Gregynog 2018 Abstracts

Monday 21st May – Seminar Room 1

16:40 – 17:40 The Farey graph, continued fractions and SL_2-tilings: Part I Ian Short

In the 1970's, Coxeter studied certain arrays of integers that form friezes in the plane. He and Conway discovered an elegant way of classifying these friezes using triangulated polygons. Recently, there has been a good deal of interest in expanding Conway and Coxeter's ideas and relating them to other mathematical structures. Our objective in these two talks is to demonstrate how we can use basic techniques from hyperbolic geometry and the theory of continued fractions to shed light on some of the advances in the subject of integer tilings.

In the first talk we will review the work of Coxeter and others before discussing some of the fundamentals of hyperbolic geometry. The star of the show is the Farey graph, a beautiful object that connects geometry, number theory and graph theory. We will establish an elegant relationship between the Farey graph and integer continued fractions, which will prove to be essential for our understanding of integer tilings.

17:40 – 18:10 A mathematical model of nutrient influence on fungal competition Graeme Boswell

Fungi have a well-established role in nutrient cycling and are widely used as agents in biological control and in the remediation of polluted landscapes. Competition for resources between different fungal communities is common in these contexts and its outcome impacts on the success of such biotechnological applications. In this investigation, a mathematical model is constructed to represent competition between two fungal colonies that have access to different resources. It is shown that the model equations display a multitude of travelling wave solutions and that the outcome of competition between two fungal biomasses can be controlled through the simple manipulation of the nutrient resources available to each.

18:10 – 18:40 Data, Lagrangian, action: simulating a mechanism direct from a text description John Pryce

This is about linkage mechanisms, built from rigid bodies, springs etc., connected by joints of various kinds. For simulation, a Lagrangian approach to such systems is popular because of its economy and flexibility. The economy is because by d'Alembert's principle a Lagrangian function L, in contrast to direct use of Newtons laws, can omit mention of forces that do no work, e.g. the reaction force under smooth sliding. The flexibility is because the system can be described in any vector q of "generalised coordinates" that specify its position.

If q is such that constraint equations are involved (say, a 2D simple pendulum in terms of x,y coordinates) the equations of motion form an index-3 differential-algebraic equation (DAE) system. If not (say, the pendulum in terms of its angle with the vertical), they are reducible to an ODE. Since DAEs have been considered difficult, much work has gone into ways of describing a system by coordinates, usually angles, that give an ODE.

However coordinates consisting of x, y or x, y, z positions of suitable points on the moving parts of the mechanism usually give a simpler, more readable cartesian Lagrangian. Using our C++ DAE solver DAETS we have built a "Lagrangian facility" that converts code for L direct to the equations of motion at run time using automatic differentiation (AD). On top of this we have built a "mechanism facility" that reads a formalised text description of the mechanism and converts this to a cartesian L, also at run time, with no computer algebra manipulation involved.

I aim to show how for small mechanisms one can go from a problem description in a text editor, to viewing a Matlab animation, in a few seconds.

Tuesday 22nd May morning – Seminar Room 1

9:00 – 10:00 Modelling infectious disease control: dealing with what you can't see and withpopulationsthatvary. Jane White

Using mathematics to understand infectious disease dynamics has transcended the disciplines to a point where the model parameter R_0, which provides a measure of infectiousness is commonly used in the public health arena to understand the possible scale of an infection outbreak. By contrast, theoretical work on control of infections has yet to significantly impact decisions about how to contain infections.
In this talk, I will discuss some of my mathematical modelling work on infectious disease control. I will highlight the challenges that we face in trying to impact health policy and will use those challenges to explore robust approaches for mathematical modellers that might provide useful public health insights.

10:00 – 10:30 Mathematical Modelling of DNA Methylation Jason Roberts

There is growing evidence that associates DNA methylation with a number diseases related to ageing. Although there are some existing mathematical models which have contributed significantly to the understanding of this process, there is still much work to be done in this area. In this talk we look at how the introduction of nonlinear dynamics to one such model can produce a more biologically plausible model and act as a stepping stone to further understanding of the process.
Acknowledgements: This is joint work with Dr Mark Mc Auley, Dr Nikos Kavallaris, Loukas Zagkos (all University of Chester).

10:30 – 11:00 The structure of additive Systems of Integers Karl Michael Schmidt

A sum-and-distance system is a collection of finite sets of integers such that the sums and differences formed by taking one element from each set generate a prescribed arithmetic progression. Sum systems are an analogous concept where only sums of elements are considered.
In the talk, I'll show that there is a bijection between sum systems, sum-and-distance systems and principal reversible cuboids, which are a generalisation of reversible squares. Moreover, we have a structure theorem which provides an explicit construction formula for all sum systems in terms of joint ordered factorisations of their component set cardinalities. This is joint work with Martin Huxley and Matthew Lettington.

11:30 – 12:30 Efficient parameter estimation - a semi-complete data likelihood approach Ruth King

Statistical models are fitted to data to learn about the system under study, or to obtain estimates of unknown quantities of interest. The likelihood (or joint probability density function) of the data given the parameters is often a key component in the statistical analysis: the likelihood is either maximised with respect to the parameters to obtain the associated maximum likelihood estimates within a classical analysis; or combined with the prior distribution of the parameters to obtain the posterior distribution of the parameters within a Bayesian analysis. However, for many models the likelihood is not available in closed form and only expressible in terms of an analytically intractable integral. A Bayesian data augmentation technique is often applied in such situations to enable estimation of the posterior distribution of interest – however this approach can suffer from very poor computational performance. For such cases we will describe a "semi-complete data likelihood" approach for obtaining inference on the parameters which is significantly more efficient than the standard data augmentation approach – combining a partial data augmentation approach with a low-dimensional numerical integral. We illustrate the approach to examples of estimating hidden population sizes.

12:30 – 13:00 Packing problems, phyllotaxis and Fibonacci numbers Adil Mughal

We study the optimal packing of hard spheres in an infinitely long cylinder. Our simulations have yielded dozens of periodic, mechanically stable, structures as the ratio of the cylinder (D) to sphere (d) diameter is varied. Up to $D/d = 2.715$ the densest structures are composed entirely of spheres which are in contact with the cylinder. The density reaches a maximum at discrete values of D/d when a maximum number of contacts are established. These maximal contact packings are of the classic "phyllotactic" type, familiar in biology. However, between these points we observe another type of packing, termed line-slip. We review some relevant experiments with small bubbles and show that such line-slip arrangements can also be found in soft sphere packings under pressure. This allows us to compute the phase diagram of columnar structures of soft spheres under pressure, of which the main feature is the appearance and disappearance of line slips, the shearing of adjacent spirals, as pressure is increased.
We provide an analytical understanding of these helical structures by recourse to a yet simpler problem: the packing of disks on a cylinder. We show that maximal contact packings correspond to the perfect wrapping of a honeycomb arrangement of disks around a cylindrical tube. While line-slip packings are inhomogeneous deformations of the honeycomb lattice modified to wrap around the cylinder (and have fewer contacts per sphere). Finally, we note that such disk packings are of relevance to the spiral arrangements found in stems and flowers, when labelled in a natural way, which are generally represented by some triplet of successive numbers from the Fibonacci series $(1, 1, 2, 3, 5, 8, 13...)$. This has been an object of wonder for more than a century. Hundreds of papers and several books offer interpretations with various degrees of complexity, sophistication and ad hoc inventiveness. Despite this, it is doubtful whether the phenomenon is well understood: many websites still speak of mystery. We review some of this history and offer yet another straw in the wind to the never-ending debate.

Tuesday 22nd May afternoon – English – Seminar Rooms 1 and 2

14:00 – 15:00 The Farey graph, continued fractions and SL_2-tilings: Part II — Ian Short

Continuing from the first talk, we demonstrate how several significant theorems on integer tilings can be explained in a simple, coherent way using the Farey graph and continued fractions. This geometric approach also suggests some new results in the subject. In particular, using work of Ivrissimtzis and Singerman on quotients of the Farey graph, we put forward a programme for classifying certain integer friezes modulo n.

15:00 – 15:20

Training memory one strategies for the Prisoner's Dilemma — Nikoleta Glynatsi

According to Charles Darwin's theory of evolution, natural selection is ruled by the survival of the fittest. However, in spite of all the 'selfish genes' animal communities seem to altruistically help each other and cooperate. Vampire bats share part of their meal with members of the community that failed to find prey; similarly humans collaborate which leads to the creation of governments.
The question remains: why and how does cooperation emerge? In the field of game theory a game called the prisoner's dilemma has been used for decades to explain the emergence of altruistic behavior. In the 1980's, a political scientist called Robert Axelrod carried out a computer tournament. A number of strategies playing the iterated prisoner's dilemma, clashed in a round robin tournament.
Some recent work explored the effects of how good a strategy's memory is. The results stated that in the prisoner's dilemma interactions memory is not advantageous. As a game theorist I disagree with the above statement. I am proposing to talk about my work which focuses on proving that memory size can be advantageous in multi agent interactions.

Distributing Cohomology Computations via Sheaf Cohomology — Alvaro Torras Casas

Sheaf Cohomology has a number of applications in Topological Data Analysis including signal processing, network coding and sensor integration. In my PhD project I would like to generalise a result that appeared in a 2015 paper by Justin Curry, Robert Ghrist and Vidit Nanda. They developed a discrete Morse theory algorithm for computing sheaf cohomology in an efficient way. In particular, the authors present a result about distributed cohomology computation: They express the nth cohomology group of a compact, Hausdorff, locally contractible space X using Leray sheaves they obtain from a map to another space Y and a finite cover of the image. They have to make the simplifying assumption that the nerve of the cover is one-dimensional. In the proof they use the Leray spectral sequence. The dimension restriction implies that the differentials vanish on the second page. In my project I would like to explore the possibility of relaxing this dimensionality constraint on the nerve, starting with the 2-dimensional case.

15:20 – 15:40

Oscillatory Boundary Layers and Electrochemistry — Scott Morgan

This talk will explore exciting new applications of rotating and rocking disk hydrodynamic stability theory to electrochemistry, and discuss some directions for future interdisciplinary collaboration.
Voltammetry is a method for analysing the change in current given a controlled change in potential difference at an electrode, and has applications in electroplating and the measurement of ion transport in redox and oxidation reactions. Hydrodynamic effects are included to increase convection, thereby increasing the rate of mass transport at the electrode. One such well-established technique is known as rotating disk voltammetry, where an electrode embedded in a disk is rotated in the electrolyte at a constant rate. Another very new technique involves the disk rocking back-and-forth at a prescribed rocking angle, and Ahn et. al. discuss the advantages of this method over the traditional rotating disk setup.
The experiments require a laminar flow across the disk surface, as controlled convection and mass transport is vital to maintain consistency in measurements. There are very limited theoretical, computational or experimental studies on the transition to turbulence in the rocking disk configuration, and this talk will outline the preliminary ideas required for a fundamental study of this flow configuration.

Particle density of the CAR algebra and particle-hole duality in continuum — Alshehri Maryam

Let X be an underlying locally compact Polish space equipped with a Borel measure σ. Let $K(x,y) : X^2 \to \mathbb{C}$ and let K denote the integral operator in $L^2(X,\sigma)$ with integral kernel $K(x,y)$. A point process μ on X is called determinantal with the correlation operator K if the correlation functions of μ are given by $k^{(n)}(x_1,\dots,x_n) = \det[K(x_i,x_j)]_{i,j=1,\dots,n}$. If the operator K is self-adjoint, a determinantal point process with correlation operator K exists if and only if K is locally trace-class and $0 \le K \le 1$. Each determinantal point process with a Hermitian correlation kernel can be understood as the (spectral measure of) the particle density $\rho(x) = \partial_x^\dagger \partial_x$ $(x \in X)$, where the operator-valued distributions $\partial_x^\dagger$, ∂_x come from a gauge-invariant quasi-free representation of the canonical anticommutation relations (CAR). If the space X is discrete and divided into two disjoint parts, X_1 and X_2, by exchanging particles and holes on the X_2 part of the space, one obtains from a determinantal point process with correlation kernel K a determinantal point process with correlation kernel $\widehat{K} = KP_1 + (1-K)P_2$, where P_i is the orthogonal projection onto $L^2(X_i,\sigma)$. In particular, the operator $\widehat{K}$ is J-self-adjoint. In the case where the space X is continous, a direct procedure of swapping particles and holes makes no sense. Nevertheless, we prove that it is possible to carry out such a procedure by swapping creation operators $\partial_x^\dagger$ with annihilation operators ∂_x on the X_2 part of the space. This leads to a quasi-free representation of CAR and the corresponding particle density is a determinantal point process with correlation operator $\widehat{K}$, which is J-self-adjoint.

15:40 – 16:00

Droplet Spreading, Chemically Treated Surfaces and Mathematics

Danny Groves

Whether it's the raindrops on your car's windshield, or the water running off a plant leaf, we frequently encounter the rich physics behind droplet motion and yet remain unaware of its impact on the modern world. For many decades this class of phenomena has fascinated academics from all areas of science and engineering, furthermore, this interest has brought the development of new technologies such as ink-jet printers, and the design of self-cleaning surfaces. From a mathematical point of view, this situation leads to fourth order non-linear partial differential equations, where solutions rely on the use of powerful numerical tools. Therefore, emphasis is placed on theoretical methods such as matched asymptotic expansions which reduce the complexity of the full equations to form approximate models. These derived simpler models retain the key physics that drive droplet motion, allowing us to further explore the physics behind droplet spreading, as well as obtain vast speedups to the full numerical calculations where a sample simulation has shown to be 250,000 times faster than a supercomputer calculation.

Alternating sign matrix lattice and its properties

Hasan Izanloo

An alternating sign matrix of order n, ASM for short, is an n by n matrix with entries from the set $\{-1, 0, 1\}$ in which all its row/column sum equal to 1 and non-zero entries in each row/column alternate in sign. ASMs are well studied combinatorial objects in the literature. In this talk, I will briefly discuss ASMs from the partially ordered point of view and their basic properties. I would also discuss an application of P-partition theory to ASM lattice.

16:30 – 16:50

On the predictive power of functional principal components analysis

Ben Jones

Principal Components Analysis is a commonly used dimension reduction technique in both the Statistics and Machine Learning literature. It is an unsupervised method usually used before supervised procedures such as classification and regression algorithms.

This practice has historically been controversial, questioned by some and defended by others, because there is no guarantee that the response variable will be more highly correlated with the higher-ranking principal components than the lower-ranking ones. Nevertheless, simulations and experience with data suggest that this often, but not always, the case so there have been works that provide probabilistic justifications for this phenomenon. These justifications have been established for models of increasing generality including linear regression, single-index, and sufficient dimension reduction models. They focus on the classical multivariate setting where the predictor is a random vector and the response is a random scalar. Principal Components Analysis can be extended to when the predictor is a random function as it only requires the computation of inner products. It is our aim to establish similar probabilistic results for this setting. We explain the surprising fact that it is not possible to define a notion of a uniform distribution on such spaces, resulting in rather different assumptions to the classical case being required to prove our results. This is a work in progress so we present our work thus far.

Eigenvalues of the Periodic p-Laplacian

Matthew Lewis

We introduce the p-Laplacian, a nonlinear differential operator, in a one-dimensional periodic setting. We compare this nonlinear equation to linear second order equations of Sturm-Liouville type, with periodic coefficients. For problems of this form, the spectrum can be characterised entirely through techniques such as Floquet Theory, and Oscillation Theory. However, the former fails completely in this nonlinear case. We discuss how the structure of the spectrum is different between these linear and nonlinear cases.

16:50 – 17:10

Analysis of bending elastic plates

Joe Bishop

In the modern scientific world many complex problems rely on powerful computing tools to determine solutions, however, as advanced as computing power may be, there still remains limitations. The numerical modelling of microstructures can be quite costly even for simple simulations, since the numerical grid required needs to be small enough in order to resolve each individual micro-cell.

This is the nature of our problem where we begin from a non-linear elasticity setting and consider the bending energy of a thin elastic plate which is periodically perforated throughout the domain. We derive the gamma-limit of the functional that describes the bending energy of the plate (as the thickness of the plate and the period of the perforations tend to zero) through simultaneous homogenisation and dimension reduction. Therefore obtaining a macroscopic model that retains information of the microstructure.

An introduction to horizontal mean curvature flow

Raffaele Grande

The horizontal mean curvature flow equation is a particular nonlinear degenerate elliptic PDE defined in a sub-Riemmanian geometry, which describes the motion of an hypersurface evolving with normal velocity proportional to its horizontal mean curvature. This equation has interesting applications in biology, such as the Citti-Sarti model for visual cortex, and in computer science. I will give a brief introduction about sub-Riemmanian geometries, with a focus on Carnot groups, and about viscosity solutions. Finally I will present the level sets formulation for the, so called, generalised evolution by horizontal mean curvature flow.

17:10 – 17:30	Transient behaviour of visco-elastic fluids in boundary layers — Martina Cracco	Spatio-temporal evolution of hypoxia and its role in HAP-Radiation effectiveness in solid tumours — Sara Hamis
	The behaviour of many real fluids is well described by Navier-Stokes theory. This theory is based on the assumption of a Newtonian constitutive equation. Many rheological complex fluids such as polymer solutions, soaps, blood, paints, shampoo, ketchup are not adequately described by a Newtonian constitutive equation. Viscoelastic fluids are examples of non-Newtonian fluids, they exhibit both viscous and elastic properties when undergoing deformation. The aim of my research is to understand the stability behaviour of such fluids in boundary layers, thin layers of fluid close to a surface. Results based on two-dimensional linear stability analysis for a fluid of second grade demonstrate the stabilising effects of elasticity. The analysis is expanded to three-dimensional disturbances and a nonmodal approach is adopted in order to have a more complete idea of the short-term behaviour of disturbances. It is shown that elasticity generally increases the energy of the perturbations over short-time periods. The stability analysis is extended to more complicated models of viscoelastic fluids.	Hypoxic cancer cells in solid tumours express reduced sensitivity to anticancer treatments such as radiotherapy and some chemotherapeutic drugs. Thus hypoxia has an adverse effect on treatment delivery and significantly impacts clinical outcome. Consequently, multiple strategies to combat hypoxia have been explored. Hypoxia-Activated Prodrugs (HAPs) present a means to not only combat, but also exploit, hypoxia. HAPs are bioreductive prodrugs that reduce, and thus convert, to active cytotoxins upon reaching hypoxic regions. These drugs act as trojan horses, being harmless until they are converted in target areas. Despite being conceptually promising, clinical trials of HAPs have produced mixed results. In order to closely study the appropriate conditions and optimal delivery of multimodality treatment regimes that involve HAPs, we have developed a three-dimensional *in silico* framework. Our framework is based on a multiscale mathematical model, specifically a cellular automaton incorporating intracellular, extracellular and intercellular dynamics. Our results indicate that the successfulness of HAP-Radiation combination treatments depends not only on tumour oxygenation status, but also on spatio-temporal implications of hypoxia.

17:30 – 17:50	Ligand binding dynamics and the effects of cooperativity: linear and nonlinear models for dimerised receptors — Carla White	Blow-ups and Spherical Twists — Chris Seaman
	Evidence suggests that many G protein-coupled receptors (GPCRs) are bound together forming dimers. The implications of dimerisation for cellular signalling outcomes, and ultimately drug discovery and therapeutics, remain unclear. Consideration of ligand binding and signalling via receptor dimers is therefore required as an addition to classical receptor theory, which is largely built on assumptions of monomeric receptors. A key factor in developing theoretical models of dimer signalling is *cooperativity* across the dimer, whereby binding of a ligand to one protomer affects the binding of a ligand to the other protomer. We present and analyse linear models for ligand binding dynamics at homodimerised receptors, as an essential building block in the development of dimerised receptor theory. Furthermore, different receptor types may dimerise in response to ligand binding which leads to a related but nonlinear model.	The autoequivalence group of a given derived category has been the subject of much research. In this talk I will present some motivation for this, plus an example of non-trivial autoequivalences in the form of spherical twists of the derived category of the blowup of a cyclic quotient singularity.

17:55 – 18:15	Least Squares Estimator for path-dependent Mean-field SDEs via Discrete-time Observations — Panpan Ren	Effective numerical model for hydraulic fracturing — Gaspare Da Fies
	In this talk, we study a least squares estimator for an unknown parameter in the drift coefficient of a path-distribution dependent stochastic differential equation involving a small dispersion parameter. Our estimator is based on discrete time observations of the path-distribution dependent SDEs involved. More precisely, if the coefficients satisfy global Lipschitz condition, the estimator is based on classical Euler-Maruyama scheme, whereas, in the case that the coefficients obey the weak monotone condition, the estimator is established on tamed Euler-Maruyama algorithm. We show that the least squares estimator obtained is consistent with the true value, and moreover, we obtain the rate of convergence and derive the asymptotic distribution of least squares estimator.	Hydraulic fracturing (HF) is a process in which a fluid is pumped at high pressure into a solid material, with or without a pre-existing crack or fault. The push of the fluid makes the fracture open and propagate. This coupled problem (fluid-solid interaction) reveals very hard to solve because of numerical stiffness, strong non-linearity, presence of singularities and moving boundaries. There are a number of numerical simulators (mostly commercial ones) dealing with this problem, but even for the simplest 1D models (time dependent and 1D in space, it represents a planar straight or radial fracture) there is still room for improvement and better understanding. Recently, several groups have been working on the topic, resulting in some significant improvements. We are working on a fast and accurate algorithm for the 1D classic models based on the use of asymptotic analysis. Other computational advantages of our method come from the use of an improved version of the model that takes in account the shear stress induced by the fluid, previously neglected. Our future work will be focused on using the knowledge gained from the experience on the classic 1D models to tackle the much more difficult case of the 2D model (time dependent and 2D in space, it represents a non symmetric planar fracture). We also plan to consider the similar problem of interaction between the fluid and a thin non-elastic tissue, that can be useful in biological applications. This is joint work with Gennady Mishuris.

18:15 – 18:35	Surfactant transport in dry two-dimensional foams	Francesca Zaccagnino	Modifying PCA: Sparse Dimension Reduction for Exponential Family Data	Luke Smallman

The present work describes a two-dimensional numerical tool to study the rheology of dry foams, overcoming the limitations of previous models in their treatment of viscous dissipation processes. We examine the T1 topological process of bubble rearrangement and investigate the influence of viscoelastic parameters on the film evolution after a T1, as the film moves towards the final equilibrium configuration. Extending previous models, we consider surfactant transport, and consequently the surface tension variation, along all films. In a foam flowing at high velocity, the tangential component of the velocity associated with the gradient of surfactant concentration is not negligible.

Moreover, experiments on a simple system of five films between two parallel plates suggest that the diffusion of curvature along the film can not be neglected. Therefore we merge our surfactant transport (ST) model with the two-dimensional Viscous Froth (VF) model.

The VF+ST model is validated by fitting experimental data for the evolution of the length of a film after a T1 in systems containing different surfactants. Extending the VF model, which allows us to estimate the drag coefficient, our VF+ST model predicts two additional parameters, the Gibbs elasticity and the surface viscosity, for each sample. Although at very short times the VF model is able to fit the data for anionic surfactants, at long times the introduction of the additional viscous factors within the VF+ST model is crucial in order to fit data for both anionic surfactants and proteins.

We also apply the VF+ST model to ordered (hexagonal) foams subjected to both a step strain and an oscillating strain, and we predict the shear modulus in each case. The authors kindly acknowledge A. Audebert for sharing experimental data, and funding from the project MATRIXASSAY.

Principal Component Analysis (PCA) is one of the most widely used dimension reduction tools, but it is largely unsuitable for data which is not normally distributed. In this talk, I will briefly summarise efforts in the literature to extend PCA to exponential family data, then explain my work extending these methods to produce sparse loadings. I will also illustrate why such loadings are desirable.

18:35 – 18:55	Homogenous and heterogeneous populations of active rods confined within two dimensional channels	Vladimir Khodygo	The characters of a sharply 5-transitive subgroup of A_{12}	Sam Hughes

Active swarms, consisting of of individual agents which consume energy to move or produce work, are known to produce a diverse range of collective behaviour. Many examples of active swarms are biological in nature (e.g. fish shoals and bird flocks) and have been modelled extensively by numerical simulations. Numerical simulations of swarms assume that the swarm is homogeneous: that is every agent has exactly the same dynamical properties. However, real biological swarms are often heterogeneous, such as in the case of a microbial population in the gut or in the soil (where many different species of bacteria may be present simultaneously). Here we conduct molecular dynamics simulations of active rods confined within a two-dimensional rectangular channel. Such simulations serve as a simple model for the dynamics of a swarm of motile rod-like bacteria in the absence of hydrodynamic effects. We first explore the case of homogeneous swarms and show that the key parameter governing both dynamics is ratio of the motility force to the steric force. Next we explore heterogeneous or mixed swarms in which the constituent self-propelled rods have a range of motilities and steric interactions. Our results show that the confining boundaries play a strong role in driving the segregation of such mixed populations.

The central object of group representation theory over the complex field is the character table of a group. In 1904, Frobenius calculated the character table of the groups known as the Mathieu groups, M_{12} and M_{24}; these groups are famous for being the only 5-transitive groups that are not symmetric or alternating.
In this talk we will focus on the character tables of the small Mathieu groups M_9, M_{10}, M_{11} and M_{12}. Specifically, we will discuss how to calculate character table of a group G_k, such that G_k is a sharply $(k-7)$-transitive subgroup of $Alt(k)$ for $k = 9, \ldots, 12$. As the small Mathieu groups satisfy this condition we obtain their character tables without using a construction of the groups, giving a more general result than Frobenius.

Tuesday 22nd May – Welsh – Writing Room

15:00 – 15:50 Cynllunio Aerodynamig Awyrennau a Cheir Uwchsonig Ken Morgan

Crëwyd y system gyfrifiadurol FLITE3D yn wreiddiol yn Abertawe i gynorthwyo'r broses o gynllunio aerodynamig yn y diwydiant aerofod. Fe ddefnyddiwyd FLITE3D yn helaeth gan Airbus wrth iddynt gynllunio'r A380. Profwyd, yn achos THRUST SSC, ei bod hi'n posibl i ddefnyddio'r system hefyd i ddadansoddi perfformiad aerodynamig ceir cyflym. THRUST oedd y car cyntaf i fynd â Record y Byd am Gyflymder ar y Ddaear yn uwch na chyflymder sain.

Fe fydd y ddarlith yn edrych yn ôl dros y datblygiadau hyn ac yn dangos sut y cafodd FLITE3D ei defnyddio yn ddiweddar ym Mhroject BLOODHOUND. Nôd y Project hwn yw cynllunio car sy'n gallu teithio'n gyflymach na THRUST a mynd â Record y Byd am Gyflymder ar y Ddaear i tua 1 000 mya. Mae'r broses o gynllunio BLOODHOUND nawr ar ben ac fe fydd y sialens yn dechrau'n ddiweddarach eleni yn Ne Affrica.

16:30 – 17:00 Modelu ewynnau hylif gan ddefnyddio efelychiadau rhifiadol Tudur Davies

Mae'r rhyngweithiad rhwng ewynnau hylifol a gwrthrychau neu ronynau sy'n disgyn trwyddynt yn greiddiol i'r broses o wahanu mwynau trwy arnofiant. Mae'n bosib hefyd y gall y rhyngweithiad rhwng gwrthrychau solid ac ewynnau trefniedig ganfod lle mewn cymwysiadau newydd mewn meicro-hylifeg, lle mae grymoedd capilari yn bwysig. Yn y patrymedd hwn, mae'n bosib y gall grym tensiwn arwyneb â strwythur trefnedig rhai ewynnau gael eu defnyddio i adleoli neu ail-gyfeirio gwrthrychau a gronynnau mewn ffordd reoledig. Byddaf yn trafod diweddariadau i ganlyniadau efelychiadau rhifiadol diweddar lle rwy'n modelu'r rhyngweithiad rhwng ewyn bambŵ a gwrthrych caled. Byddaf yn ystyried sut mae'r rhyngweithiad yn amrywio gyda pharamedrau megis siâpiau'r gwrthrych a cynhwysydd yr ewyn, a'r ongl gyswllt rhwng y gwrthrych ac arwyneb yr ewyn. Byddaf yn dangos sut mae'r paramedrau yma yn effeithio ar faint mae'r ewyn yn cael ei aflonyddu gan y gwrthrych, yn ogystal â'r grymoedd mae'r ewyn yn ei weithredu ar y gwrthrych.

17:00 – 17:30 Led-Grwpiau Feller i Brosesau Adio – gan ddefnyddio Gweithredyddion Differol-Ffug / From Feller Semigroups to Additive Processes – an approach using Pseudo-Differential Operators Kristian Evans

Bydd y ddarlith yn dechrau gyda chyflwyniad byr i weithredyddion differol-ffug a lled-grwpiau Feller. Mae gweithredyddion differol-ffug wedi cael eu hastudio dros gyfnod hir a chyflwynir rhai o'r prif syniadau yn y ddarlith. Mae'r gweithredyddion hyn wedi cael eu hystyried ar $\mathbb{Z}^m$ ac $\mathbb{R}^n \times \mathbb{Z}^m$ - ystyrir y rhesymau y tu ôl hyn a'r syniadau cyffredinol. Bydd y ddarlith yn gorffen gan edrych ar waith mwy diweddar ar brosesau adio a gweithredyddion differol-ffug sy'n dibynnu ar amser. Mae'r ddarlith yn seiliedig ar waith ar y cyd gyda Niels Jacob, Chenglin Shen, Lewis Bray ac Owen Morris.

The talk will begin by giving a brief introduction into pseudo-differential operators and Feller semigroups. Pseudo differential operators on $\mathbb{R}^n$ have been studied over a long period of time and some of the main ideas will be summarised. These operators have been studied on $\mathbb{Z}^m$ and $\mathbb{R}^n \times \mathbb{Z}^m$ - the motivation for this and some general ideas will also be considered. The talk will conclude with more recent work on additive processes and time-dependent pseudo-differential operators. This talk is based on joint work with Niels Jacob, Chenglin Shen, Lewis Bray and Owen Morris.

17:30 – 17:50 Cynhyrchydd o grwp lled is-Markovian L^2 a Grwp Unedol / Generators of L^2 sub-Markovian semigroup and Unitary Groups Huw Fry

Rydym ni'n astudio gweithredwr gyda chyfernodau p'run yr ydym yn dangos sydd gyda estyniad sy'n cynhyrchu grwp lled is-Markovian L^2. Ar ben hynny, rydym yn ymestyn hyn i ddangos bod hefyd gan y gweithredwr estyniad hunan-gydiad sy'n cynhyrchu grwp unedol.

We study an operator with coefficients which we show has an extension generating a L^2 sub-Markovian semigroup. Moreover, we extend this to show that the operator also has a self-adjoint extension generating a unitary group.

17:50 – 18:10 Topics on Hamiltonian Dynamics Related to Symbols of Certain Schrödinger Operators Associated with Generators of Lévy Processes Elian Rhind

Arwaina prosesau Lévy at lled-grwpiau gweithredydd un-parametr sy'n cadw positifedd, sef sylfaen ar gyfer nifer o astudiaethau. Diffiniwyd y grwpiau yma yn hollol gan eu esbonydd nodweddiadol sy'n ddi-dor ac yn bendant negyddol. Yn ddiweddar, mae yna diddordeb mewn y weithredau Schrödinger cyfatebol, yn enwedig yn eu theori spectrol. Y nod yw i ddeall y system dynamig "classigol" a ddaw o hyn.

I wneud hyn canolbwyntiwn ar y weithredau Schrödinger, yn bennaf ar y ffwythiant Hamilton cyfatebol. Am fod egwyddor Hamilton yn ffynhonnell allweddol astudiwn y ffwythiant Lagrange cyfatebol hefyd. Byddai'n ddefnyddiol i gael datrasiadau ar gyfer enghreifftiau diriaethol sy'n cynnwys potensialau penodol. Oherwydd hyn cynnigwn addasiadau ar gyfer enghreifftiau gwyddom yn dda o mecaneg classigol sy'n rhoi fformiwlau a all ein helpu i ymchwilio'n bellach.

Wednesday 23rd May – Seminar Room 1

9:00 – 10:00 | What makes a good drug for transdermal delivery or monitoring? Insights from mathematical modelling. | Jane White

The main purpose of our largest organ, the skin, is to provide a barrier function, protecting the body from harmful external substances whilst preventing excessive water loss from it. So when it comes to thinking about delivering or monitoring drugs across the skin, it is clearly challenging to understand how that might be possible. However, since the skin is large and accessible, there is a real interest in exploring the potential to exploit it for pharmaceutical purposes.

In this talk, I will present a selection of projects that I have worked on that describe the dynamics and distribution of drug molecules in the skin. I will highlight how the models have been used both to understand empirical data to explore the impact of phenomenological processes using models that have been developed in collaboration with colleagues working in the lab. And I will use this to discuss the potential for mathematical modelling to impact on future developments in pharmaceutical science.

10:00 — 10:30 | k-domination in graphs and placement of electric vehicle charging stations in road networks | Andrei Gagarin

Electric, hybrid, and alternative fuel vehicles play an increasing role in road transport networks. However, their efficient usage requires development of the corresponding refueling/charging infrastructure. Given a particular road network layout, determining appropriate locations and capacities for refueling/charging stations is a challenging multi-objective optimisation problem with many constraints. Some of the key objectives are to minimise the length of detours from a desired route necessary for refueling/recharging while assuming a reasonably small number of refueling/charging stations to serve the whole road network.

We propose to model the facility location problem for placement of charging stations as a k-domination problem in reachability graphs, which are derived from the original road network layout. This model takes into consideration natural assumptions such as a threshold for the remaining battery charge, and provides some guaranteed minimal choice for traveling to recharge the battery. Greedy and randomized solution approaches are proposed and discussed.

(Joint work with Padraig Corcoran, School of Computer Science and Informatics, Cardiff University)

10:30 – 11:00 | On Sum-and-Distance Systems, Reversible Square Matrices and Divisor Functions | Matthew Lettington

A d-dimensional sum-and-distance system is a collection of d finite sets of integers such that the sums and differences formed by taking one element from each set generate a prescribed arithmetic progression.

In the talk, I will establish that for a fixed dimension n, there exists a bijection between the set of principal reversible square matrices and the set of 2-dimensional sum-and-distance systems. The number of 2-dimensional sum-and-distance systems can then be obtained by using Ollerenshaw and Bree's enumeration argument for the number of principal reversible square matrices. By reworking their argument one finds that the number of such principal reversible square matrices, (and so 2-dimensional sum-and-distance systems) can be expressed in terms of sums of products of the jth non-trivial divisor function $c_j(n)$.; this counts the total number of proper ordered factorisations of the integer n into j factors (i.e. excluding the factor 1, but counting permutations of the factors). If j is greater than the total number of prime factors of n, including repeats, then $c_j(n) = 0$. The non-trivial divisor function c_j has been far less studied than its multiplicative cousin, the jth divisor function d_j. Further relations concerning these two functions are discussed in the talk.

This is joint work with Sally Hill, Martin Huxley and Karl Michael Schmidt.

11:30 – 12:00 | Sampling and spectral approximation | Bertrand Gauthier

Integral operators related to symmetric positive-semidefinite kernels are intrinsically related to kernel-based methods, and naturally appear in many machine learning and statistics problems, for example. In practice, designing sparse quadratures for the approximation of such operators (i.e., approximating the initial measure by a discrete measure supported by a small number of points) is specially important when one aims for instance at computing the spectral decomposition of the approximate operator. We will investigate the design of "optimal" quadratures, and discuss the computation of accurate spectral approximations of the initial operator. We will also highlight the connections between such problems, kernel LASSO and one-class SVM models.

12:00 – 13:00 | How mathematicians "count" what they cannot see | Ruth King

In this general mathematics talk I will look at some of the history of estimating population sizes from simple beginning to modern day cases. We will discuss the data that are often collected in such studies, the mathematical models that are often fitted to the data and the associated assumptions of these models. We will also discuss how the modeling approach can be modified to address violations of the assumptions and the impact of ignoring such issues. Real data examples will be used throughout the talk to illustrate many of the ideas.