University of Reading SIAM-IMA Student Chapter Conference 2022

10 – 11 AM

Dr Ruth Bowness, University of Bath

"Modelling infectious diseases within-host using a hybrid multiscale individual-based model"

Abstract:

During the talk I will describe a hybrid multiscale individual-based model that we have developed, which simulates pulmonary infection spread, immune response and treatment within in a section of human lung. The model contains discrete agents which model the spatio-temporal interactions (migration, binding, killing etc.) of the pathogen and immune cells. Cytokine and oxygen dynamics are also included, as well as Pharmacokinetic/Pharmacodynamic models, which are incorporated via PDEs. In this talk, I will describe my work using this model to study two infectious diseases: Tuberculosis and COVID-19.

11 – 11.30 AM

Nikoleta Vavouraki, University of Reading

" Modelling macroautophagy and its interplay with Parkinson's disease "

Abstract:

Background: Macroautophagy is a complex biological process associated with multiple human diseases, including neurodegenerative diseases, such as Alzheimer's disease, Frontotemporal dementia, Amyotrophic lateral sclerosis, and Parkinson's disease (PD). PD is the second most common neurodegenerative disease but disease-modifying therapies are still unavailable. Understanding the interplay of macroautophagy with PD could aid in the identification of therapeutic interventions. Therefore, in this project we created a mathematical model of macroautophagy, in which we simulated the effect of PD, and explored the differential effect of LRRK2 mutations leading to PD. Methods: A mathematical model simulating the main events of the initiation of macroautophagy was created based on ordinary differential equations using the SimBiology toolbox of MATLAB. Parameterisation was performed by mining the literature. Two states were simulated: a healthy state and a PD state that differed in the relative amount of the model entities. Data regarding how mutations in LRRK2 that lead to PD affect macroautophagy were also incorporated in the model.

Results: The comparison of healthy versus PD state suggested that macroautophagy is initiated earlier but progresses with a slower rate in PD. In addition, two LRRK2 mutations were simulated providing a mechanistic explanation for their differential severity in human health. G2019S was shown to decrease the level of macroautophagy, whilst D1994A to increase macroautophagy.

Conclusions: The mathematical model of macroautophagy created in this study was able to simulate differential behaviour of macroautophagy in PD compared to a healthy state. Furthermore, it provides a mechanistic explanation for the differential effect of two LRRK2 mutations leading to PD that could be utilised for designing therapeutic interventions. Overall, modelling the interplay of complicated biological processes and diseases is a powerful approach that can accelerate the development of disease-modifying therapies.

11.30 AM – 12 PM

Vishu Antani, University of Exeter

" Bayesian and Classical Statistical Modelling of Infectious Diseases "

Abstract:

This talk would present two separate reports: "Bayesian Modelling of the Spread of COVID Variants in the UK" and "Modelling the Spread of Tuberculosis in Brazil using Generalised Additive Models (and Mixed Models)". The presentation of the reports would be focussed on highlighting the key differences in the two schools of probability, how those differences reflect in terms of building a model, and the kind of statements that can be inferred from the models. The aim of the talk would be to equip the audience with necessary knowledge to understand different modelling techniques and decide for themselves the kind of models they would like to use in their next tasks.

1 – 2 PM

Dr Larissa Serdukova, University of Reading

"Levy-noise versus Gaussian-noise-induced Transitions in the Ghil-Sellers Energy Balance Model "

Abstract:

We study the impact of applying stochastic forcing to the Ghil-Sellers energy balance climate model in the form of a fluctuating solar irradiance. Through numerical simulations, we explore the noise-induced transitions between the competing warm and snowball climate states. We consider multiplicative stochastic forcing driven by Gaussian and α-stable L\'evy - $\alpha\in(0,2)$ - noise laws, examine the statistics of transition times, and estimate most probable transition paths. While the Gaussian noise case - used here as a reference - has been carefully studied in a plethora of investigations on metastable systems, much less is known about the L\'evy case, both in terms of mathematical theory and heuristics, especially in the case of high- and infinite-dimensional systems. In the weak noise limit, the expected residence time in each metastable state scales in a fundamentally different way in the Gaussian vs. L\'evy noise case with respect to the intensity of the noise. In the former case, the classical Kramers-like exponential law is recovered. In the latter case, power laws are found, with the exponent equal to $-\alpha$, in apparent agreement with rigorous results obtained for additive noise in a related - yet different - reaction-diffusion equation as well as in simpler models. This can be better understood by treating the L\'evy noise as a compound Poisson process. The transition paths are studied in a projection of the state space and remarkable differences are observed between the two different types of noise. The snowball-to-warm and the warm-to-snowball most probable transition path cross at the single unstable edge state on the basin boundary. In the case of L\'evy noise, the most probable transition paths in the two directions are wholly separated, as transitions apparently take place via the closest basin boundary region to the outgoing attractor. This property can be better elucidated by considering singular perturbations to the solar irradiance.

2 – 2.30 PM

Niccolò Zagli, Imperial College London

"Dimension Reduction for noisy multi-agent systems "

Abstract:

High dimensional systems feature a huge numbers of interacting degrees of freedom, possibly spanning various orders of magnitude in space and time. An exact theoretical description of these systems is an incredibly hard modelling task to achieve. Moreover, even if one had such models at hand, it would be very difficult to handle them with the computational power we have at the moment. Dimension reduction techniques allow to find a suitable representation of the time evolution of a few relevant number of degrees of freedom whose dynamics is shaped by the neglected variables.

In this talk I will be presenting our latest results on dimension reduction techniques for interacting multi agent systems. I will show that the dynamics can be written in terms of a few variables, defined as the cumulants of a suitable probability distribution that one obtains in the big number of agents limit. The reduced dynamics can reproduce not only the stationary properties of the system, but also its dynamical linear response features.

2.30 – 3 PM

Joe Zhang, Brunel College London

"Markov Chain Monte Carlo –Bayesian Inference "

Abstract:

In the Bayesian world, “random” means stating that a random variable – could be a scalar, tensor, network, etc. – takes a value with a probability, i.e. it attains a value that lies in a given interval, with uncertainty. Here such a probability is given by a probability distribution that underlines this random variable, conditional on the data and/or belief systems. In general, we want to make inference on the unknown parameters in a model, using the modelled probability distribution of each such unknown, given the data. In my talk, I will present the background, along with the motivation for undertaking inference via sampling from the (joint) probability of all unknowns given the data, using Markov Chain Monte Carlo (MCMC) methods. I will illustrate this with implementation on a real-world problem, namely, the learning of the probability of failure of the O-rings of the Challenger Space Shuttle, at a given atmospheric temperature.

3.30 – 4.30 PM

Dr Ali Aouad, London Business School

"Algorithm Design for Operational Decision-Making: From Online Platforms to Cultural Institutions"

Abstract:

Matching supply with demand is a fundamental task in online optimization with application to operations and economics. In this talk, I will describe two recent research projects that illustrate new theoretical and practical issues in this area. In the first paper, I explore the importance of timing and delays in reaching efficient allocations of resources in matching markets. We propose a new Bayesian model of dynamic matching and devise simple matching algorithms that admit strong worst-case performance guarantees for a broad class of graphs. We demonstrate the practical benefits of this approach on a realistic simulator of a car-pooling platform. In the second paper, we explore the application of analytics and operations research to the visitor experience in a major museum. We empirically validate a sequential choice model describing visitors' interactions with the artworks on display in the layout, and we simulate simple layout interventions that can significantly enhance visitor engagement.

4.30 – 5 PM

Ignacia Fierro, University College London

"An On-Surface-Radiation Condition Preconditioner for the Electric Field Integral Equation"

Abstract:

The Electric Field Integral Equation (EFIE) is commonly used to solve high-frequency electromagnetic scattering problems. However, the EFIE being a First Kind Fredholm operator, needs a regulariser in order to use iterative solvers [1]. A regulariser alternative is the exact Magnetic-to-Electric (MtE) operator, which has the disadvantage of being as expensive as solving the EFIE. However, the authors in [2] have developed a local surface approximation of the MtE for time-harmonic Maxwell's equations that can be efficiently evaluated through the solution of sparse linear systems. In this research we demonstrate the preconditioning properties of the approximate MtE operator for the EFIE using a Bempp implementation and show a number of numerical comparisons against other preconditioning techniques like the Calderon Preconditioner.

References: [1] H. Bagci, F.P. Andriulli, K. Cools, F. Olyslager and E. Michielssen, A Calder on multiplicative preconditioner for the combined field integral equation, IEEE Transactions on Antennas and Propagation 57 (2009) pp.3387-3392.

5 – 5.30 PM

Gabriele Di Bona, Queen Mary University of London

"Socially-enhanced discovery processes"

Abstract:

Discoveries are essential milestones for the progress of our society. Therefore, unveiling the hidden mechanisms behind the emergence of new ideas is not only interesting from a scientific point of view, but also has a tangible sociological and economical impact. Recently, different mathematical approaches have been proposed to investigate and model the dynamics leading to the emergence of the new. Among these, of particular interest are random processes with reinforcement, such as urn models and biased random walks. These models successfully replicate the basic signatures of real-world discovery and innovation processes. However, they neglect the effects of social interactions. In particular, by considering the exploration dynamics as the one of a single entity and thus neglecting the multi-agent nature of the process, these models (i) do not capture the heterogeneity of the pace of the individual explorers; (ii) do not include the benefits brought by collaborations, more broadly, social interactions. Indeed, empirical evidences of these mechanisms have been found in various contexts, from music-listening and language to politics and voting.

In this talk I give insights on how our peers can influence our experience of the new, using theoretical and data-driven mathematical models. In the first part of the talk, I introduce the model proposed in Physical Review Letters 125.24 (2020), p. 248301, where each explorer is associated with an urn model with triggering that governs its exploration and discovery dynamics. Urns are coupled through the links of a complex network, so that each exploration process is also subjected to interactions with the processes of the neighboring nodes, and explorers can exploit opportunities (possible discoveries) coming from their social contacts, in a cooperative manner. We study the impact of the network topology on the exploration dynamics and we find that the pace of discovery of an explorer strongly depends on its position in the social network, suggesting that a strategic location on the social network correlates with the discovery potential of an individual. In particular, we show that the ranking of the nodes that distinguishes the fastest explorers can be predicted analytically by using

the eigenvector centrality. This highlights that the structural (not just local) properties of the nodes can strongly affect the agents' ability to make novel experiences.

In the second part of the talk I investigate a data set containing the whole listening histories of a large, socially connected sample of users from the online music platform Last.fm. We demonstrate in arXiv:2202.05099 that users exhibit highly heterogeneous discovery rates of new artists and that their social neighborhood significantly influences their behavior. In particular, we find that more explorative users tend to interact with peers more prone to explore new content. We capture this phenomenology in a data-driven modeling scheme where users are represented by random walkers exploring a graph of artists and interacting with each other through their social links. As in the previous model, each agent is associated to an urn, but, differently from it, they interact with their peers by checking the current artist listened by one of their friends. Interestingly, even starting from a uniform population of agents (no natural differences among the individuals), our model predicts the emergence of strong heterogeneous exploration patterns, with users clustered according to their musical tastes and propensity to explore.

We hope our work can represent a significant step forward to develop a general framework to understand how social interactions shape discovery and innovation processes.