Department of Mathematics and Statistics Seminars, 2018-2019

Friday, 14 September 2018, 16:00

Speaker: Vladimir Zubkov (School of Computing, Engineering & Mathematics, University of Brighton, UK).

Title: **Mathematical modelling of problems in physics and biology.**

Abstract: The research focuses on the application of numerical and asymptotic methods for Mathematical Biology and Fluid Dynamics. Initially, my research focused on fluid dynamics. My current research interest has been related to the mathematical modelling of the human tear film in the context of dry eye pathology and to the mathematical modelling of the kidney morphogenesis. We have formulated and explored a model describing the spatial distribution of tear film osmolarity across the ocular surface of a human eye during one blink cycle, incorporating detailed fluid and solute dynamics. We also have considered a mathematical model of kidney morphogenesis. Mammalian kidneys are vital organs that filter wastes such as urea from the blood. Kidney development is initiated by the outgrowth of a ureteric bud (UB) of epithelial cells into a population of mesenchymal cells. Interactions between the epithelial and mesenchymal cells coordinate the processes of cell proliferation and branching, leading to the formation of a highly branched structure known as the urinary collecting system. While models of fluid and solute transport within the mature kidney have been developed, little attention has been devoted to kidney morphogenesis. We considered a mathematical model of growing kidney in culture medium, where the epithelium is modelled as a continuous medium with elastic boundary using Navier-Stokes equations. Studying stability of growing kidney with the use of analytical and numerical methods, we explained the archetypal mechanism of branching. We have also formulated a spatially-averaged mathematical model of kidney morphogenesis in which the time evolution of key cell populations is described by a system of ordinary differential equations. The mathematical model and its predictions were validated against experimental data collected from developing mouse kidneys.

Friday, 21 September 2018, 16:00

Speaker: Andy Stewart (Department of Physics & Bernal Institute, University of Limerick).

Title: Reconstruction algorithms for transmission electron microscope data.

Abstract: Transmission electron microscope (TEM) data is not directly interpretable, because it has a non-linear relationship with the scattering from the object. A number of different approaches and algorithms are used to reconstruct both imaging and diffraction data to overcome the dynamical scattering problem, improve the resolution achievable and low the radiation dose the specimen receives. I will present iterative reconstruction algorithms used to recover the average crystal structure form diffraction data. Ptychography which is used to improve resolution and lower dose to the specimen. As well as introduce initial results from compressed sensing reconstruction experiments.

Friday, 28 September 2018, 16:00

Speaker: Isabella Gollini (School of Mathematics and Statistics, University College Dublin).

Title: Latent variable modelling of interdependent ego-networks.

Abstract: Ego networks consist of a focal node ("ego") and the nodes to whom ego is directly connected to ("alters"). Often network data are collected as interdependent ego-networks (a network of ego networks) and they require ad hoc modelling approaches to explain the complexity of their data structure. We present a Bayesian latent variable network modelling framework to describe the connectivity structure of interdependent ego-networks. This allows us to explain both the ego ego and ego-alter relational structures simultaneously by estimating the positions of all the individuals in a latent "social space". The challenge concerning this model is represented by the intractability of the likelihood; to efficiently overcome this difficulty we adopt an efficient variational algorithm. The flexible modelling framework presented together with a fast inferential approach can be adapted to a wide range of network settings. In this work, we illustrate this new methodology by exploring the structure of human smuggling network out of Libya consisting of ego-networks based on the wiretaps acquired by the Italian police on 29 suspects during an investigation period lasting from January to October 2014.The statistical challenge with these ego-networks is that the large number of alters (more than 15k) can potentially be members of several ego-networks. The analysis is carried out using the lvm4net package for R that is available on CRAN.

Friday, 5 October 2018, 16:00
Speaker: Mehakpreet Singh (Department of Chemical Science, Bernal Institute, University of Limerick).
Title: Numerical Approximations of Pure Aggregation Population Balance Equation and its Applications.
Abstract: Population balance equation (PBE) is a classical approach to describe the temporal changes in the number distribution function due to various particulate processes such as aggregation, breakage, growth and nucleation which are involved in many engineering applications. In this work, numerical approximations for solving the one-dimensional aggregation PBE equation on non-uniform meshes has been analysed. Among the various available numerical methods, finite volume methods have explicit advantage such as mass conservation and an accurate prediction of different order moments. So, two finite volume schemes are developed which are different in a sense that one scheme is merely focused on conserving the total mass in the system whereas the other scheme preserves the total number of particles as well as conserves the total mass in the system. Both schemes rely on introducing weights in their formulations to retain different properties such as total mass and total number of particles in the system. The accuracy of both methods is tested with some benchmark aggregation kernels. In addition, a study of modeling and simulation for a top sprayed fluidized bed granulator (SFBG) is presented which is substantially used by the pharmaceutical industry to prepare granules. The idea is to build a mathematical model using the notion of population balances by dividing a top SFBG into two different zones namely wet zone (correspond to aggregation) and dry zone (correspond to breakage). To solve a two-compartmental model, an existing accurate and efficient finite volume scheme is modified. The validation of the compartmental model is done by deriving new class of analytical moments are derived corresponding to various combinations of aggregation and breakage kernels.

Friday, 12 October 2018, 16:00
Speaker: Eberhard Mayerhofer (Department of Mathematics & Statistics, University of Limerick).
Title: Positive Semigroups: I. The finite-dimensional case.
Abstract: I construct linear (!) norm-like functions on cones, which generate Lyapunov maps on their duals. Using multivariate comparison arguments for ODEs, we characterize generators of positive (cone-valued) linear semigroups on cones and their resolvents and

understand their spectral bound as the largest eigenvalue. The main statement allows to test linear maps for strictly negative spectral bound. Applications lie in ODE theory (stability, e.g. for Matrix Riccati Differential equations) and the theory of high-dimensional Markov processes on cones (geometric ergodicity). Our theory recovers well known results for M and Z matrices as well. The presentation addresses anybody with interest in Linear Algebra.

Friday, 19 October 2018, 16:00
Speaker: Merlin Etzold (Centre for Mathematical Sciences, Cambridge, UK).
Title: Removal of viscous contaminants from gaps and cracks[1]
Abstract: Problems of industrial cleaning usually consider equipment optimised to be cleaned easily. Decontamination after accidents or the deployment of chemical weapons, in contrast, requires the treatment of complex, neither smooth nor impermeable, surfaces as they are found on equipment or urban structures. The first step towards understanding realistic surfaces is to consider the implications of cracks and gaps on decontamination time. These common features act as capillary traps for liquid contaminants and hinder decontamination efforts. We consider the removal of a soluble, viscous contaminant droplet from gaps and cracks by a surface washing technique. We consider both rectangular and V-shaped geometries. The mass transfer from the droplets is related to boundary layers and Graetz-type problems (heat transfer in pipe flow), with the added complication of a non-uniform lateral concentration profile due to the lateral variation of the velocity profile. We present 3D solutions for the diffusive boundary layer and demonstrate that a 2D mean-field model, for which we calculate Graetz-type and similarity solutions, predicts the average mass flux with high accuracy. We present also analytical expressions valid in the limit of large and small Péclet numbers. To predict actual decontamination times, the mass transfer model has to be merged with a model for droplet response. We will consider models for the droplet behaviour, one for the shrinking of a bulk contaminant droplet and one model for a diluted contaminant in a polymer-thickened solution. We will also present some experimental data for both cases. Evaporation-driven transport through soft hydrogels in contact with awater-reservoir[2]. I also hope to briefly introduce an intriguing problem where we study the deformation of hydrogels due to evaporative transport. In these experiments, we place a hydrogel bead with an evaporative surface in contact with a water reservoir. Depending on the pressure in the water reservoir and relative humidity of the surrounding air, the bead changes its size… - and we have a model (only 1D at the moment therefore only qualitative) which explains what is going on. This work is part of an effort to understand how tall (> 10 cm) tree scan overcome the problem of cavitation in the xylem.

[1]with Julien Landel and Stuart Dalziel.
[2]with Paul Linden and Grae Worster.

Friday, 26 October 2018, 16:00
Speaker: Ivan Graham (Department of Mathematical Science, University of Bath, UK).
Title: Solving frequency domain wave equations at high frequency.
Abstract: In several important applications - e.g. seismic exploration or earthquake prediction - one seeks to infer unknown material properties of the earth's subsurface by sending seismic waves down and measuring the scattered field which comes back. In the process of solving the inverse problem (so-called "full-waveform inversion") one needs to

iteratively solve the forward scattering problem, each time using an improved guess of the unknown material properties.

In industry practice, each step is usually done by solving the appropriate wave equation (elastic or acoustic) using explicit time stepping. However in many applications it would be more efficient to solve in the frequency domain, except for the fact that the linear systems which arise in this case are extremely difficult to solve iteratively.

In the simplest (acoustic) case the frequency domain problem is the Helmholtz equation. Its iterative solution is of great current interest. To understand the problem we use a combination of linear algebra (iterative methods for non-normal complex linear systems) and PDE theory (stability theory for highly oscillatory non-self-adjoint PDEs). In the talk I'll describe progress in this area with concentration on the use of parallel domain decomposition methods in a non-standard setting, aiming to solve discrete Helmholtz problems of dimension N in order N time.

The techniques which I'll describe also can be used for the elastic wave equation and Maxwell's equations in the frequency domain and I'll give some examples of this as well.

Friday, 2 November 2018, 16:00
Speaker: Ali Faqeeh (MACSI, University of Limerick).
Title: The impact of structure on dynamics and function of networked systems.
Abstract: Many social, technological or biological systems are formed by a complex pattern of connections between their constituents; for example, billions of users interact through online networks such as Facebook and Instagram, billions of electronic machines interact via physical connections in the Internet, and thousands of billions of synaptic connections comprise the neural network of our brain. The network structure of such systems is known to have a huge impact on how they operate. Here, I review some of our recent findings about the effect of structure on networked behavior. I present results regarding different aspects of structural properties, including, network hidden geometry, multilayer networks, community structures, and noisy (imperfect) data on structure and/or dynamics. I discuss how each of these properties play a crucial role in various applications such as determining robustness of networks, optimal vaccination strategies, efficient navigation, and identification of the most influential spreaders.

Friday, 9 November 2018, 16:00
Speaker: Nicholas Devaney (School of Physics, N.U.I., Galway).
Title: Enhancing the Detection of Exoplanets in direct images.
Abstract: Over 2000 planets have now been detected around stars other than our sun, and the number is likely to increase dramatically in coming years. However, the vast majority of detections are indirect as directly detecting exoplanets in images is extremely challenging. I will explain this challenge, and describe approaches to post-processing which we have developed to optimise the detection rate for exoplanets, as well as improve brightness estimates. These estimates (especially as a function of wavelength) are fundamental to understanding the nature of the detected exoplanets.

Friday, 16 November 2018, 16:00
Speaker: Rebekka Burkholz (Department of Computer Science, ETH Zurich).
Title: Explicit size distributions redefine systemic risk on finite networks.
Abstract: How big is the risk that a few initial failures of nodes in a network amplify to large cascades that endanger the functioning of a system as a whole? Common answers to this question are based on estimates of the average final cascade size. Two main analytic approaches allow its computation: a) (heterogeneous) mean field approximation and b) belief propagation. The former applies to infinitely large locally tree-like networks, while the latter is exact on finite trees. Yet, cascade sizes in finite systems can be distributed broadly and multi-modally. In this case, they are not well represented by their average. The full distribution information is essential to identify likely events worth preparing for and to estimate the tail risk, i.e. the probability of extreme events. Here, we lay the basis for a general theory to calculate the cascade size distribution in finite networks. We present an efficient, distributed message passing algorithm that is exact on any finite tree and a large class of cascade processes. An approximation version performs well on locally tree-like networks.

Friday, 23 November 2018, 16:00
Speaker: Maxence Cassier (Fresenel Institute, Marseilles, France).
Title: Limiting amplitude principle for Maxwell's equations at the interface of a metamaterial.
Abstract: In this talk, we are interested in a transmission problem between a dielectric and a metamaterial. The question we consider is the following: does the limiting amplitude principle hold in such a medium? This principle defines the stationary regime as the large time asymptotic behavior of a system subject to a periodic excitation.

An answer is proposed here in the case of a two-layered medium composed of a dielectric and a particular metamaterial (Drude model). In this context, we reformulate the time-dependent Maxwell's equations as a conservative Schrödinger equation and perform its complete spectral analysis. This permits a quasi-explicit representation of the solution via the "generalized diagonalization" of the associated unbounded self-adjoint operator. As an application of this study, we show finally that the limiting amplitude principle holds except for a particular frequency, called the plasmonic frequency, characterized by a ratio of permittivities and permeabilities equal to -1 across the interface. This frequency is a resonance of the system and the response to this excitation blows up linearly in time.

Joint work with Christophe Hazard (Poems team) and Patrick Joly (Poems team).

Wed., 28 November 2018, 16:00 (Note: Unusual Day!)
Speaker: Matt Ritchie (Department of Electronic & Electrical Engineering, UCL, UK).
Title: TBA
Abstract: TBA

Friday, 7 December 2018, 16:00
Speaker: Kevin Hayes (Department of Mathematics & Statistics, University of Limerick).
Title: TBA
Abstract: TBA

Friday, 14 December 2018, 16:00
Speaker: TBA
Title: TBA
Abstract: TBA