**UK and Republic of Ireland Section of SIAM**

20TH ANNIVERSARY SECTIONAL MEETING

University of Cambridge, January 7, 2016

**PROGRAMME**

SESSION 1
Chair: Dr Jennifer Scott

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10:10 - 10:15 Introduction and Welcome

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10:15 - 11:00 **Prof Martin Hairer**, FRS
Stochastic PDEs and Their Approximations

11:00 - 11:25 **Dr Jennifer Pestana**
Symmetrizing Toeplitz Matrices and Consequences for Solving Linear Systems

11:25 - 12:10 **Prof Simon Tavaré**, FRS, FMedSci, LMS President
How Useful is Mathematical Modelling in Cancer Research?

12:10 - 12:45 **Business Meeting**
AGENDA: Review of Section Activity in 2015; Discussion of future plans; Any other business.

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12:45 - 14:00 Lunch and Poster Presentations

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SESSION 2
Chair: Prof Des Higham

14:00 - 14:45 **Prof Pam Cook**, SIAM President
Models of Transiently Networked Fluids: Wormlike Micelles

14:45 - 15:10 **Dr Sarah Mitchell**
Numerical Challenges Facing an Application of Stefan Problems: Continuous Casting of Metals

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15:10 - 15:50 Discussions and Coffee

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SESSION 3
Chair: Dr Angela Mihai

15:50 - 16:15 **Dr Jasmina Lazic**
MATLAB and the Mathematics of Our Lives: from Stacking Shelves in Supermarkets to Personalising Car Insurance Premiums

16:15 - 17:00 **Prof Barbara Wohlmuth**, IMA Sponsored Speaker
Cost Reduction in PDE Simulation

# ABSTRACTS

## Models of Transiently Networked Fluids: Wormlike Micelles

Pam Cook

University of Delaware, USA
President, Society for Industrial and Applied Mathematics

Complex fluids are fluids which exhibit unusual (non-Newtonian) properties including elasticity and/or non constant viscosity - a viscosity that changes with applied shear rate. Complex, particularly visco-elastic fluids may also show fading memory and dynamic effects such as spurt and shearbanding, These fluids often contain permanently or transiently networked structures at the mesoscale. Transiently networked fluids include colloidal mixtures, polymer mixtures, and surfactant mixtures. Surfactant mixtures occur in bodily fluids (for example mucus), in consumer products (detergents, shampoos), in the oil industry (fracking agents) among other places. In this talk experimental observations and macroscale and mesoscale modeling and simulations of self-assembling surfactant mixtures will be presented and contrasted. Mathematically the framework is: at the macroscale, a coupled system of nonlinear reaction diffusion equations; at the mesoscale stochastic differential equations with the topology of the structures tracked. Particular attention is paid to the fluid behavior under changing conditions such as concentration or temperature, in which case the characteristics of the dynamic behavior change.

## MATLAB and the Mathematics of Our Lives: from Stacking Shelves in Supermarkets to Personalising Car Insurance Premiums

Jasmina Lazic

MathWorks Application Engineering, UK

Mathematical models are critical to understanding and accurately predicting the behaviour of complex systems. In this talk we will show how several leading UK companies have used MATLAB to build mathematical models and leverage large datasets in order to create insight and achieve desired business outcomes. We will discuss the challenges that mathematical analysts in industry are facing in a modern technology environment with the abundance of big and complex datasets from a plethora of different sources. From detecting traffic collisions and optimising supermarket product price reductions, to real-time process monitoring and estimating oncology drug efficiency, we will demonstrate a number of ways in which MATLAB bridges the gap between mathematical modelling and business integration, including:

- Sophisticated algorithms for machine learning and predictive modelling;
- Techniques for handling big data;
- Deployment and integration options.

### Numerical Challenges Facing an Application of Stefan Problems: Continuous Casting of Metals

Sarah Mitchell

University of Limerick, Ireland

In a continuous casting process, such as the strip casting of copper, molten metal first passes through a water-cooled mould region, before being subjected to a high cooling rate further downstream. Consequently, the molten metal solidifies and the solidified metal is withdrawn at a uniform casting speed. Industrialists need to understand the factors influencing product quality and process productivity. Of key significance is the heat transfer that occurs during solidification, particularly the location of the interface between molten metal and solid. The modelling of the continuous casting of metals is known to involve the complex interaction of non-isothermal fluid and solid mechanics. Typically, the flow in the molten metal is turbulent, and it is generally believed that a computational fluid dynamics (CFD) approach is necessary in order to correctly capture the heat transfer characteristics. However, we can show that an asymptotically reduced version of the CFD-based model, which neglects this turbulence, gives predictions for the pool depth, local temperature profiles and mould wall heat flux that agree very well with results of the original CFD model. This reduced model can be described as a steady state 2D heat flow Stefan problem, with a degenerate initial condition and non-standard Neumann-type boundary condition. In this work we highlight some numerical challenges in solving these types of systems. We also discuss extensions which include allowing for shrinkage in the metal and in calculating the thermally-induced stresses and strains, which are again of interest to industrialists.

### Symmetrizing Toeplitz Matrices and Consequences for Solving Linear Systems

Jennifer Pestana

University of Strathclyde, UK

Linear systems involving Toeplitz matrices are found in many applications, including differential and integral equations, signal and image processing, control theory and time series. When the Toeplitz matrix is symmetric we can, for a large class of problems, guarantee rapid convergence of popular iterative methods (CG or MINRES) by utilizing circulant preconditioners. However, the situation is rather different for nonsymmetric problems. Although circulant preconditioners often work well in practice, convergence rates are in general only guaranteed if we solve the normal equations, which tends to be significantly slower. Here, we present a simple symmetrization of nonsymmetric Toeplitz matrices that allows us to guarantee rapid convergence for MINRES. We also discuss connections between MINRES and GMRES for banded Toeplitz matrices. This is joint work with Sean Hon, Elle McDonald and Andy Wathen.

## How Useful is Mathematical Modelling in Cancer Research?

Simon Tavaré

Director, Cancer Research UK Cambridge Institute
Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK
President, London Mathematical Society

The mathematical sciences have contributed substantially to our understanding of many aspects of biology and medicine. For example, stochastic process and statistical methods are crucial in population and evolutionary genetics, and computer science and machine learning play a key role in applications of genomics to human health. Conversely, questions in biology and medicine have led to novel mathematics. In this talk I will discuss a relative newcomer to the world of "mathematical biology", namely cancer evolution. Cancer is a disease of the genome, so my focus will be on mutations in DNA and what they tell us about tumour evolution. I will discuss aspects of tumour heterogeneity, the DNA sequence variation observed between tumours and within them, and what this tells us about progression, treatment and relapse. I hope to make the case that mathematical modeling is essential to understanding how tumours evolve, and is likely to point the way to better treatments for cancer.

## Cost Reduction in PDE Simulation

Barbara Wohlmuth

Technische Universität München, Germany
IMA Sponsored Speaker

In this talk we present different examples for reducing the computational complexity in the numerical solution of PDEs. Our special focus is on problems related with the mathematical modelling in vibro-acoustics and in transport within networks. We combine a reduced basis approach with mortar techniques in the case of eigenmode analysis. Firstly, the mortar approach allows us to reduce the complexity of the mesh and to reduce thin 3D layered inclusions onto 2D interface couplings. A modal assurance study shows that the reduced model is able to resolve accurately the eigenmodes. Secondly, the parameter dependent orthotropic elasticity problem is handled by a reduced basis scheme. We provide an error estimator bounding simultaneously all eigenvalues of interest. The estimator is not restricted to single eigenvalues. Compared to a POD approach, the greedy strategy yields almost the same accuracy while being considerably less computational cost intensive. The full potential of dimension reduced techniques can be exploited in case of the numerical study of physiological effects. Although the dimension reduction enters as a measure valued source term into the right hand side, no pollution effect in a fully 0D-1D-3D model occurs. Here we restrict ourself on the numerical study of compensation effects in case of a peripheral arterial stenosis.