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Uniqueness Implies Existence and Uniqueness
Conditions for Boundary Value Problems for 4th Order Differential Equations

Nasiba Albatni

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Abstract: In studies in disconjugacy, it has been established for many years that under suitable hypotheses, the uniqueness of solutions of $n$-point conjugate boundary value problems on an interval $(a, b)$ implies the existence of solutions for any conjugate point boundary value problem on $(a, b)$ for an $n$th order differential equation. In this talk, we consider a fourth order ordinary differential equation and we consider a family of boundary value problems different than and related to the conjugate boundary value problems. In particular, we shall assume the uniqueness of solutions of 4-point right focal type boundary value problems and show the existence of solutions of a broad family of two, three and four point boundary value problems. The primary tool is an unpublished precompactness condition for families of solutions of ordinary differential equations. The precompactness condition is due to Jackson and Schrader.
Boolean modeling of gene networks

Alan Veliz-Cuba

University of Dayton

Abstract: Due to the lack of kinetic information of biochemical interactions, it is difficult to study and analyze continuous models of gene networks. The nonlinearity of these interactions makes the problem even less tractable. The Boolean framework (where gene activity is assumed to be either 0=OFF or 1=ON) provides a complementary approach that focuses on qualitative analysis. In this talk, I will show how the Boolean framework is used in modeling biological systems, and how tools from graph theory and combinatorics are well-suited for the analysis of these Boolean models.

This talk will have the format of a tutorial/lecture.
Dynamics of Conjunctive Boolean Networks

Alan Veliz-Cuba
University of Dayton

Abstract: In the last talk we introduced Boolean networks (BN) as qualitative models of gene networks. In this talk we will explore how tools from graph theory and combinatorics can be used to study the dynamics of conjunctive Boolean networks (also known as AND BN). We will focus on finding steady states and periodic orbits. This talk will be more technical, but examples of definitions/theorems will be provided.
The Mathematics of Arctic Tipping Points

Ivan Sudakov
University of Dayton

Abstract: Important elements of the Arctic climate system such as sea ice and permafrost were formed under temperature change resulting in phase transition, primarily between water and ice. Phase transitions in the Arctic cryosphere remain of continuing interest as the climate system warms, and are crucial for the stability of the climate system. Also, such phase transitions lead to changes in shapes of the different patterns in the Arctic Cryosphere.

During the Arctic melt season, melt pond (that develops on the surface of sea ice floes) geometry has a complex fractal structure as a result of the fractal dimension transition. I will discuss a standard conceptual energy balance climate model with ice–albedo feedback taking into account the albedo of melt ponds. Different tipping points were obtained for this model. One of them may be quite interesting for climate projections, where the temperature of this system is stabilized (after phase transition) only due to the fractal transition in melt pond geometry.

Another important problem, where geometrical changes of the patterns can lead to the tipping points in a climate system, is modeling permafrost lakes. I will discuss the nonlinear phase transition model for permafrost which was used to compute the methane emission generated by lakes in the Arctic. Simulations show that there are two different possible scenarios for methane emission. One of them lead to abrupt temperature change, that is a tipping point in the climate system.
Cartan Subalgebras in $k$ – Graph $C^*$ – Algebras

Dilian Yang

University of Windsor

Abstract: $k$ – graphs (or higher rank graphs) are a higher dimensional generalization of directed graphs; directed graphs are naturally identified with 1 – graphs. They provide many important and interesting examples of (not necessarily self-adjoint) operator algebras. One key feature of those operator algebras is that there is nice interplay between their algebraic/analytic properties and visual properties of their underlying graphs.

In this talk, I will first review $k$ – graph $C^*$ – algebras, and then present some results on their Cartan subalgebras.
Hidden Markov Model and Applications

Nguyet Nguyen
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Youngstown State University

Hidden Markov Model (HMM) is a well-known model for signal detection based on Markov chain process. It has been used in many fields such as speech recognition, hand writing recognition, biomathematics, and financial economics. In this talk, I will give a brief introduction on HMM and introduce its applications. In particular, I have been using the HMM to predict regimes of some macro economics variables such as Gross Domestic Product, Consumer Price Index, Stock Market Index and Market Volatility, the major economics indicators that significantly impact the stock market. In one of my recent works, we analyze the performances of all of the S&P 500 stocks during the major economic variables’ regimes to make a monthly stock selection for our investment portfolio. Numerical results showed that our portfolio had higher returns and lower risk compared to the benchmark index S&P 500. Other applications of HMM will also be proposed with great details.
An Inverse Semi-Group Approach to Classification of Cartan Pairs

David Pitts
University of Nebraska-Lincoln

ABSTRACT: In a pair of landmark papers appearing in 1977, Feldman and Moore studied Borel equivalence relations on a measure space \((X, \mu)\) and developed a cohomology theory for such relations. They used their work to classify Cartan pairs, which are pairs \((M, D)\) consisting of a von Neumann algebra \(M\) with a suitable maximal abelian subalgebra \(D\). The remarkable feature of this work is that the inclusion of \(D\) in \(M\) can be used to introduce ‘coordinates’ on \(M\), so that \(M\) can be thought of as an algebra of (generalized) matrices with (generalized) matrix operations analogous to the matrix operations on \(n \times n\) matrices. This viewpoint allows considerable insight into the structure of \(M\).

The Feldman-Moore work requires considerable measure-theoretic prowess, and the use of equivalence relations for classification is more “point-based” than “operator based.”

In this talk, I will discuss a new classification of Cartan pairs due to Donsig, Fuller and Pitts, in terms of extensions of inverse semigroups. This classification is algebraic in nature, suppresses the measure theory, and seems conceptually simpler than the Feldman-Moore approach. If time permits, I will show how our approach can be used to give a correct proof of an interesting assertion of Muhly, Saito and Solel regarding maximal triangular algebras.
Dynamic Data Integration on GPUs for forecasting porous media flows

Arunasalam Rahunanthan

Central State University

Abstract: In CO2 sequestration in deep saline aquifers, contaminant transport in subsurface, or oil or gas recovery, we often need to forecast flow patterns. In the flow forecasting, subsurface characterization is an important step. To characterize subsurface properties we establish a statistical description of the subsurface properties that are conditioned to existing dynamic (and static) data. We use a Markov Chain Monte Carlo (MCMC) algorithm in a Bayesian statistical description to reconstruct the spatial distribution of two important subsurface properties: rock permeability and porosity. The MCMC algorithm requires repeatedly solving a set of nonlinear partial differential equations describing displacement of fluids in porous media for different values of permeability and porosity. The time needed for the generation of a reliable MCMC chain using the algorithm can be too long to be practical for flow forecasting. To speed-up the generation of MCMC chains we consider two approaches. In a two-stage MCMC approach, we use a computationally inexpensive coarse-scale model to screen proposals before computing fine-scale simulations at a second-stage, resulting in enhanced MCMC performance. With the availability of inexpensive GPUs (Graphics Processing Units), one could also use the pre-fetching algorithm to parallelize an MCMC chain. In this talk, we compare two-stage approach to pre-fetching, without screening, for predictive simulation of two-phase flows in a Bayesian framework.
Discrete Models for the Simulation and Control of Gene Regulatory Networks

David Murrugarra
University of Kentucky

Abstract: Understanding how the physiology of organisms arises through the dynamic interaction of the molecular constituents of life is an important goal of molecular systems biology, for which mathematical modeling can be very helpful. Different modeling strategies have been used for this purpose. Dynamic mathematical models can be broadly divided into two classes: continuous, such as systems of differential equations and their stochastic variants and discrete, such as Boolean networks and their generalizations. This talk will focus on the discrete modeling approach, which employs techniques from discrete mathematics, combinatorics, graph theory, and computational algebra. Discrete models play an important role in modeling processes that can be viewed as evolving in discrete time, in which state variables have only finitely many possible states. This talk will present an approach for stochastic simulations of discrete models. This stochastic setting will be used to study optimal control problems to identify a control policy to navigate the system so that the probability of reaching a desirable state is maximized. Our algorithms assume a set of intervention targets represented by control nodes and edges in the wiring diagram and use techniques from Markov decision processes for the identification of a control policy that dictates how to move from one state to another.
Stokes' Theorem: Vectors vs. Differential Forms

Tyler Masthay
University of Dayton

Abstract: Green’s Theorem and its generalization Stokes’ Theorem are two of the most famous results studied in an introductory multivariable calculus course. Many problems often deal with integrating flux across the boundary of a region in two-space or three-space. As is often the case with problems such as this, it is very natural to describe the system in terms of vector-valued functions. However, trying to develop the theory using this notation becomes rather unwieldy and because of this, the concept of a differential form is introduced and is central to the development. I will introduce the fundamentals of this notation as well as present the graphical motivation behind why this notation is used rather than vector notation. I will end the discussion by going through how differential forms lead to a simple and elegant proof of Stokes’ Theorem.
Abstract: In this paper, we study the periodicity properties of functions that arise in quantum calculus, which has been emerging as an important branch of mathematics due to its various applications in physics, and other related fields. The paper has two components. First, a relationship between two existing periodicity notions is established. Second, the existence of periodic solutions of a q-Volterra integral equation, which is a general integral form of a first order q-difference equation, is obtained. At the end, some examples are provided. These examples show the effectiveness of the relationship between the two periodicity notions that is established in this paper.
Comparative Analysis of Hedging Performance of Stock Options: Dynamic Versus Static Hedging

Sheng Kang
University of Dayton

Abstract: The purpose of this article is to examine the hedging performance of the stock options by applying two dynamic, and one constant conditional correlation models—bivariate asymmetric Glosten-Jagannathan-Runkle-Generalized Autoregressive Conditional Heteroscedastic (GJR-GARCH) model and dynamic conditional correlation multivariate GARCH (DCC-GARCH) model, constant conditional correlation multivariate GARCH (CCC-GARCH) model. Traditional static hedging model—Ordinary Least Square (OLS) regression model is used as the benchmark model. The objective function of portfolio variance minimization was used to measure the optimal hedge ratio and hedging effectiveness. Options are grouped into three categories: in the money, at the money and out of the money. The results show that (1) Most of the models examined in this article can substantially reduce portfolio risk; (2) The results reveal that the bivariate asymmetric GJR GARCH models are superior to the other models in put option hedging; (3) Hedge ratio and hedging effectiveness heavily depend on the moneyness of the options; (4) The hedging effectiveness of put option is better than the call option for all the models. Overall, the dynamic conditional correlation models achieve better performance than the constant conditional correlation models and OLS model. However, the transaction cost is not taken into account to judge which moneyness option is more cost effective.
Monotone Methods for Boundary Value Problems at Resonance

Samerah Al Mosa

University of Dayton

Abstract: We consider a simple boundary value problem at resonance for an ordinary differential equation. We employ a shift argument and construct a regular fixed point operator. We employ the monotone method coupled with a method of upper and lower solutions and obtain sufficient conditions for the existence of solutions of boundary value problems at resonance for nonlinear boundary value problems. We present three applications in which explicit upper solutions and lower solutions are exhibited. Of interest, the upper and lower solutions are elements of the kernel of the linear problem at resonance.