AARMS-CMS Student Poster Session
Présentations par affiches des étudiants - AARMS-SMC

(Org: **Emily Carlson** (University of Waterloo))

STÉPHANIE ABO, University of Waterloo
Modeling the circadian regulation of the immune system: sexually dimorphic effects of shift work

Shift work has a negative impact on health and can lead to chronic diseases and illnesses. Under regular work schedules, rest is a night time activity and work a daytime activity. Shift work relies on irregular work schedules which disrupt the natural sleep-wake cycle. This can in turn disrupt our biological clock, called the circadian clock, a network of molecular interactions generating biochemical oscillations with a near 24-hour period. Clock genes regulate cytokines before and during infection and immune agents can also impact the clock function. We provide a mathematical model of the circadian clock in the rat lung coupled to an acute inflammation model to study how the disruptive effect of shift work manifests itself in males and females during inflammation. Our results show that the extent of sequelae experienced by male and female rats depends on the time of infection. The goal of this study is to provide a mechanistic insight of the dynamics involved in the interplay between these two systems.

DENIZ ASKIN, Carleton University
Coarse-To-Fine Semantic Parsing with Transformers

Semantic Parsing is the task of translating a natural language sentence to a language that can be processed by a computer (e.g. first-order-logic, lambda calculus and Prolog). This translation allows one, for example, to query databases and command virtual assistants using natural language. An example of a semantic parsing dataset is the Geo880, which contains 880 sentences in English on US geography, and their corresponding translations in Prolog format.

Ex: what is the population of oregon ? answer (A , (population (B , A) , const (B , stateid (oregon))))

Currently, neural network based models called Transformers (the engines behind Google's Translate) give state-of-the-art results on all of the benchmark sematic parsing datasets.

In this poster presentation, we will propose our own Transformer-Based Semantic Parser (TBSP) which uses a two-layered approach, each layer being a Transformer.

Our method uses a rough sketch of the parse (a 'coarse' parse) at the first layer, where the rough sketch contains an ordered list of all the logical operators, predicates, relations and constants present in the semantic parse of the inputted natural language sentence.

The second layer accepts this rough sketch as input and outputs the final semantic parse (a 'fine' parse).

We will be reporting on our model's performance on the Geo880 and its improvement over the accuracy of a one-layered TBSP.

HARRIS HAMID, McMaster University
Lebesgue Integration

This type of integration is modern and is another approach to integrating exotic functions. This method is a way to solve non-elementary functions such as the normal distribution function without error. It was invented by Henri Lebesgue, a French mathematician who noticed that the Riemann integral could not solve most of the non-elementary functions, so he introduced a newer approach to overcome the problems that the Riemann integral cannot solve.

YUYING LI, Western University
Modelling and pricing cyber security risk

The cyber risk insurance market is rapidly developing with more products being developed that cover the potential losses attributed to cyber attacks. This requires the insurance business to have a modelling and pricing framework necessary to obtain a fair price that will enable policy issuers to fulfill their future obligations. We present a valuation framework that integrates cyber risk modelling and calibration. A regime-switching Markov model is put forward to capture the occurrences of cyber attacks. The transition probabilities of the Markov chain are governed by another hidden Markov chain representing the various states of the cybersecurity environment. Based on the stages of the cyber attack, a cyber kill chain is built. The states are firewall working, firewall fail, and antiphising fail. A cyber attack happens when there is a transition from either of the first two states to the third state. With the aid of change of reference probability measures and the EM algorithm, dynamic estimates of the model parameters are obtained. Our main point of interest is the random loss from cyber attack, which is modelled by a doubly-truncated Pareto distribution. The Vasiček model is utilized to describe the interest rate process for the discounting of losses. The premium for a cyber security insurance contract is calculated via a simulated data set based on two pricing principles. Our methodology featuring dynamic parameter estimation and flexible adjustments in modelling various risk factors widens the available tools for valuation and risk management beneficial to insurance companies and regulators.

RAJARSHI MAITI, Queen's University Belfast

NICOLE MOON-KECA, Concordia University of Edmonton
An Application of the LLL Algorithm in Number Theory

The Mertens conjecture if proven to be true would imply one of the millennium problems, the Riemann Hypothesis. Odlyzko and te Riele disproved this conjecture by utilizing the Lenstra-Lenstra-Lovász algorithm (LLL). Moreover, the LLL algorithm can efficiently provide solutions for the problem of simultaneous Diophantine approximation. The purpose of this project is to study applications of the LLL algorithm, namely, Diophantine approximation and Mertens conjecture.

JAMES MORAN, University of Montreal
Non-linear ladder operators and coherent states for the 2:1 oscillator

The 2:1 two-dimensional anisotropic quantum harmonic oscillator is considered and new sets of states are defined by means of normal-ordering non-linear operators through the use of non-commutative binomial theorems as well as solving recurrence relations. The states generated are good candidates for the natural generalisation of the su(2) coherent states of the two-dimensional isotropic oscillator. The two-dimensional non-linear generalised ladder operators lead to several chains of states which are connected in a non trivial way. The uncertainty relations of the defining chain of states are calculated and it is found that they admit a resolution of the identity and the spatial distribution of the wavefunction produces Lissajous figures in correspondence with the classical 2:1 oscillator.

GAVIN OROK, University of Waterloo
Local Dimensions of Self-Similar Measures in the Sierpinski Gasket

This project attempted to determine the set of all possible local dimensions of points in the support of probability measures in the iterated function system (IFS) that generates the Sierpinski Gasket fractal. The Sierpinski Gasket is the generalization of the Sierpsinski's Triangle fractal to the case where the contraction factor of the IFS is in $(\frac{1}{2}, \frac{2}{3})$. Calculations of the fractal's Hausdorff dimension and the local dimensions of measures are challenging in this case because there are overlaps between the triangular images from the IFS. The method used in this project to overcome difficulties caused by these overlaps was based on work by Kathryn Hare, Kevin Hare and Kevin Matthews that studied the one-dimensional version of this problem, the Bernoulli convolutions. Like in this work, the analysis focused on multinacci number contraction factors that resulted in the measures used being of finite type. First, a system of finitely many characteristic vectors was constructed that partition the images from the IFS into sets with disjoint interior. Then, a system of transition matrices was derived that relate the measures of consecutive parents and children in admissible paths through the characteristic vectors. Products of these matrices were used in place of closed balls to simplify calculations of local dimensions. Finally, these simplified calculations were analyzed over possible paths of characteristic vectors and points in the support to determine bounds on the local dimensions. Overall, the research managed to find trends in heuristic upper and lower bounds on the set of local dimensions.

ELKIN RAMÍREZ, McMaster University
Singularity Formation in the Deterministic and Stochastic Fractional Burgers Equation.

Motivated by the results concerning the regularity of solutions to the fractional Navier-Stokes system and questions about the influence of noise on the formation of singularities in hydrodynamic models, we have explored these two problems in the context of the fractional 1D Burgers equation. First, we performed highly accurate numerical computations to characterize the dependence of the blow-up time on the fractional dissipation exponent in the supercritical regime. The problem was solved numerically using a pseudospectral method where integration in time was performed using a hybrid method combining the Crank-Nicolson and a three-step Runge-Kutta technique. A highlight of this approach is automated resolution refinement. The blow-up time was estimated based on the time evolution of the enstrophy (H^1 seminorm) and the width of the analyticity strip. The consistency of the obtained blow-up times was verified in the limiting cases. In the second part of the thesis we considered the fractional Burgers equation in the presence of suitably colored additive noise. This problem was solved using a stochastic Runge-Kutta method where the stochastic effects were approximated using a Monte-Carlo method. Statistic analysis of ensembles of stochastic solutions obtained for different noise magnitudes indicates that as the noise amplitude increases the distribution of blow-up times becomes non-Gaussian. In particular, while for increasing noise levels the mean blow-up time is reduced as compared to the deterministic case, solutions with increased existence time also become more likely.

TURNER SILVERTHORNE, University of Toronto
Promoter methylation in a mixed feedback loop circadian clock model

The circadian (about a day) clock strikes a balance between robust intrinsic rhythmicity and plasticity to environmental cues. At a cellular level, interconnected transcription-translation feedback loops produce reliable limit cycle oscillations in core clock proteins. Although there has been extensive mathematical modelling, important questions remain about the effects of environmental signals on the molecular circadian clock. For instance, recent experiments suggest that epigenetic factors play a role in stably altering the circadian period. Briefly, epigenetic factors encompass a variety of molecular modifications that convey heritable information without altering the DNA sequence. In this poster, we present and analyze a novel, minimal model of the circadian clock. By including an additional degree of freedom in the classical mixed feedback loop model of Francois and Hakim, we analyze how epigenetic regulation alters the dynamics of the clock. We obtain conditions for equilibrium uniqueness and an asymptotic approximation to the clock's period, which allow us to bound the influence of epigenetic factors in our model. We then use another set of approximations to connect our model to a modified version of the Goodwin oscillator, previously studied in this context by Kim and Forger. Analysis of this reduced model reveals that although epigenetic factors can alter the period, they may also result in a loss in rhythmicity. Our analysis adds a quantitative perspective to an active area of biological research and offers several avenues for future work.

AXEL G. R. TURNQUIST, New Jersey Institute of Technology

YOUNES VALIBEIGI, McGill University
Development of a closed-feedback loop device between graphics card simulations and cardiac tissue

Cardiovascular disease is number one cause of death worldwide. Tachycardias, which are potentially deadly rapid rhythms, are often associated with reentry. Reentry is either anatomical, where a wave rotates around an unexcitable obstacle, or functional, where the wave has a spiral or scroll morphology in the tissue. Methods for studying and generating strategies for abolishing reentrant waves are limited due to difficulties in dynamically responding to the wave in real-time. A hybrid computer tissue interface that controls cardiac tissue in real-time therefore has the potential to revolutionize approaches for treating arrhythmias. However, until recently the development of computational simulations that predict cardiac electrophysiological wave propagation required the use of dedicated workstations that typically took many minutes to simulate seconds of activity. With the aid of a newly developed computational library (Abubu.js) that harnesses the power of the graphics card, it is now possible to develop large-scale simulations that predict wave dynamics in real-time. Using these GPU based simulations, we built a closed feedback loop device that connects a cultured cardiac monolayer with 2D simulations in real-time. This device can control cardiac tissue through the use of optogenetic tools that sensitize the tissue to light. Motion detection cameras with the aid of appropriate algorithms read the monolayer activations and provide information to the simulation, which in turn stimulates the tissue using microcontrollers and LEDs. We plan to use our closed-feedback loop to investigate anatomical re-entrant waves and also aim to study the effect of neuronal input on anatomical waves.

STÉPHANE VINET, Université de Montréal

Excitations and ergodicity of critical quantum spin chains from non-equilibrium classical dynamics

We study a critical quantum spin-1/2 chain that is dual to the non-equilibrium Kawasaki dynamics of a classical Ising chain coupled to a bath. The quantum spin chain is stoquastic, and depends on a single parameter: the Ising coupling divided by the bath's temperature. We give its exact ground states, and single-magnon excitations. Solutions for the two-magnon spectra are derived via a Bethe ansatz scheme. In the antiferromagnetic regime, the two-magnon branch states show intricate behavior, especially regarding hybridization with the continuum. Our analysis, when combined with previous studies, suggests that the system hosts multiple dynamics at low energy. Finally, we analyze the full energy level spacing distribution as a function of the Ising coupling. We conclude that the system is non-integrable for generic parameters, or equivalently, that the corresponding non-equilibrium classical dynamics are ergodic.