
AARMS-CMS Student Poster Session
Présentations par affiches des étudiants - AARMS-SMC
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WILLIAM FORGET, Bishop's University

Understanding Neural Networks Through the Knowledge Matrix

This project investigates formal methods for analysing neural network performance using a compact knowledge matrix that captures relationships among learned features across all layers of the model. For each input, the knowledge matrix is treated as a point in a high-dimensional space, forming a point cloud that reflects the network's internal representation of the data. We then apply dimensionality reduction techniques such as PCA and LDA to study the structure of these representations in lower dimensions. The resulting embeddings are compared with representations from the penultimate and output layers in order to evaluate how well the knowledge matrix preserves information about the network's behaviour.

FATIMA ISLAM, University of New Brunswick

Impact of Dispersal on Total Equilibrium Biomass in Patch-Structured Logistic Models.

Understanding how dispersal asymmetry influences total equilibrium biomass in spatially structured populations remains a key challenge in mathematical ecology. This study extends classical two-patch logistic models by incorporating a mixed dispersal strategy that combines random and density-dependent movement. The dispersal rate from each patch is governed by a fitness function parameterized by dispersal strength and asymmetry ratio. Using geometric phase-plane analysis, specifically the intersection of an ellipse and a hyperbola derived from the equilibrium conditions, we characterize the unique positive equilibrium and prove its global asymptotic stability via Dulac's criterion and the Poincaré–Bendixson theorem. Our results reveal four distinct dispersal regimes based on the position of a limiting hyperbola relative to three critical points on the ellipse. These regimes determine whether total equilibrium biomass increases, decreases, peaks at an intermediate dispersal strength, or crosses the isolated baseline. The framework resolves the so-called Perfect-Mixing Paradox by showing that asymmetry fundamentally alters the relationship between connectivity and total biomass, offering a more complete picture than previous symmetric or purely nonlinear models.

HIN LON LAO, York University

TRANSVERSAL MATROIDS AND THEIR PRESENTATIONS

A matroid M on a finite ground set S is said to be *transversal* if its collection of independent sets are partial transversals of a system $\mathfrak{A} = (A_1, \dots, A_n)$ of subsets of S . The system \mathfrak{A} can be represented by a bipartite graph $G_{\mathfrak{A}} = (S \cup V, E)$. We are going to see how to spot the circuits of M by looking at $G_{\mathfrak{A}}$. If $S' \subseteq S$, let $S'_{\mathfrak{A}}$ denote the induced subgraph of S', V' in $G_{\mathfrak{A}}$, where V' is the elements from V which are adjacent to at least one element in S' . If a $G_{\mathfrak{A}}$ for a transversal matroid M is acyclic, then $C_{\mathfrak{A}}$ admits a particular nice description for every circuit C of M . Moreover, if the members of $\{C_{\mathfrak{A}} : C \text{ is a circuit of } M\}$ intersect in some particular way in $G_{\mathfrak{A}}$, we can get another presentation $G_{\mathfrak{A}'}$ of M such that part of $G_{\mathfrak{A}'}$ is acyclic.

MARZIEH ROSHANI, University of Manitoba

Rate-Dependent Tipping in Human–Ecological Systems

Tipping points are thresholds beyond which ecosystems undergo dramatic and sometimes irreversible regime shifts. Rate-induced tipping (r-tipping) occurs because external changes outpace a system's capacity to adapt. This is especially relevant in socio-ecological systems, where rapid increases in resource exploitation, pollution, or abrupt policy shifts can drive the system away from its basin of attraction, triggering unintended regime shifts. Pollution rates depend on ecological, economic, and social factors, and policy interventions such as fines or incentives can influence them. The rate at which interventions change can trigger r-tipping, shifting the system between ecologically desirable and undesirable states. For example, rapid

policy relaxation can lead to abrupt shifts to highly polluted states. On the other hand, sufficiently rapid strengthening of incentives can deliberately induce a shift toward healthy ecosystems, making r-tipping either a risk or a management tool. Oscillation amplitude also affects outcomes in complex ways. Under certain circumstances, only intermediate amplitudes can trigger r-tipping to an ecologically undesirable state; low amplitudes produce no tipping (as expected), but surprisingly, very high amplitudes also avoid tipping. This non-trivial pattern is not yet theoretically understood and highlights a clear direction for further research. I plan to explore how seasonal fluctuations in social, economic, and associated ecological costs affect ecological outcomes. I will model these seasonal effects by allowing associated parameters to oscillate and change in biologically meaningful ways. In addition, I will investigate gradual parameter shifts, such as slowly increasing fines or climate change trends that alter baseline ecological conditions.

AIDEN TAYLOR, University of Calgary
Learnable Wavelet Filter Banks in Convolutional Neural Networks

Deep learning methods such as a Convolutional Neural Network (CNN) typically learn filters directly from data, which reduces the need for engineers to design filters for specific problems. This is great for general use, but learned filters in deep learning methods are usually unintelligible due to their lack of mathematical structure, and multiresolution/multiscale behaviour is learned implicitly. An easy solution to both of these problems is to incorporate wavelet transforms into ones deep learning model because wavelet transforms provide a framework for multiresolution analysis, where wavelet filter banks naturally arise from, as well as provable approximation properties in terms of the vanishing moments of a wavelet. However, in practice, said wavelet filter bank are often fixed and do not learn from the data given to them. This motivates the question of whether or not we can formulate learnable wavelet filter banks. In our research, we explore using the vanishing moments of wavelets as a viable avenue for learnability as wavelet filters can be factorized in a way to fix the number of vanishing moments along with certain degrees of freedom. To investigate the relationship between the number of vanishing moments (denoted L) and the degrees of freedom (denoted N), we compute the classification accuracy of a labeled dataset of images with different combinations of L and N . In the end, we find that the vanishing moments of wavelets are indeed a viable avenue for learnable wavelet filter banks as well as a heuristic proportional relationship between L and N .

LUYAO ZHAO, University of New Brunswick
A Unified Mathematical Study of Four Within-Host Mycobacterium tuberculosis Models

Tuberculosis infection within a host is shaped by interactions among uninfected macrophages, infected macrophages, and extracellular *Mycobacterium tuberculosis* (MTB). In this poster, we develop and compare four within-host MTB models within a unified three-dimensional framework. The models share the same infection and bacterial-production structure, but differ in how they represent macrophage maintenance, local proliferation, local crowding, and macrophage-mediated bacterial loss. For each model, we derive the nontrivial disease-free equilibrium and compute the basic reproduction number R_0 using the next-generation matrix method. A unified Lyapunov approach is then used to establish global stability of the disease-free equilibrium when $R_0 \leq 1$, under suitable biological assumptions.

We further study the existence and local stability of positive equilibria, which represent persistent chronic infection states. The analysis shows how different modeling assumptions change the threshold conditions for infection persistence and the stability of chronic infection. In addition, Hopf bifurcation analysis with respect to the infection rate β illustrates that increasing infection efficiency may destabilize the positive equilibrium and generate oscillatory dynamics in infected cells and extracellular bacterial load. Numerical simulations are used to support the analytical results and to compare stable, unstable, and oscillatory regimes. Overall, this work highlights how local macrophage regulation, external cell recruitment, and bacterial clearance mechanisms jointly shape MTB persistence and within-host infection dynamics.