POSTERS

- **Sarah Murphy** (*University College Dublin*) – Emergent Roughness from Non-Uniform Melting Processes

  Rippled surface patterns are observed in a wide range of natural environments, such as glacier surfaces and cave walls [1]. However, when modelling large scale ice-ocean dynamics, the interface between the glacier and the sea is assumed to be smooth due to uncertainties surrounding the effect the roughness has on the heat transfer [2]. Using simple models, we aim to understand how the shape of the emergent surface roughness depends on variations in the local melt rate. Following a similar approach to [3], we discretise the domain and model the melting process by evolving the interface locally in the normal direction. We control the strength of the melting at each grid point using a melt-rate function. We begin by reproducing and verifying the results previously reported for one-dimensional homogeneous melting in [3], thereby establishing a benchmark for our methodology. We then extend this framework to investigate the evolution of a two-dimensional interface subject to slope-dependent melting to mirror the profile of the conductive sublayer seen in [4]. We introduce several non-uniform melting regimes, including sinusoidal and asymmetrical melting. In doing so, we aim to investigate the emerging roughness patterns as a result of the heterogeneous melting.

  References

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- **Ann Paterson** (*Trinity College Dublin*) – An Iterative Block Matrix Inversion Algorithm for Symmetric Positive Definite Matrices with Applications to Covariance Matrices

  Obtaining the inverse of a large symmetric positive definite matrix is a continual challenge across many mathematical disciplines. The computational complexity associated with direct methods can be prohibitively expensive, making it infeasible to compute the inverse. We present a novel iterative algorithm (IBMI), which is designed to approximate the inverse of any large, dense, symmetric positive definite matrix. The matrix is first partitioned into blocks, and an iterative process using block matrix inversion is repeated until the matrix approximation reaches a satisfactory level of accuracy. We demonstrate that the two-block, non-overlapping approach converges for any positive definite matrix, while numerical results provide strong evidence that the multi-block, overlapping approach also converges for such matrices.

- **Leo Creedon & Iqra Naz** (*Atlantic Technological University, Sligo*) – Algebraic Cellular Automata for Biological Modelling

  Traditionally, differential equations have been used to model biological systems and are analysed through analytical, statistical and computational approaches. As cellular automata (CA) are discrete and rule-based, they can provide an alternative framework that represent evolving local interactions and global behaviours of the system. CA can produce complex global patterns despite their discrete nature, which makes them a useful tool for modelling dynamic processes in nature. CA are discrete computational models that simulate complex systems through simple local rules. The mathematical theory of CA has been significantly improved by its connection to topology and group theory. The states of a CA evolves in discrete time steps according to a given local rule which updates the value of each cell based on the values of the cells in its neighbourhood. In this research, we focus on algebraic cellular automata, which includes the analysis of equivariant mappings, action of groups, and group rings. The goal of the project is to create a link between abstract algebra and modelling of biological processes by exploring the algebraic structures of cellular automata. This will lead to applications of algebraic cellular automata in veterinary and biological systems.

- **Ramen Ghosh** (*Atlantic Technological University, Sligo*) – When a Single Antagonist Breaks Ergodicity: Collapse and Recovery in Stochastic Networks

  Think of a noisy network in which most nodes cooperate, but one node keeps sending harmful feedback to its neighbors. The question is not just whether disagreement appears for a while, but whether that one bad actor can change the entire long-run statistical behavior of the network. Our answer is yes. Beyond a critical antagonism level, the network can lose its unique long-run regime. We then show two ways the network can protect itself: add sparse local damping, or let the topology adapt by rewiring away from persistent disagreement. The catch is that restoring statistical stability can come at a control cost: the network becomes harder to steer, reflected by spectral collapse of the controllability Gramian.

- **Jekaterina Mosalska** (*University of Galway*) – Conditioning of Linear Systems Coming from Singularly Perturbed Convection–Diffusion Problems

  Singularly perturbed convection-diffusion problems arise in many applications, such as fluid dynamics and transport processes. These problems often exhibit sharp boundary or interior layers, which makes them challenging to approximate numerically. Standard discretization methods typically lead to large linear systems that are poorly conditioned and therefore difficult to solve efficiently. In this work, we study finite difference discretizations with upwinding on layer-adapted Shishkin meshes for convection-diffusion equations in one and two dimensions. In the one-dimensional case, we analyse the structure of the resulting matrices and prove bounds on their condition numbers, showing how these depend on the mesh size and the perturbation parameter. Numerical experiments in Python confirm the theoretical results. We extend the study to the two-dimensional case, where the matrices are more complex, and investigate the behaviour of the condition number numerically. The results agree well with the one-dimensional theory and provide a basis for efficient solution methods. Future work will focus on extending the theoretical results to the two-dimensional case and developing effective LU-based preconditioners for these systems.

- **Lyudmila Ivanova** (*TU Dublin*) – Internal Ocean Waves in the Presence of Currents: A Benjamin–Ono Model

  Internal water waves arise from density nts: stratification in the ocean, caused by variations in temperature and salinity, and propagate along the interface between fluid layers. These waves usually coexist with ocean currents. A typical example occurs in the equatorial region of the Pacific Ocean, where internal waves are widespread, and the Equatorial Undercurrent (EUC) has a depth-dependent velocity profile that creates vertical shear. We consider a nonlinear model for interfacial waves in a two-layer system with a finite upper layer and an infinitely deep lower layer. In a suitable asymptotic regime, this model is described by the integrable Benjamin–Ono equation, which admits stable soliton solutions. We analyse the influence of shear currents on wave dynamics. The results show that even small variations in the shear lead to substantial changes in soliton amplitude and propagation speed.

- **John Butler & Rebecca Brady** (*TU Dublin*) – Mathematical Modelling of Neuronal Processing and Behavioural Responses to Multisensory Signals

  Efficient navigation in everyday environments depends on the brain's ability to integrate information from multiple sensory modalities. Behavioural studies have demonstrated both winner-take-all dynamics and statistically optimal integration during multisensory processing. In contrast, impairments in multisensory integration have been linked to increased fall risk in older adults relative to age-matched healthy controls. Although the model of sensory decision-making proposed by Wong and Wang (2006) has been highly influential, existing computational work has largely focused on unisensory tasks. To address this limitation, we extend their reduced two-variable model to simulate both unisensory and multisensory neural processing and associated behavioural responses. The resulting model, formulated using biologically grounded ordinary differential equations, is applied to audio-visual speeded reaction-time tasks and visual-vestibular decision-making paradigms. The extended model successfully reproduces key behavioural findings reported in the multisensory literature. Itt also provides new insights into the relative proportions of unisensory and multisensory neurons required to achieve optimal multisensory integration. The model provides a computational framework for investigating adaptive and maladaptive multisensory processing.