect neuroendocrine regulation in humans.

Modelling and Control of Human Brain Disorders

Aran Dabbaghchi, University of Exeter

Neural disorders has become a hot topic for almost all areas of science and engineering. According to the oscillatory/synhronization nature of neurons, it's sensible to model neural activity of the related areas of brain and CNS in terms of synchronizations model to investigate the reasons of appearance of these disorders as well as simulate and analyse any control and suppression techniques. In this research, we have considered the Kuramoto model as a representative model of the neural oscillations, to develop theories for learning-training procedures based on adaptive control strategies. In simple words, we're considering a gigantic network of 3-Kuramoto systems, a healthy one (HNN), a disease one (DNN), and the trainer interface which helps DNN to recover its functionality based on the reference behaviour and features of HNN. In other words, consider we have a Victorian house that has some technical faults in its wiring system. At the beginning, we don't know where is the exact area of dysfunction (although we have some information about probable target areras), but we have a reference of proper activity and a plug-in instrument that connects to some visible areas to identify the damaged area and then fix them based on a reference data. For this aim, we exploit adaptive control strategies as well as nonlinear dynamical systems theory to develp the base model, and then expand the structure of the model to make it closer to real-time treatment methods such deep-brain stimulation (DBS).

Pricing Asian option under mean reversion and jumps, based on Fast Fourier Transform, Artificial Neural Networks and Deep Learning methods

Kimaro Kairuntu, University of Essex

We propose an efficient pricing approach for arithmetic Asian options by utilising machine learning techniques, specifically neural networks and deep learning, in scenarios where a closed-form formula is unavailable. Our method explicitly incorporates mean reversion and jump components into the underlying price dynamics, which are well-supported by empirical literature as significant anomalies in certain asset classes, including commodities. The approach is specifically designed for discretely monitored European-style arithmetic Asian options. The analytical solutions derived from our Fast Fourier Transform are employed to generate option price values for training and testing our machine learning models. The results are then benchmarked against Monte Carlo simulation-based pricing to assess accuracy and computational efficiency.

Asymptotic and Numerical Analysis of Cortisol Infusion Protocols for Adrenal Insufficiency

Ariba Shakeel, University of Birmingham

People with adrenal insufficiency or impaired stress response disorders in which the body does not produce enough cortisol, need to take cortisol medication. This simplified model of medication transport into the body includes both continuous intravenous infusion (CIV) and intravenous bolus (IV). The study examines drug injection (IV) dynamics over a short time scale (1 minute) during which the drug binds into corticosteroid-binding globulin (CBG). It considers the drug's unbinding from CBG and ultimate excretion from the body in the following long-term phase, which restores systemic equilibrium. According to the cortisol protein binding model, the process is biphasic, with a long-term equilibrium phase followed by a quick short-term phase (dosing period). This problem is examined using the matched asymptotic expansion technique and examined in both saturation and non-saturation phases due to the single perturbation problem. The derived asymptotic approximations in distinct temporal regions align closely with numerical solutions within their respective time scales. The cortisol-CBG interaction thus serves as an accessible model system for mathematical biology, bridging theoretical analysis with practical biomedical insights.

Discrete Morse Theory - the Art of Reduction

Ali Aziz, University of Southampton

We are interested in the homology of discrete spaces such as simplicial complexes. Homology identifies the number of 'holes' of a space. Classical Morse theory seeks to reduce the usual homology calculations - for example - by producing a simpler 'model' of our space. Recently two discrete versions of Morse theory have emerged independently due to R. Forman and M. Chari. They offer the language of the main theorems but not the proofs. This talk explores how we can prove these results by combinatorial means and in the process uncovers some hidden symmetries within Morse theory.

K-moduli of exceptional del Pezzo hypersurfaces

Charlotte Satchwell, University of Essex

The minimal model program predicts that Fano varieties are one of the building blocks of all other varieties. Birkar won a fields medal for showing there are a finite number of Fano's when we control the singularities allowed on them which allows the study of them. However the large number of automorphisms associated to them can cause problems. K-modulo was introduced as a solution to this to give a well behaved moduli space. In this project we use non-reductive Geometric Invariant to describe the K-moduli of the exceptional del Pezzo hypersurfaces. This is the first time non-reductive GIT has been applied to Fano's.

The spherical Mukai conjecture

Heath Pearson, University of Nottingham

Fano varieties are important building blocks in algebraic geometry, and their classification is a central research topic. In 1988, S. Mukai conjectured a succinct inequality which characterises a distinguished class of Fanos using just three fundamental quantities. Mukai's conjecture has attracted significant attention, yet remains open today.
I will sketch how, in joint work with G. Gagliardi and J. Hofscheier, we proved the Mukai conjecture for a rich class of varieties admitting a group action.

Maximal Intersecting Families: A Simple Double Exponential Bound

Allan Flower, University of Birmingham

A family \(\mathcal{F}\) of \(k\)-element subsets of \(\{1, \dots, n\}\) is \textit{intersecting} if every pair of sets in \(\mathcal{F}\) has non-empty intersection. The much-celebrated Erd\H{o}s--Ko--Rado Theorem gives a sharp upper bound on the size of any one such family - but what if, instead, we ask how many unique intersecting families there are with specific properties?
Here we focus on a natural structured subclass: maximal left-compressed intersecting families. These are intersecting families that cannot be extended without losing the intersection property, and which are closed under a compression operation. Importantly, any intersecting family can be transformed into a left-compressed one without reducing its size, making left-compression a powerful tool in the study of intersecting set systems.
In this talk, we present a simple and self-contained proof that the number of \(k\)-uniform maximal left compressed intersecting families grows as a double exponential in \(k\), answering a question posed by Barber.

SESSION 4 ROOM 310

Positive codegree thresholds for Hamilton cycles

Camila Zárate-Guerén, University of Birmingham

The problem of finding degree conditions for the existence of Hamilton ℓ-cycles in k-uniform hypergraphs has been widely studied for decades. One of the possible degree conditions to consider is the minimum codegree: a k-graph H with minimum codegree d satisfies the property that every set of $k-1$ vertices of H is contained in at least d edges. The asymptotic minimum codegree threshold for Hamilton ℓ-cycles in k-graphs have been fully determined for all k and ℓ, with the exact best possible condition remaining open for many cases of k and ℓ.

While a codegree condition is a powerful tool to work with, it is too strong, preventing many natural settings to have a codegree greater than zero (for example, multipartite k-graphs). This issue motivates the consideration of the minimum positive codegree, which only takes into account sets of $k-1$ vertices belonging to a common edge. In other words, minimum positive codegree d implies that any set of $k-1$ vertices is either in at least d edges or in exactly zero edges.

In this talk, I will show best possible asymptotic minimum positive codegree conditions for the existence of a Hamilton ℓ-cycle in a k-graph, for all k and ℓ. The special case $\ell=k-1$ of our result establishes an asymptotic version of a recent conjecture of Illingworth, Lang, Müyesser, Parczyk and Sgueglia on tight Hamilton cycles in hypergraphs.

Every Graph is Essential to Large Treewidth

Pedro Bureo Villafana, University of Leeds

We show that for every graph H, there is a hereditary weakly sparse graph class C_H of unbounded treewidth such that the H-free (i.e., excluding H as an induced subgraph) graphs of C_H have bounded treewidth. This refutes several conjectures and critically thwarts the quest for the unavoidable induced subgraphs in classes of unbounded treewidth, a wished-for induced counterpart of the Grid Minor theorem.

POSTERS

1 – Antilinear representations of the double covers of the symmetric group

Robin Allen, University of Loughborough

The linear representation theory of finite groups over the reals is closely related to the complex theory, with three types of irreducible representations being distinguished by the Frobenius-Schur indicator. The theory of antilinear representations provides a generalisation in which one considers both complex linear and antilinear maps, acting compatibly on the same space. Here one encounters ten distinct types of irreducible representation. We present this classification of irreducible representations for the pairs of groups given by the double covers of the symmetric and alternating groups. This turns out to have a simple combinatorial description, which may be obtained from Schur's original results on the irreducible real representations.

2 – A Variational Derivation of Shallow Water Equations with Full Rotation Vector

James Arthur, University of Exeter

In this poster we derive some new shallow water equations from a Lagrangian Mechanics point of view. Following on from the work of Stewart and Dellar we present some new Shallow Water and Green-Nagdi equations for a shallow water system in a rotational box, from here we derive Poisson Brackets that allow entrance into numerical solutions of these systems.

3 - Understanding How iFFBS Can Be Applied to Household Epidemic Data

Feargus Ball, University of Birmingham

Stochastic epidemic models allow for modelling of disease acquisition between individuals at a fine level of detail, incorporating information such as different groups within the population. The disease process can be modelled as a Coupled Hidden Markov Model (CHMM) in discrete time, where each hidden Markov chain represents the disease carriage status of an individual on a given day. The rate of infection for each individual is based on an external infection rate and the number of infectious individuals within the same household. The data for such models come from diagnostic tests, which can be imperfect and are usually not available for every time point. Bayesian methods can be used to impute the hidden carriage states and estimate model parameters simultaneously. Estimating the hidden states of a CHMM is a computationally intensive task which has been significantly sped up by the recent introduction of individual forward filtering backward sampling (iFFBS) as a more efficient alternative to previous methods (Touloupou et al., 2019). Previously, Touloupou et al. applied this method to data on the transmission of E. coli in cattle, where all cattle remained in the same household throughout. We propose an extension that allows individuals to move between households, potentially transferring disease as they move. Our simulations show that iFFBS combined with MCMC parameter updates can successfully infer parameters for this extended model. Developments to the model include considering the spread of disease in a healthcare setting. Here we receive data from diagnostic tests for both patients and their beds, with the model including the beds as pseudo-individuals with differing transmission rates to the patients. Initial results from this model are also promising.

4 - Counting linear constituents in character restriction from symmetric groups to Sylow p-subgroups

Bim Gustavsson, University of Birmingham

Let p be a prime, $n\geq p$ a natural number and let P denote a Sylow p-subgroup of the symmetric group S_n. Let χ be an irreducible character of S_n. In 2017, E. Giannelli and G. Navarro proved that if p divides $\chi(1)$, then $\chi\big\downarrow_P$ has at least p distinct linear constituents. We determine the set of irreducible characters of S_n for which equality holds. In particular, for $p=2$ we give an explicit formula to compute the mulitplicity of these linear characters in the restriction of so called 'almost hook' characters. This is a joint project with Stacey Law.

5 - Bridging Perspectives on the Transition to University: Enhancing the Student Experience in Mathematics Higher Education

Niamh Brereton, University of Birmingham

Understanding student experiences in mathematics higher education is crucial for informing policy, improving departmental support structures, and driving curricula. This poster presents multiple studies examining key aspects of undergraduate learning, including student engagement with various learning opportunities and the perspectives of staff working within mathematics departments across the UK.

The findings highlight the challenges of transitioning to university mathematics, revealing reasons for students' (non-)engagement with optional learning opportunities, and suggesting a mismatch between student and staff views. Across these studies, examples of themes emerging include accessibility, effective support mechanisms, and the role of feedback for students.

By combining insights across these studies, this work illustrates the broader significance of mathematics education research in enhancing learning environments for both staff and students and guiding both departmental and institutional change. It also demonstrates where further work would now be beneficial.

6 - Modular Representation Theory

Pete Gautam, University of Manchester

In this poster, we explore general background on modular representation theory and connect that to a specific conjecture - Donovan's conjecture. We survey the progress in proving the conjecture, in particular, looking at the work done by Eaton on Suzuki 2-groups and Eaton-Külshammer-Sambale on minimal nonabelian groups, and explore some possible ways to generalise this result.

7 - The matrix potential game and structures of self-Affine sets

Richard Alasdair Howat, University of Birmingham

We present a new variant of the Potential Game and show that certain compact subsets of $ \R^n$ are winning. We prove that sets with sufficiently strong winning conditions are non-empty, provide a lower bound for their Hausdorff dimension and show that they have good intersection properties. Hence given some $N\in\N$, we can verify that certain fractal sets, namely some self-affine sets, have a homothetic copy of every set with at most N elements and show that this new game can be used to verify large intersections of given fractal sets.

8 – Discrete Morse Theory – the Art of Reduction

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9 – Infinite-dimensional contact geometry

Fraser Sanders, University of Manchester

A contact manifold is a $(2n+1)$-dimensional manifold paired with a differential 1-form η which causes each tangent space to split into a $2n$-dimensional symplectic vector space, and a 1-dimensional ``vertical'' vector space. This contrasts with symplectic manifolds, which are even dimensional, and whose tangent spaces are equipped with symplectic structures without being split first. Interestingly, the standard definition of a contact form explicitly references the finite dimension, where the definition of a symplectic form does not.
Symplectic geometry is the natural setting in which to do Hamiltonian mechanics and models situations such as simple harmonic oscillators or orbiting planets. We call such systems ``Hamiltonian''. We can also analyse infinite-dimensional Hamiltonian systems such as the wave equation, and ideal fluids, most famously by Arnold, Khesin, and Marsden and others.
As an odd-dimensional counterpart to symplectic geometry, contact geometry has been applied to mechanical systems in which energy is not conserved, as well as thermodynamical systems. Such systems are called ``contact-Hamiltonian'', and they include simple examples such as the damped harmonic oscillator.
Until now, these two ideas have not been combined. This recent work shows that it makes sense to define contact geometry in infinite dimensions if we loosen the definition slightly and we find that infinite-dimensional contact-Hamiltonian systems are still well-defined. For example, it is very simple to go from the wave equation to the damped wave equation.

10 - Mathematical modelling of a mass-conserving electrolytic cell

Georgina Ryan, University of Oxford

The electrochemical processes in electrolytic cells are the basis for modern energy technology such as batteries. Electrolytic cells consist of an electrolyte (an ionic compound in solution), two electrodes, and a battery. The Poisson–Nernst–Planck equations are the simplest mathematical model of steady state ionic transport in an electrolytic cell. These equations are traditionally solved with ionic concentration boundary conditions. We instead find the matched asymptotic solutions for the ionic concentrations and electric potential with mass conservation and known flux boundary conditions. These new boundary conditions are often used in numerical simulations and reflect the electroneutrality of the electrolyte. Unlike ionic concentration boundary conditions, the mass conservation condition necessitates solving for a higher order solution in the outer region. Our results provide insight into the behaviour of an electrochemical system with a known voltage and current, which are both experimentally measurable quantities.

11 - Well-posedness of a multi-species system of nonlocal advection diffusion equations

Joseph McCusker, University of Birmingham

Non-local PDEs are widely used to model phenomena such as aggregation, segregation and adhesion by capturing how the movement of individuals are influenced by data within a neighbourhood of each individual. Such models allow for insights into self-organising processes in a range of applications within biology, including cancer invasion, cellular dynamics, swarming behaviour in animals, and the emergence of territorial patterns.
For the single species case, the specific family of PDEs of interest can be stated over the domain [0,T] x R^d as $u_t + \nabla \cdot (u \nabla (K \ast u) = \nu \Delta u$,
where K denotes a 'sensing kernel' and ν is a positive constant. The goal for this project is to see how much one can relax the necessary regularity of the initial data $u_0(x) = u(0,x)$ and the kernel K in order to have local and global well-posedness respectively. That is, we show what conditions are sufficient for existence and uniqueness of solutions for some small time $T > 0$ and then go onto demonstrate finiteness of the solutions in L^2 if enough extra regularity has been added to the kernel. Numerical simulations will also be presented.

12 - K-moduli of exceptional del Pezzo hypersurfaces

Charlotte Satchwell, University of Essex

The minimal model program predicts that Fano varieties are one of the building blocks of all other varieties. Birkar won a fields medal for showing there are a finite number of Fano's when we control the singularities allowed on them which allows the study of them. However the large number of automorphisms associated to them can cause problems. K-modulo was introduced as a solution to this to give a well behaved moduli space. In this project we use non-reductive Geometric Invariant to describe the K-moduli of the exceptional del Pezzo hypersurfaces. This is the first time non-reductive GIT has been applied to Fano's.

13 - A joint latent class model with time-varying class membership for longitudinal and survival data

Qendresa Selimi, University of Manchester

The motivation is the study on children suffering from inflammatory diseases at GOSH NHS Foundation Trust. Inflammatory diseases may damage the kidneys, which leads to either chronic kidney disease (CKD) or acute kidney injury (AKI). The aim is to differentiate between these two types, which will facilitate clinical decision-making and treatment for this group of patients, as well as prevent misdiagnosis. Joint latent class models are used to account for the association between the time to event (CKD/AKI/ death) and potential longitudinal biomarkers, such as creatinine measurements, whilst also accounting for heterogeneity in the population through the presence of unobserved classes. The model allows patients to change classes over time, enabling distinguishment between AKI or CKD by certain underlying latent profiles and class membership change patterns. One of the main goals is the early detection of disease progression, achieved by considering the joint distribution of longitudinal and survival outcomes at each time point, allowing for the optimal use of all available information. A novel estimation approach in a frequentist framework is proposed, aiming to improve risk prediction and parameter estimation.

14 – Persistent Homology in Spatial Transcriptomics: Bridging Spatial and Expression Landscapes

Kylie Savoye, University of Birmingham

Spatial transcriptomics is a technique that detects gene expression signals at single-cell resolution. It measures gene expression while preserving the positional information of RNA molecules. This technology generates high dimensional data, with each cell associated with thousands of genes, making biological interpretation challenging. While existing analytical approaches typically examine spatial relationships and transcriptomic profiles separately, potentially losing critical information through inference, here we explore the potential of persistent homology in bridging the gap in current analysis approaches.

15 – Decomposition Classes

Joel Summerfield, University of Birmingham

Decomposition Classes provide a natural way of partitioning a Lie algebra into finitely many pieces, collecting together adjoint orbits with similar Jordan decompositions. The current literature surrounding these tends to only cover certain cases – such as in characteristic zero, or under the Standard Hypotheses. Building on the prior work of Spaltenstein, Premet-Stewart, Topley-Saunders and Ambrosio, we have adapted many of the useful properties of Decomposition Classes to work in greater generality.

This poster will introduce Decomposition Classes for the Lie algebras of connected reductive algebraic groups – defined over arbitrary algebraically closed fields. We will then present some structure results about Decomposition Classes and their closures, which are called Decomposition Varieties. Finally, examples of the closure order structure will be given via Hasse diagrams for the Decomposition Classes of certain Type A algebraic groups.

16 - Hierarchical Modelling for the Bradley Terry Model with Applications in Violence Against Women and Girls

Charlotte Norridge, University of Birmingham

The Bayesian Bradley-Terry model is widely used to estimate the relative strengths of objects in pairwise comparisons. However, standard implementations assume that all judges have equal expertise, which can introduce bias, especially in subjective assessments. This limitation is particularly relevant in cases where direct measurement is challenging, such as estimating the prevalence of violence against women and girls across local authority wards.

In this work, we develop an extension to the Bayesian Bradley-Terry model, where judge perceived ability scores can be estimated, addressing known variation in judges' experience. This is done using a hierarchical Bayesian framework, which allows for simultaneous estimation of global ability scores and judge-perceived ability scores. The model is estimated using Markov Chain Monte Carlo.

Performance of these models was assessed using simulation studies using different initial parameters. Comparisons were made between the hierarchical model and the standard Bayesian Bradley Terry model to assess improvements in estimation accuracy.

Our results demonstrate a framework in which judge specific effects can be incorporated into a Bayesian Bradley Terry model using a hierarchical modelling structure.

We demonstrate the effectiveness of our model on a simulation study of violence against women and girls ahead of real data collection.

Despite the computationally intensive nature of this framework, this model provides a more nuanced approach to the Bradley-Terry model. Future research involves ways to reduce computational demands such as clustering judges based on their reliability.

17 - Motion Groups

Ibby Sajid, University of Leeds

An introduction to the theory of motion groups and its relationship to the theory of knots and braids.

18 - Eliciting Some generalisations of Dirichlet distributions as priors for Multinomial models

Nayana Unnipillai, Open University

The Dirichlet distribution, arising in the context of probability theory and statistical modelling, is a workhorse, especially for multinomial sampling models. Its strength lies in the way it can simulate proportions across several categories, which is why it is so useful in various disciplines, from biology to information and communication theory. However, as our understanding of complex systems evolves, there arises a need to extend and generalise existing models to better capture the subtleties of real-world phenomena. This has led us to explore beyond the Dirichlet distribution, searching new formulations that can better accommodate diverse scenarios and data structures. To address these limitations, researchers have proposed various generalisations of the Dirichlet distribution, including the Scaled Dirichlet distribution, the Flexible Dirichlet (FD) distribution, and the Extended Flexible Dirichlet (EFD) distribution. These generalisations provide more flexibility in capturing the expert's beliefs and dependencies among the components in the elicitation context. While the elicitation of the standard Dirichlet distribution has been well documented, the elicitation of these more flexible generalisations is a relatively new area of research. We have developed a Shiny R application to facilitate this process, enabling experts to input and visualize their beliefs using these generalisations more accurately. This tool represents a significant step forward in the practical application of these theoretical advancements, offering improved methods for eliciting expert knowledge.

19 - Dynamics of Forced Kuramoto Models: Recovering Lost Complexities in Damaged Neural Systems

Aran Dabbaghichi, University of Exeter

Learning-training strategies have become highly attractive and useful in a diverse range of real-world applications.
Assume a network of phase oscillators consisting of three Kuramoto sub-systems representing “healthy”,“damaged” and “interface” networks.
The aim is to develop a strategy in terms of adaptive feedback-control to force the damaged network to recover its regular dynamical behaviour by learning the behaviour of the healthy network (training) through the stimulations transmitted by the interface network.
Our motivation comes from the treatment of neural disorders, such as Parkinson’s disease, where each network represents a part of the brain and the interface might represent deep-brain stimulation (DBS) – a popular controlling method.

With special thanks to the University of Birmingham and MAGIC

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