Dynamical systems and applications
Systèmes dynamiques et leurs applications
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SKYE DORE-HALL, University of Victoria
Ramp Function Approximations of Michaelis-Menten Functions in a Model of Plant Metabolism

Adams, Ehlting, and Edwards showed that in a model of plant phenylalanine metabolism following Michaelis-Menten kinetics, there are two mechanisms by which primary metabolism can be prioritized over secondary metabolism when input is low: the *Precursor Shutoff Valve* (PSV) and threshold separation. Analysis of the model was made difficult due to the presence of the Michaelis-Menten terms; hence, it is worth considering whether linear approximations of these terms can be used to both simplify the model and keep its qualitative behaviour intact. In this talk, we will introduce piecewise approximations of Michaelis-Menten functions called *ramp functions*. We will show that when the Michaelis-Menten terms are replaced by ramp functions in the model, the PSV is completely effective when it comes to the prioritization of primary metabolism under low input conditions, while threshold separation is effective when the PSV is absent, but only if the threshold constant of the secondary metabolic pathway is sufficiently larger than that of the primary pathway.

JUDE KONG, York University
Phytoplankton competition for nutrients and light in a stratified lake: a mathematical model connecting epilimnion & hypolimnion

In this talk, I will present several mathematical models describing the vertical distribution of phytoplankton in the water column. In particular, I will introduce a new mathematical model connecting epilimnion and hypolimnion to describe the growth of phytoplankton limited by nutrients and light in a stratified lake. Stratification separates the lake with a horizontal plane called thermocline into two zones: epilimnion and hypolimnion. The epilimnion is the upper zone which is warm (lighter) and well-mixed, and the hypolimnion is the bottom colder zone which is usually dark and relatively undisturbed. The growth of phytoplankton in the water column depends on two essential resources: nutrients and light. The critical thresholds for the settling speed of phytoplankton cells in the thermocline and the loss rate of phytoplankton are established, which determine the survival or extirpation of phytoplankton in epilimnion and hypolimnion. This is joint work with Jimin Zhang (Heilongjiang University), Junping Shi (William & Mary) and Hao Wang (University of Alberta).

MICHAEL Y LI, University of Alberta
Accurate Long-Term Projections of COVID-19 Epidemics by Incorporating Human Behaviours

Many lessons can be learned during the COVID-19 pandemic to improve epidemic modeling in order to produce accurate long-term model projections of epidemics. In the talk, I will show that why the final-size formula can explain the over-projections made by many epidemic models at the beginning of the pandemic, and how our understanding of real epidemics can be improved by examining all important drivers that collectively determine when an epidemic peak and terminate, and how human behaviours can be incorporated into the standard epidemic models to produce accurate and reliable long-term model projections.

JUNLING MA, University of Victoria
An SIR Contact Tracing Model for Randomly Mixed Populations

Contact tracing is an important intervention measure to control infectious diseases. We present a new approach that borrows the edge dynamics idea from network models to track contacts included in a compartmental SIR model for an epidemic spreading in a randomly mixed population. Unlike network models, our approach does not require statistical information of the contact network, data that are usually not readily available. The model resulting from this new approach allows us to study

the effect of contact tracing and isolation of diagnosed patients on the control reproduction number and number of infected individuals. We estimate the effects of tracing coverage and capacity on the effectiveness of contact tracing. Our approach can be extended to more realistic models that incorporate latent and asymptomatic compartments.

FELICIA MAGPANTAY, Queen's University
A quantification of transient dynamics

The stability of equilibria and asymptotic behaviors of trajectories are often the primary focuses of mathematical modeling. However, many interesting phenomena that we would like to model, such as the "honeymoon period" of a disease after the onset of mass vaccination programs, are transient dynamics. Honeymoon periods can last for decades and can be important public health considerations. In many fields of science, especially in ecology, there is growing interest in a systematic study of transient dynamics. In this work we attempt to provide a technical definition of "long transient dynamics" such as the honeymoon period and explain how these behaviors arise in systems of ordinary differential equations. We define a transient center, a point in state space that causes long transient behaviors, and derive some of its properties. In the end, we define reachable transient centers, which are transient centers that can be reached from initializations that do not need to be near the transient center.

YOUNGMIN PARK, University of Manitoba
Models of Vimentin Organization Under Actin Retrograde Flow

Intermediate filaments are elements of the cytoskeleton where their organization determines their functions in cells. In this study, we observe and model the movement of GFP-labeled vimentin fibers after preventing microtubule polymerization with nocodazole to inhibit microtubule related transport driven by molecular motors. Hence, in our data, vimentin is only subjected to actin-driven transport. To model this phenomenon, we assume that vimentin may exist in two states, mobile and immobile, and may switch between the states at unknown rates. In addition, we assume that mobile vimentin may advect from the cell plasma membrane to the nuclear envelope because of actin retrograde flow. We introduce several biologically realistic models using these assumptions. For each model, we use dual annealing to find the best parameter sets resulting in a solution that most closely matches the experimental data. Then the best candidate model is identified using the Akaike Information Criterion. Using the best candidate model, we reconstruct the spatially-dependent profile of the actin retrograde flow, and discuss the biological implications of our results.

Work with S. Etienne-Manneville (Institut Pasteur, Paris), C. Leduc (IJM, Paris) and S. Portet (University of Manitoba)

STACEY SMITH?, The University of Ottawa
Is a COVID-19 vaccine likely to make things worse?

In order to limit the disease burden and economic costs associated with the COVID-19 pandemic, it is important to understand how effective and widely distributed a vaccine must be in order to have a beneficial impact on public health. To evaluate the potential effect of a vaccine, we developed risk equations for the daily risk of COVID-19 infection both currently and after a vaccine becomes available. Our risk equations account for the basic transmission probability of COVID-19 (β) and the lowered risk due to various protection options: physical distancing; face coverings such as masks, goggles, face shields or other medical equipment; handwashing; and vaccination. We found that the outcome depends significantly on the degree of vaccine uptake: if uptake is higher than 80%, then the daily risk can be cut by 50% or more. However, if less than 40% of people get vaccinated and other protection options are abandoned — as may well happen in the wake of a COVID-19 vaccine — then introducing even an excellent vaccine will produce a worse outcome than our current situation. It is thus critical that effective education strategies are employed in tandem with vaccine rollout.

JONATHAN TOT, Dalhousie University
On the Equilibria and Bifurcations of a Rotating Double Pendulum

The double pendulum, a simple system of classical mechanics, is widely studied as an example of, and testbed for, chaotic dynamics. In 2016, Maiti et al. [Phys.Lett.A 380 p.408-412] studied a generalization of the simple double pendulum with equal point-masses at equal lengths, to a rotating double pendulum, fixed to a coordinate system uniformly rotating about the vertical. In this work, we have studied a considerable generalization of the double pendulum, constructed from physical pendula, and ask what equilibrium configurations exist for the system across a comparatively large parameters space, as well as what bifurcations occur in those equilibria. Elimination algorithms are employed to reduce systems of polynomial equations, which allows for equilibria to be visualized, and also to demonstrate which models within the parameter space exhibit bifurcations. We find the DixonEDF algorithm for the Dixon resultant, written in the computer algebra system Fermat, to be capable to complete the computation for the challenging system of equations that represents bifurcation, while attempts with other algorithms were terminated after several hours.

CUIPING WANG, Memorial University
Dynamic Analysis of Cancer-Immune System with Therapy and Delay

In this talk, we propose a two-dimensional differential system with delay for human immunological system describing the interaction of effector cells and cancer cells. We investigate the existence of equilibria, in detail, with respect to the system parameters, especially with the action delay and the therapy rate, and discuss the stability of these equilibrium points, theoretically and numerically.

YAHUI WANG, Lanzhou University, Memorial University of Newfoundland
Propagation Direction of Traveling Waves to a Competitive Integrodifference System with Bistable Nonlinearity

Traveling wave propagation is a significant phenomenon observed in population biology. Due to the occurrence of nonlocal effect in integrodifference systems, a deep understanding of the wavefront in the propagation direction is challenging. In this paper, we study the sign of wave speed for bistable traveling waves to a two-species competitive integrodifference system that biologically models the dynamics of two species in competition for a common resource. By a proper choice of the kernel functions, we transfer our model into a coupled functional differential system and shed a new light on how to determine the wave speed sign. Sufficient conditions with symmetry are obtained on the propagation directions of the wavefronts. This symmetry is further verified in the final analysis and numerical simulations are provided to illustrate our theoretical results. This talk is based on a joint work with Drs. Guo Lin and Chunhua Ou.

GAIL S. K. WOLKOWICZ, McMaster University
The Augmented Phase-Plane for Analyzing Discrete Planar Models

After showing why phase plane analysis has not been particularly useful for analyzing discrete planar models as it is for planar ordinary differential equations, it will be shown how to augment the phase plane by not only considering the direction field and the nullclines, but by also including curves that we call the next iterate root-curves associated with the nullclines. These root curves determine on which side of the associated nullcline the next iterate lies. We demonstrate this method on e.g., a predator-prey model and a well-known Lotka-Volterra type discrete model. This provides an elementary method to obtain some global properties of the dynamics. This is joint work with Sabrina Streipert.

PEI YUAN, York University
Dynamical modelling and complex dynamics for the control of pest leafhopper with generalist predatory mite in tea plantations

The tea green leafhopper *Empoasca onukii* Matsuda (Hemiptera: Cicadellidae) is one of the important insect pests threatening the tea production. Both nymph and adult of *E. onukii* suck the tea buds, leaves, and shoots and make wounds in tea plants, which finally leads to the symptom from blade curling, bronzing, shriveling, necrosis to stand loss, even severe hopperburn, affecting the quality and yield of the tea. The pesticides were the commonly applied which caused the undesirable pesticide residues on brewed tea. A potential biological control agent, the mite *Anystis baccarum*(L.) is a significant predator of the

leafhopper in various agricultural systems. Based on the field experiment and data, we propose a predator-prey model with a generalist predator and aim to understand the dynamics of leafhopper pest *E. onukii* and predatory mite *A. baccarum* for the purpose of finding a plausible control mechanism. In this talk, I will present the bifurcations and complex dynamics of the model, which include saddle-node bifurcation, Hopf bifurcation, Bogdanov-Takens bifurcation, and even bifurcation of nilpotent singularities of codimension 3. In the end, I will present the bifurcation diagrams to explain and interpret the complex dynamics of the model. This is a joint work with Lilin Chen, Mingsheng You and Huaiping Zhu.

KEXUE ZHANG, Queen's University

Hybrid Event-Triggered Stabilization of Time-Delay Systems

Event-triggered control strategies allow for updating the control inputs when an event, triggered by a certain event-triggering rule, occurs. The unpredictable sequence of event times is determined explicitly by the event-triggering rule. The event-triggering mechanism has the advantage of reducing the number of control input updates while still guaranteeing the underlying desired performance. Due to the advantages of event-triggered control in efficiency improvements and the significance of time-delay systems in modeling real-world phenomena, the study of event-triggered control strategies for time-delay systems is of great importance. There are two main challenges in this study. First, the control algorithms for delay-free systems cannot be applied to time-delay systems directly. Another challenge, which is also the main difficulty of this research, is to exclude Zeno behavior from the closed-loop control systems. In this talk, we will introduce an event-triggered control algorithm that is based on the Lyapunov-Razumikhin technique. However, Zeno behavior can be easily examined in a class of linear time-delay systems. Therefore, a hybrid event-triggered control and impulsive control mechanism will be proposed to rule out Zeno behavior. This is joint work with Bahman Gharesifard.