ICDEA 2016
The 22nd International Conference on Difference Equations and Applications
Osaka, Japan
July 24 to 29, 2016
Abstracts Book
# Program of ICDEA2016

## Sunday, July 24

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## Monday, July 25

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<td>09:40-10:40</td>
<td>Cushing Saber Elaydi (USA), Global Dynamics of Difference Equations: Applications to Population Dynamics</td>
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<td>11:00-12:00</td>
<td>Schreiber Ryusuke Kon (Japan), Bifurcations in nonlinear Leslie matrix models</td>
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<tr>
<td>14:00-14:25</td>
<td>Kon Youssef Raffoul (USA), Boundedness of Solutions in Almost Linear Volterra Difference Equations Using Fixed Point Theory and Lyapunov Functionals</td>
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<td>14:25-14:50</td>
<td>Kon Yukihiro Nakata (Japan), Stability of a logistic equation with multiple delays</td>
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<td>14:50-15:15</td>
<td>Raffoul Kaori Saito (Japan), On the Stability of an SIR epidemic discrete model with a delay</td>
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<td>15:15-15:40</td>
<td>Raffoul Inese Bula (Latvia), About neuron model with period two and three internal decay rate</td>
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<tr>
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<tr>
<td>16:00-16:25</td>
<td>Nakata</td>
<td>Shinji Nakaoka (Japan), Exploration of combinatorial emergence in coupled boolean network systems</td>
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<tr>
<td>16:25-16:50</td>
<td>Nakata</td>
<td>Mansoor Saburov (Malaysia), Applications of non-autonomous discrete dynamical systems into nonlinear consensus problems</td>
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<td>16:50-17:15</td>
<td>Nakaoka</td>
<td>Kuo-Chih Hung (Taiwan), Allee effect and its applications</td>
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<td>17:15-17:40</td>
<td>Nakaoka</td>
<td>Wirot Tikjha (Thailand), Prime period 4 behavior of certain piecewise linear system of difference equations where initial condition are some points in positive x-axis</td>
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<tr>
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<td>Nishimura</td>
<td>Aiko Tanaka (Japan), An evolutionary game model of families' voluntary provision of public goods</td>
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<td>14:25-14:50</td>
<td>Nishimura</td>
<td>Takashi Honda (Japan), Operator theoretic phenomena of the Markov operators which are induced by stochastic difference equations</td>
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<td>14:50-15:15</td>
<td>Nishimura</td>
<td>Ryoji Hiraguchi (Japan), On a solution path to the optimal growth model with multiplicative habits</td>
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<tr>
<td>15:15-15:40</td>
<td>Nishimura</td>
<td>Takuma Kunieda (Japan), Asset Bubbles, Financial Crisis, and Unemployment</td>
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<tr>
<td>16:00-16:25</td>
<td>D'Aniello</td>
<td>Hikmet Kemaloglu (Turkey), Uniqueness of Potential Function in Sturm-Liouville Difference Equation</td>
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<tr>
<td>16:25-16:50</td>
<td>D'Aniello</td>
<td>Yan-Hsiou Cheng (Taiwan), Eigenvalue estimates for the Sturm- Liouville equation</td>
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<tr>
<td>16:50-17:15</td>
<td>Kemaloglu</td>
<td>Petr Zemánek (Czech Republic), Self-adjoint extensions of minimal linear relation associated with discrete symplectic system</td>
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<td>17:15-17:40</td>
<td>Kemaloglu</td>
<td>Nobuyuki Higashimori (Japan), Convergence of finite difference schemes applied to the Cauchy problems of quasi-linear partial differential equations of the normal form</td>
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<td>09:00-10:00</td>
<td>Yu</td>
<td>Christian Pötzsche (Austria), Numerical dynamics of integrodifference equations</td>
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<td>10:10-11:10</td>
<td>Zhang</td>
<td>Eduardo Liz (Spain), Complexity in discrete-time seasonal population models with harvesting</td>
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<tr>
<td>11:30-11:55</td>
<td>Liz</td>
<td>István Győri (Hungary), Asymptotic constancy in linear difference equations</td>
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<tr>
<td>14:00-14:25</td>
<td>Schreiber</td>
<td>Ziyad Al-Sharawi (UAE), A prey-predator model with refuge and toxic effect in prey</td>
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<td>14:25-14:50</td>
<td>Schreiber</td>
<td>Stephen Baigent (UK), Convexity of invariant manifolds of Kolmogorov maps</td>
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<td>14:50-15:15</td>
<td>Al-Sharawi</td>
<td>Rafael Luis (Portugal), Recent advances in global stability of monotone maps: application to population dynamics</td>
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<td>15:15-15:40</td>
<td>Al-Sharawi</td>
<td>Cónall Kelly (Jamaic), Stabilisation of difference equations with noisy prediction-based control</td>
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<td>16:00-16:25</td>
<td>Luis</td>
<td>Roman Kozlov (Norway), The adjoint equation method for constructing first integrals of delay differential equations</td>
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<td>16:25-16:50</td>
<td>Luis</td>
<td>Emma D'Aniello (Italy), Iterated Function Systems and Attractors</td>
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<td>Stehlik</td>
<td>Jeremias Epperlein (Germany), Cellular automata as topological dynamical systems and topological conjugacies between them</td>
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<tr>
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<td>Zdun</td>
<td>Elvan Akin (USA), On Nonoscillatory Solutions of Two Dimensional Nonlinear Delay Time-Scale Systems</td>
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<td>14:25-14:50</td>
<td>Zdun</td>
<td>Agnieszka B. Malinowska (Poland), The Cucker-Smale type models on isolated time scales</td>
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<td>14:50-15:15</td>
<td>Akin</td>
<td>Ewa Girejko (Poland), Extension of the Cucker-Smale model to isolated time scales</td>
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<td>15:15-15:40</td>
<td>Akin</td>
<td>Andrejs Reinfelds (Latvia), Integral stability for dynamic systems on time scales</td>
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<td>Bula</td>
<td>Marek Cezary Zdun (Poland), Regular iterations connected with an initial value problem of a nonlinear difference equation</td>
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<td>Alexander Zuevsky (Czech Republic), Non-commutative symmetries for generalized Davey-Stewartson equations</td>
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<tr>
<td>16:50-17:15</td>
<td>Zhang</td>
<td>Linfeng Zhou (China), Roughness of tempered exponential dichotomies</td>
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<td>Jim Cushing (USA), Matrix Models Defined by Systems of Nonlinear Difference Equations and the Fundamental Bifurcation Theorem when the Projection Matrix is Imprimitive</td>
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<td>Sebastian Schreiber (USA), Population Persistence and Species Coexistence in Random Environments</td>
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<td>Zuzana Došlá (Czech Republic), Decaying solutions for discrete boundary value problems on the half line</td>
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<td>Liz</td>
<td><strong>Weinian Zhang (China)</strong>, Regularity of $C^1$ Linearization</td>
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<td><strong>Mihály Pituk (Hungary)</strong>, The growth of positive solutions of difference equations with applications to delay differential equations</td>
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<td>Olaru</td>
<td><strong>Seiji Saito (Japan)</strong>, Converse theorems on globally asymptotic stability of solutions for nonlinear difference equations</td>
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<td>Tikjha</td>
<td><strong>Ignacio Bajo (Spain)</strong>, Invariants for a class of discrete dynamical systems given by rational mappings</td>
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<td>Bajo</td>
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<td>Malinowska</td>
<td><strong>Zbigniew Leśniak (Poland)</strong>, On topological invariants of Brouwer flows</td>
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<td><strong>Dorota Mozyrska (Poland)</strong>, Fractional discrete-time of Hegselmann-Krause's type consensus model</td>
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<td><strong>Tatiana Odzijewicz (Poland)</strong>, Discrete fractional Cucker-Smale optimal control problem</td>
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<td>Yoshitsugu Kabeya (Japan), Difference equation and the related Schrödinger operator</td>
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<td>Hamaya</td>
<td>Masanori Shiro (Japan), Equations with five variables give the second Feigenbaum constant</td>
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<td>Kabeya</td>
<td>Toshiyuki Kohno (Japan), On the behavior of the error in numerical iterative method for PDE</td>
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<td>Győri</td>
<td>Petr Stehlík (Czech Republic), Evolutionary games on graphs and discrete dynamical systems</td>
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<td>Pituk</td>
<td>Sorin Olaru (France), Set Invariance for Delay Difference Equations</td>
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<td>10:35-11:00</td>
<td>Pituk</td>
<td>Yoshihiro Hamaya (Japan), On the asymptotic stability of a discrete combat model</td>
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<td>Masakazu Onitsuka (Japan), On the Hyers-Ulam stability of a first-order linear difference equation</td>
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<tr>
<td>11:40-12:40</td>
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<td>Hiroshi Kokubu (Japan), Topological Computation Theory for the Global Dynamics of Multi-Parameter Systems</td>
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<td>Cheng</td>
<td>Cheng-Hsiung Hsu (Taiwan), Entire solutions in a bistable periodic lattice dynamical system</td>
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<td>10:35-11:00</td>
<td>Cheng</td>
<td>Jian Jhong Lin (Taiwan), Traveling wave solutions for discrete-time model of delayed cellular neural networks</td>
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<td>Hsu</td>
<td>Tzi-Sheng Yang (Taiwan), Stability for Monostable Wave Fronts of Delayed Lattice Differential Equations</td>
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Plenary Lectures
In population biology, the discrete time dynamics of structured populations are described by systems of difference equations, which when written in vector form are called matrix models. The vector of state variables $x$ is iterated forward in time by the multiplication of a projection matrix $P(x)$. This matrix encodes the modeling assumptions about basic vital rates (birth, death, etc.) and state transitions (young to old, juvenile to adult, large to small, etc.) and how they depend on the state variable (through so-called density effects). The resulting nonlinear map $x(t + 1) = P(x(t))x(t)$ has fixed point $x = 0$. Since extinction-versus-persistence is a basic concern in population biology, the stability of $x = 0$ is of fundamental importance. The linearization principle implies stability/instability of $x = 0$ can be determined by the eigenvalues of the Jacobian evaluated at $x = 0$, which is just $P(0)$. Generally $P$ is primitive and, as a result, stability of $x = 0$ is determined by the (strictly) dominant eigenvalue $r$ (the spectral radius) of $P(0)$. The nature of the bifurcation that occurs at $r = 1$ is, in this case, well understood: a global continuum of positive equilibria bifurcates from $x = 0$ at $r = 1$, which near the bifurcation point is stable if the bifurcation is forward and which is unstable if it is backwards. Backward bifurcations are of interest in one important way: they generally give rise to an interval of $r < 1$ values on which a strong Allee effect occurs and to a tipping point $r^* < 1$ below which a sudden population crash occurs (through a blue-sky bifurcation). There are, however, applications which give rise to matrix models with imprimitive projection matrices $P$. When $P$ is imprimitive the bifurcation at $r = 1$ is more complicated and, in general, is not well understood. I will describe some example cases and some new theorems concerning the bifurcation at $r = 1$. These models and theorems are motivated by field observations of my ecologist collaborators working on Protection Island National Wildlife Refuge in the state of Washington. Our project concerns the effects of climate change on marine birds nesting on the Island and the prospect for their future survival in lieu of increasing mean sea surface temperature. Since adaptation is important in this regard, I will also describe an evolutionary version of matrix models and the form that the fundamental bifurcation theorem takes for the resulting “Darwinian” models.
Global Dynamics of Difference Equations: Applications to Population Dynamics

Saber Elaydi

Trinity University
San Antonio, Texas, USA
selaydi@trinity.edu

In this talk we will present the latest development in the global dynamics of two types of systems generated by triangular maps and monotone maps. The dynamics of planar monotone maps have been well understood through the work of Hal Smith. The theory of monotone maps is now extended to higher dimensional maps via geometrical interpretation of monotonicity. Another class of maps for which the Global dynamics have been successfully established, is the class of triangular maps where the Jacobian matrix of the map is triangular. Applications of our theory to population biology will be presented. For instance, hierarchical models may be represented by triangular maps defined on $\mathbb{R}^k_+$. In particular, we focus our attention on models with the Allee effect. The general theory of the global dynamics of triangular maps was established by Balreira, E., and Luis [1]. Here we extend these results to include the difficult case of non-hyperbolic maps, building upon the work by Assas et al. [2,3]. We show that in the case of non-hyperbolic maps, the center manifold is semi-stable from above. Finally, we show how immigration to one of the species or to both would change drastically the dynamics of the system. It is shown that if the level of immigration to one or both species is above a specified level, then there will be no extinction region.

References


Topological Computation Theory for the Global Dynamics of Multi-Parameter Systems

HIROSHI KOKUBU

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Kyoto 606-8502, Japan
kokubu@math.kyoto-u.ac.jp

The fundamental theorem of dynamical systems due to C. Conley asserts that the complement of the chain-recurrent set in the phase space is gradient-like for any finite-dimensional dynamical systems. In general, the chain-recurrent set, which is the weakest notion of recurrence in dynamics, has infinitely many component, and thus, it is hard to exactly capture it. Together with my collaborators, I have been working on developing a computational method, combined with several topological ideas, for obtaining a slightly weaker form of the “recurrent vs gradient-like decomposition” of the phase space, called the Morse decomposition of the global dynamics of multi-parameter systems. In this talk, I will explain the basic ideas of these topological computation methods, and discuss some applications and extensions.

References


This talk considers the dynamics of the following system of nonlinear difference equations

\[
\begin{align*}
\begin{cases}
    u_{1,k+1} &= f_1 \phi_1(u_k)u_{1,k} + f_2 \phi_2(u_k)u_{2,k} + \cdots + f_n \phi_n(u_k)u_{n,k} \\
    u_{2,k+1} &= s_1 \sigma_1(u_k)u_{1,k} \\
    u_{3,k+1} &= s_2 \sigma_2(u_k)u_{2,k} \\
    \vdots \\
    u_{n,k+1} &= s_{n-1} \sigma_{n-1}(u_k)u_{n-1,k},
\end{cases}
\end{align*}
\]

\[u_k = (u_{1,k}, u_{2,k}, \ldots, u_{n,k})^\top,\]

which is a nonlinear Leslie matrix model with \(n \geq 2\) age-classes. The variable \(u_{i,k}\) denotes the number of individuals of age \(i \in \{1, 2, \ldots, n\}\) at time \(k \in \{1, 2, \ldots, \}\). Since the nonlinear Leslie matrix model exhibits complicated behavior even if \(n = 2\) [1], we focus on the bifurcation of the population-free equilibrium point \(u = 0\) and show that the bifurcation problem can be seen as the stability problem for Lotka-Volterra differential equations if the population is semelparous (i.e., \(f_1 = f_2 = \cdots = f_{n-1} = 0\)). Furthermore, we extend this result to both iteroparous and multi-species cases. The study gives a mathematical base to [4] and rediscovers some results in [2, 3].

**References**


Population dynamics of many species are influenced by seasonality, and seasonal interactions have the potential to modify important factors such as population abundance and population stability [4]. We consider a discrete semelparous population model with an annual cycle divided into a breeding and a non-breeding season, and introduce harvesting into the model following [1]. We report some interesting phenomena such as conditional and non-smooth hydra effects, coexistence of two nontrivial attractors, and hysteresis. Our results highlight the importance of several often underestimated issues that are crucial for management, such as census timing and intervention time.

Finally, we analyze the interaction of sequential density dependence with other factors that affect individual fitness: carry-over effects [2] and mating limitations leading to Allee effects [5].

References


Integrodifference equations (IDEs for short) are a popular tool in theoretical ecology to describe the spatial dispersal of populations with nonoverlapping generations (cf. [1]).

From a mathematical perspective, IDEs are recursions on ambient spaces of continuous or integrable functions and therefore generate an infinite-dimensional dynamical system. Hence, for simulation purposes an appropriate numerical approximation yielding a finite-dimensional state space is due. Our goal is to study those dynamical properties of IDEs (e.g. existence of reference solutions, attractors, invariant manifolds) which are preserved under corresponding numerical methods and to establish convergence for increasingly more accurate schemes.

References


Population Persistence and Species Coexistence in Random Environments

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Stochastic fluctuations in temperature, precipitation and a host of other environmental factors occur at multiple spatial and temporal scales. As the survival and reproduction of organisms, whether they be plants, animals, or viruses, depend on these environmental factors, these stochastic fluctuations often drive fluctuations in population abundances. This simple observation leads to a fundamental question in population biology. Namely, under what conditions do stochastic environmental fluctuations hinder or facilitate the maintenance of biodiversity? This question is particularly pressing in light of global climate models predicting increasing temporal variation in many climatic variables over the next century.

One fruitful approach to tackling this question from population biology is the development and analysis of models accounting for nonlinear feedbacks among species, population structure, and environmental stochasticity. In this talk, I will discuss progress in the development of a mathematical theory for stochastic coexistence where the dynamics of the interacting species are encoded by random difference equations and coexistence corresponds to the limit points of empirical measures being bounded away from an extinction set. I will illustrate the theory with empirical based examples involving checkerspot butterflies, Kansas prairies, and coastal dunes.
Evolutionary games on graphs and discrete dynamical systems

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Evolutionary games on graphs play an important role in the study of evolution of cooperation in applied biology. In this talk we discuss these discrete dynamical systems from the mathematical point of view in the deterministic case. We focus on coexistence equilibria, attractors, update rules and update orders. For example, we use constructive proofs to show that for all graphs there exist coexistence equilibria for certain game-theoretical parameters. Similarly, for all relevant game-theoretical parameters there exists a graph yielding coexistence equilibria. We conclude with a list of open problems.

References

Some problems on the global attractivity of linear nonautonomous difference equations

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Main aim of this talk is to solve several problems on the global attractivity of the zero solution of the nonautonomous difference equation

\[ x_{n+1} - x_n + P_n x_{n-k_n} = 0, \quad n \in \mathbb{Z}(0), \]

where \( \{P_n\} \) is a sequence of nonnegative real numbers, \( \{k_n\} \) is a sequence of nonnegative integers with \( n - k_n \to \infty \) as \( n \to \infty \). Some open problems are posed on the global attractivity of equilibrium 1 for the discrete population model.
Regularity of $C^1$ Linearization

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$C^1$ linearization is of special interests because it can distinguish characteristic directions of dynamical systems. In this talk new advances on sharp regularity of $C^1$ linearization for planar hyperbolic diffeomorphisms are introduced. Moreover, results are given in the higher dimensional Euclidean space and Banach spaces in nonresonant cases and resonant cases. Those results are obtained jointly with Wenmeng Zhang and Witold Jarczyk.

References


Contributed Talks
On Nonoscillatory Solutions of Two Dimensional Nonlinear Delay Time-Scale Systems

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In this talk, we consider nonlinear two dimensional systems of first order delay dynamic equations on time scales and obtain necessary and sufficient conditions to show the existence of nonoscillatory solutions. Our approach is based on the sign of components of solutions and we use Knaster and Schauder fixed point theorems. Examples will be given to illustrate some of our results as well.

References


A prey-predator model with refuge and toxic effect in prey

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(Collaborative work with Joydev Chattopadhyay, Indian Statistical Institute)

In this talk, we discuss the dynamics of a prey-predator model with both refuge and toxic effects of prey. In particular, we consider the discrete model

\[
\begin{align*}
    x_{n+1} &= \frac{krx_n}{k + (r-1)x_n} - \beta \alpha x_n y_n \\
    y_{n+1} &= (c\beta \alpha - \theta)x_n y_n - \mu y_n,
\end{align*}
\]

where \( r \) is the intrinsic growth rate of the toxic prey (\( r > 1 \)), \( k \) is the carrying capacity of the prey (\( k > 0 \)), \( \beta \) is the predation rate (\( 0 < \beta < 1 \)), \( c \) is the conversion efficiency (\( 0 < c < 1 \)), \( \alpha \) is the portion of the prey population that does not take refuge (\( 0 \leq \alpha \leq 1 \)), \( \mu \) is the natural mortality rate of the predator population (\( 0 < \mu < 1 \)) and \( \theta \) is the toxic effect due to consumption of toxin producing prey (\( 0 \leq \theta < 1 \)).

We analyze stability of equilibrium solutions, and show that the predator free equilibrium is globally asymptotically stable if the prey density is below a threshold level. Boundedness, persistence and permanence of the system will be characterized. We show that the system undergoes Neimark-Sacker bifurcation. Also, we show that increasing the carrying capacity of the prey reduces the chance of coexistence of both populations. Thus large carrying capacity leads to the paradox of enrichment.

References


Behaviour of Solutions of Some Rational Difference Equations with a Positive Real Power

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The author investigates the local and global stability character and the periodic nature of solutions of some second order rational difference equations with a positive real power in the form:

\[ x_{n+1} = \frac{\alpha + \beta x_n^k + \gamma x_{n-1}^k}{A + B x_n^k + C x_{n-1}^k}, \quad n = 0, 1, 2, \ldots \] (1)

with non-negative parameters \( \alpha, \beta, \gamma, A, B, C \) and arbitrary non-negative initial conditions \( x_{-1}, x_0 \) such that the denominator is always positive, and \( k \in (0, \infty) \).

The boundedness character of solutions of Eq. (1) have been studied in paper [1]; furthermore, there are given several open problems and conjectures about Eq. (1). In this talk the author would like to consider some of them.

References


Convevity of invariant manifolds of Kolmogorov maps

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I will show that the planar Leslie-Gower model has a globally attracting invariant manifold that is either convex, concave, or a line segment [1]. My approach is based upon establishing when a given line segment is mapped to a convex or concave curve. I will also show the existence of convex and concave globally attracting invariant manifolds for the 3-species Leslie-Gower model. To do this I will first relate the Leslie-Gower model to a Kolmogorov differential equation. Convexity is then obtained by showing that all planes whose normals lie in a suitable invariant cone are mapped to convex surfaces [2].

References


Invariants for a class of discrete dynamical systems given by rational mappings

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An invariant or first integral of a discrete dynamical system \( x(k+1) = F(x(k)) \) with domain \( \mathcal{D} \) is a non constant map \( H : \mathcal{U} \subset \mathbb{K}^n \to \mathbb{K} \) defined in an open and dense subset \( \mathcal{U} \) of \( \mathcal{D} \) such that for all \( x \in \mathcal{U} \) it holds \( H(F(x)) = H(x) \).

In this work, we study the existence of invariants for a family of rational dynamical systems. Explicitly, let \( \mathbb{K} \) denote either \( \mathbb{R} \) or \( \mathbb{C} \). We consider the discrete dynamical systems in an open domain \( \mathcal{D} \) of \( \mathbb{K}^n \) of the form

\[
x(k + 1) = F(x(k)) = (F_1(x(k)), \ldots, F_n(x(k))), \quad x(k) \in \mathcal{D} \subset \mathbb{K}^n
\]  

(1)

where the functions \( F_i : \mathcal{D} \subset \mathbb{K}^n \to \mathbb{K} \) are linear fractionals sharing denominator:

\[
F_i(x) = \frac{a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{in}x_n + c_i}{b_1x_1 + b_2x_2 + \cdots + b_nx_n + d}, \quad i = 1, 2, \ldots, n,
\]

for \( x = (x_1, x_2, \cdots, x_n) \) and all involved parameters in \( \mathbb{K} \). Such systems can be written with the aid of homogeneous coordinates as the composition of a linear map in \( \mathbb{K}^{n+1} \) with a certain projection and their behaviour is strongly determined by the spectral properties of the corresponding linear map.

We will prove that if \( n \geq 2 \) then every system of this kind admits an invariant, both in the real and in the complex case. More precisely, our main result will be

**Theorem 1.** Consider \( n > 1 \). If the dynamical system given by (1) is defined in a nonempty open set \( \mathcal{D} \), then it admits an invariant defined in an open and dense subset

\[
\mathcal{U} = \{ x \in \mathcal{D} : Q(x) \neq 0 \},
\]

where \( Q(x) \) is a polynomial of degree 2 defined by a couple of (not necessarily distinct) eigenvectors \( u_1, u_2 \) of a matrix defined by the coefficients of the components of \( F \).

In fact, for a sufficiently large \( n \) several functionally independent invariants can be obtained and, in many cases, the invariant can be chosen as the quotient of two quadratic polynomials. In this cases one has, as a consequence, that every orbit of the system results to be contained in a certain \( F \)-invariant quadric.

**References**

Stabilisation of difference equations with noisy prediction-based control

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Prediction-based control was introduced by Ushio and Yamamoto [2] as a method of stabilising unstable periodic orbits of difference equations. In this talk, we consider the influence of stochastic perturbations on stability of a unique positive equilibrium of a difference equation subject to prediction-based control. These stochastic perturbations may be multiplicative if they arise from stochastic variation of the control parameter, or additive if they reflect the presence of systemic noise. The class of equations under consideration includes common population models like the Ricker model, the truncated logistic model, and modifications of the Beverly-Holt equation.

We begin by relaxing the control parameter in the deterministic equation, and deriving a range of values for the parameter over which all solutions eventually enter an invariant interval. Then, by allowing the variation to be stochastic, we demonstrate sufficient conditions (less restrictive than known ones for the unperturbed equation) under which the positive equilibrium will be globally a.s. asymptotically stable: i.e. the presence of noise improves the known effectiveness of prediction-based control. Finally, we show that systemic noise has a “blurring” effect on the positive equilibrium, which can be made arbitrarily small by controlling the noise intensity.

The results presented in this talk will be illustrated by numerical examples, and are published in [1].

References


About neuron model with period two and three internal decay rate

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In [1] a difference equation $x_{n+1} = \beta x_n - g(x_n), \ n = 0, 1, 2, \ldots$, was analyzed as a single neuron model, where $\beta > 0$ is an internal decay rate and a signal function $g$ is the following piecewise constant function with McCulloch-Pitts nonlinearity:

$$g(x) = \begin{cases} 
1, & x \geq 0, \\
-1, & x < 0.
\end{cases} \quad (1)$$

Now we will study the following non-autonomous piecewise linear difference equation:

$$x_{n+1} = \beta_n x_n - g(x_n), \ n = 0, 1, 2, \ldots,$$

where $(\beta_n)_{n=0}^{\infty}$ is a period two or three sequence

$$\beta_n = \begin{cases} 
\beta_0, & \text{if } n = 2k, \\
\beta_1, & \text{if } n = 2k + 1,
\end{cases} \quad \text{or} \quad \beta_n = \begin{cases} 
\beta_0, & \text{if } n = 3k, \\
\beta_1, & \text{if } n = 3k + 1, \\
\beta_2, & \text{if } n = 3k + 2,
\end{cases} \quad k = 0, 1, 2, \ldots$$

and $g$ is in form (1). In [2] we have been studied this model where $(\beta_n)_{n=0}^{\infty}$ is a period two sequence. We will investigate the periodic behaviour and stability of solutions relative to the periodic internal decay rate.

References


Eigenvalue estimates for the Sturm-Liouville equation

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Recently, the discrete Hamiltonian systems have wide attracted attention. An interesting model is the discrete Sturm-Liouville equation of the form

\[(J_n + Q_q) y = \lambda y\]

where \(Q_q\) is a diagonal matrix with diagonal elements \(q_1, q_2, \ldots, q_n\) and \(J_n\) is the \(n \times n\) tridiagonal matrix of the form

\[
J_n = \begin{bmatrix}
2 & -1 & 0 & \cdots & 0 \\
-1 & 2 & -1 & \ddots & \\
0 & -1 & 2 & \ddots & 0 \\
\vdots & \ddots & \ddots & \ddots & -1 \\
0 & \cdots & 0 & -1 & 2
\end{bmatrix}
\]

From the theory of Jacobi matrices, we know that the eigenvalues of the discrete Sturm-Liouville operator \(J_n + Q_q\) are all real and simple. In particular, most of studies are focus on the eigenvalue estimates, bound of eigenvalues and inverse spectral problem. The purpose of this talk is to introduce the problem of the gap of first two eigenvalues of the discrete Sturm-Liouville equation. We will find the optimal lower bound of the first eigenvalues gap and show the optimizer of the first eigenvalues gap is only when \(Q_q\) is a constant times the identity matrix.

References


Iterated Function Systems and Attractors

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Let $X$ be a compact metric space with $S = \{S_1, \ldots, S_m\}$ a finite set of continuous maps from $X$ to itself. Call a non-empty compact subset $F$ of $X$ an attractor (or invariant set) for the iterated function system (IFS) $S$ if $F = \bigcup_{i=1}^{m} S_i(F)$. We investigate the structure (geometry, Hausdorff dimension, etc...) of the invariant sets according to the properties of the functions in the generating systems. In particular, we focus our attention on the case when $X = [0,1]^n$, $n \geq 1$.

References


Decaying solutions for discrete boundary value problems on the half line

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Consider the functional difference equation

\[ \Delta(a_n|\Delta x_n|^{\alpha}\text{sgn } (\Delta x_n)) = \lambda F(n, x_{n+q}), \]  

(1)

where \( \lambda > 0 \) is a real parameter, \( \alpha > 0, q \in \{0, 1, 2\} \).

Some nonlocal boundary value problems, associated to (1) on unbounded domains, are studied by means of a new approach. Their solvability is obtained by using properties of the recessive solution to suitable half-linear difference equations, a half-linearization technique and a fixed point theorem in Fréchet spaces. The result is applied to derive the existence of nonoscillatory solutions with initial and final data.

References


Cellular automata as topological dynamical systems and topological conjugacies between them

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Cellular automata are discrete dynamical systems that are used to model a wide variety of phenomena in biology, computer science, traffic simulation, etc. They are also of interest from a purely mathematical point of view.

Since CA can be characterized as the continuous shift-commuting self-maps of subshifts, topological dynamics provides a natural framework for their investigation. Starting with the fundamental work [1] of Hedlund, this line of research proved to be very fruitful yielding nice results and even more intriguing open problems (see for example [2]).

We will review some of these questions and results and present some new ones concerning topological conjugacies between cellular automata.

References


The Cucker-Smale type models on isolated time scales

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We shall present results concerning two special cases of the following model:

\[
\begin{cases} 
x_i^\Delta(t) = v_i(t) \\
v_i^\Delta(t) = Av(t)
\end{cases}
\]  

(1)

for \(i = 1, ..., N\), where \(t \in \mathbb{T}\) being an isolated time scale. The evolution of agent \(i\) is described by \(t \mapsto (x_i(t), v_i(t)) \in \mathbb{E}^2\), where \(\mathbb{E}\) a finite dimensional inner product real space. For each \(t\), \(x_i(t)\) represents the state and \(v_i(t)\) its consensus parameter at time \(t\). Matrix \(A = (a_{ij})_{i,j=1}^N\) with \(a_{ij} \in \mathbb{R}\), quantifies the way the agents influence each other, \(f^\Delta\) denotes the \(\Delta\)–derivative of \(f\). It is of interest to know whether the system will converge to a consensus pattern, characterized by the fact that all the consensus parameter tend to a common value.

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Extension of the Cucker-Smale model to isolated time scales

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The purpose of this talk is to present the Cucker-Smale model on isolated time scales. This dynamical system models a consensus of emergence in a population of autonomous agents. The results establishing conditions under which such consensus occurs will be presented. We will present analytical methods as well as computer simulations.

The work was supported by Polish funds of National Science Center, granted on the basis of decision DEC-2014/15/B/ST7/05270.
Asymptotic constancy in linear difference equations

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It is found that every solution of a system of linear delay difference equations has finite limit at infinity if some conditions are satisfied. These conditions are much weaker than the known sufficient conditions for asymptotic constancy of the solutions. When we impose some positivity assumptions on the coefficient matrices, our conditions are also necessary. The novelty of our results is illustrated by examples. This is a joint work with László Horváth (University of Pannonia, Hungary).

References

On the asymptotic stability of a discrete combat model

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A model for the attrition of combat power is treated with some mathematical discrete combat model. In this talk, we consider a sufficient condition for the asymptotic stability of a discrete combat model, which appears as a model for a government army vs an anti-government army of guerrilla, a government army vs a terror army of guerrilla and an anti-government army of guerrilla vs a terror army of guerrilla, respectively, by applying the technique of a luxury Liapunov functional.

References


Asset Bubbles, Financial Crisis, and Unemployment

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A tractable overlapping-generations model with asset bubbles is presented to demonstrate that a financial crisis with the bursting of asset bubbles decreases economic growth rates and increases unemployment rates. In our model, without asset bubbles, all agents engage in capital production regardless of their idiosyncratic productivity shocks. A bubbly asset, which is intrinsically useless, has a positive market value because selling the asset is a fund-raising method for agents who draw sufficiently high productivity to initiate an investment project and purchasing the asset is a sole saving method for agents who draw too low productivity. The presence of asset bubbles corrects allocative inefficiency, relocating investment resources from low productive agents to high productive agents. Accordingly, the presence of asset bubbles promotes economic growth and reduces unemployment rates. However, extrinsic uncertainty bursts asset bubbles and causes a self-fulfilling financial crisis. High unemployment rates follow a self-fulfilling financial crisis.

References

Convergence of finite difference schemes applied to the Cauchy problems of quasi-linear partial differential equations of the normal form

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We show a result on convergence of a consistent finite difference scheme to solve the Cauchy problem, including the ill-posed cases, of the following form:

$$\frac{\partial u_i}{\partial t} = \sum_{j=1}^{m} \sum_{l=1}^{n} a_{ijl}(t, x, u) \frac{\partial u_j}{\partial x_l} + f_i(t, x, u), \quad u_i(0, x) = g_i(x) \quad (i = 1, \ldots, m). \quad (1)$$

We suppose analyticity with respect to $x = (x_1, \ldots, x_n)$ and $u = (u_1, \ldots, u_m)$ of the data $(a_{ijl}, f_i, g_i)$ and merely continuity with respect to $t$, as in the Nirenberg-Nishida theorem. For the linear case, we already have a similar result [1]. Our proof is based on a discrete version of the proof given in [2], and our result is realized numerically on multiple-precision arithmetic environments, such as exflib [3].

References


On a solution path to the optimal growth model with multiplicative habits

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In this paper, we study the optimal growth model in which consumption habits enter the utility function multiplicatively, and characterize the necessary and sufficient conditions that the optimal path must satisfy. The utility function with multiplicative habits is not concave and most of the existing theorems on the optimal control problems cannot be directly applicable to the model. To obtain the equilibrium conditions, we re-express the optimization problem in terms of the logarithm of the consumption and that of the habit stock so that the new optimization problem is concave and the Lagrangian is available. We then use these conditions to prove that the steady state growth path always exists. We also study the stability of the optimal growth path out of the steady state.

References


The purpose of this talk is to present the relation between the Jacobs-de Leeuw-Glicksberg decomposition of semigroups and the spectral decomposition of the Markov operators which are induced by stochastic difference equations. Recently we proved new results about both decomposition. In this talk, we shall show the relation between both results.

References


Traveling wave solutions for discrete-time model of delayed cellular neural networks

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In this talk, we are concerned with the existence and stability of traveling wave solutions for the following partial difference equation

\[ u_i(n+1) = (1-h)u_i(n) + h \sum_{l=0}^{d} \alpha_l f(u_{i-l}(n-\kappa_l)) + h \sum_{l=0}^{d} \beta_l f(u_{i-l}(n-\hat{\kappa}_l)), \] (1)

where \( i, n \in \mathbb{Z}, h > 0, \alpha_l, \beta_l \in \mathbb{R}, d, \kappa_l, \hat{\kappa}_l \) are nonnegative integer and \( f \) is defined by

\[ f(x) = \frac{1}{2}(|x+1| - |x-1|). \]

This partial difference equation can be regarded as a discrete-time model of delayed cellular neural networks. Using the method of step along with positive characteristic roots of the equations, we successfully prove the existence of traveling wave solutions. Moreover, we also show that all such solutions are unstable. Additionally, we provide some numerical results to support our results, and point out the different structures of traveling wave solutions between the continuous-time and discrete-time models.

References


Entire solutions in a bistable periodic lattice dynamical system

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We are interested in finding entire solutions of a bistable periodic lattice dynamical system. By constructing appropriate super- and subsolutions of the system, we establish two different types of merging-front entire solutions. The first type can be characterized by two monostable fronts merging and converging to a single bistable front; while the second type is a solution which behaves as a monostable front merging with a bistable front and one chases another from the same side of \( x \)-axis.

References


Allee effect and its applications

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In theoretical ecology, a well known difference equation describing closed single species populations that reproduce synchronously at discrete time intervals is the following equation

\[ x(t + 1) = x(t)g(x(t)), \]  

(1)

where \( x(t) \) is the population size at generation \( t \). The per capita growth rate \( g(x(t)) \) is of Allee effect type (that is, a decrease in population growth at low population sizes). We study the Allee effect in generating multiple attractors. We also give an application to a diffusive logistic equation with predation of Holling type II functional response.

References


In this talk, for a given algebraic recurrence relation

\[ P(a_n, a_{n+1}, \ldots, a_{n+k-1}) = 0, \quad (1) \]

on a real numerical sequence \( \{a_n\} \), where \( P(x_0, \ldots, x_{k-1}) \) is a polynomial of \( k \) variables, we present algorithms to obtain general terms of \( \{a_n\} \) as formal series. As an application, we investigate a recurrence relation

\[ a_{n+2} = \frac{a_n}{1 + a_{n+1}}, \quad a_0 > 0, \quad a_1 > 0, \quad (2) \]

and determine the set \( D = \{(a_0, a_1) \in \mathbb{R}_+^2 \mid \lim_{n \to \infty} a_n = 0\} \), which is proven non-empty in [1].

References

[1] S. Stević, On the recursive sequence \( x_{n+1} = x_{n-1}/g(x_n) \), Taiwanese J. Math. 6 (2002) 405–414.
Difference equation and the related Schrödinger operator

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This talk is based on the joint work with Professors Kazuhiro Ishige of Tohoku University
and El Maati Ouhabaz of Université de Bordeaux.

We consider the difference equation of the form

\[ \frac{u_{n+1} + u_{n-1} - 2u_n}{h^2} + \frac{(N-1)(u_{n+1} - u_n)}{nh^2} + V(nh)u_n = 0, \]

where \( N \geq 2 \) is a fixed natural number, \( n \in \mathbb{N} \), \( h > 0 \), and \( V \) is a given function. For suitably given \( u_0 \) and \( u_1 \), we discuss the behavior of \( u_n \) as \( n \to \infty \). Also, as a limit \( h \to 0 \), we discuss properties of radial solutions to \(-\Delta u + V(|x|)u = 0\).

References


Uniqueness of Potential Function in Sturm-Liouville Difference Equation

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The aim of this talk is to present some uniqueness theorems for discrete Sturm-Liouville equation

\[-\Delta^2 y(n) + q(n)y(n+1) = \lambda y(n+1), \ n \in \mathbb{Z}, \] (1)

and Dirichlet boundary condition

\[y(0) = y(N+1) = 0\] (2)

by using the spectrum (collection of eigenvalues), where the sequence \[q = [q(n)]_{n \in \mathbb{Z}}\] is referred to as the potential. As usual, \[\Delta\] is the forward difference operator defined by

\[\Delta y(n) = y(n + 1) - y(n), \ \Delta^2 y(n) = y(n + 2) - 2y(n + 1) + y(n).\]

It is well known that the problem (1), (2) has \(N\) simple real eigenvalues with corresponding orthogonal eigenfunctions. By using the weighted numbers and eigenvalues, we will prove some uniqueness theorems analogue of continuous Sturm-Liouville problems.

References


On the behavior of the error in numerical iterative method for PDE

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The purpose of this talk is to present the behavior of the error in classical iterative method, Jacobi, Gauss-Siedel and SOR, for solving a partial differential equations. The coefficient matrix given by using difference approximation is very simple. This problem is a just right problem to check the property of the classical method.

We consider the partial differential equation.

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = f(x,y), \quad x, y \in \Omega$$

(1)

The continuous partial differential equation (PDE) is replaced with a discrete approximation [1]. So, we have a linear system $Ax = b$. It is easy to solve this coefficient matrix with symmetry. I inspect the differences to approximate and true values. As the order of matrix becomes large, the number of iteration increases. From a numerical examples, we use some preconditioning method [2, 3] to reduce the number of iteration, but we found an error increasing.

References


A Second-Order Rational Difference Equation with a Quadratic Term

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Recently, many people have investigated rational difference equations with non-linear terms, see [1, 2, 3] for several examples. We give the boundedness character, local and global stability of solutions of the following second-order rational difference equation with quadratic denominator,

\[ x_{n+1} = \frac{\alpha + \gamma x_{n-1}}{Bx_n + Dx_n x_{n-1} + x_{n-1}} \quad \text{for } n = 0, 1, \ldots, \]

where the coefficients are positive numbers, and the initial conditions \( x_{-1} \) and \( x_0 \) are nonnegative numbers such that the denominator is nonzero. In particular, we show that in a certain region, the unique equilibrium is globally asymptotically stable, while in another region, the equilibrium is a saddle and there exist prime period-two solutions.

References


The adjoint equation method for constructing first integrals of delay differential equations

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A new method for finding first integrals of delay differential equations is presented. It can be used for delay differential equations which do not possess a variational (Lagrangian) formulation. The method is based on a newly established identity which links symmetries of the underlying delay differential equations, solutions of the adjoint equations and first integrals. The method can be considered as a generalization of the previous research concerning with first integrals of differential and discrete equations. If a sufficient number of first integrals can be obtained, it is possible to find the general solution of the delay differential equations.

References


Nonoscillatory solutions of the four-dimensional neutral difference system

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The purpose of this talk is to present some results of studying the nonlinear neutral difference system

\[\begin{align*}
\Delta (x_n + p_n x_{n-\sigma}) &= A_n f_1 (y_n) \\
\Delta y_n &= B_n f_2 (z_n) \\
\Delta z_n &= C_n f_3 (w_n) \\
\Delta w_n &= D_n f_4 (x_{\gamma n})
\end{align*}\]

(S)

where \(n \in \mathbb{N}_0 = \{n_0, n_0 + 1, \ldots\}\), \(n_0\) is a positive integer, \(\sigma\) is a nonnegative integer, \(\{A_n\}, \{B_n\}, \{C_n\}, \{D_n\}\) are positive real sequences defined for \(n \in \mathbb{N}_0\), \(\Delta\) is the forward difference operator given by \(\Delta x_n = x_{n+1} - x_n\). The sequence \(\gamma : \mathbb{N} \to \mathbb{N}\) satisfies

\[\lim_{n \to \infty} \gamma_n = \infty.\]

The sequence \(\{p_n\}\) is a sequence of the real numbers and it satisfies \(0 \leq p_n < 1\). Functions \(f_i : \mathbb{R} \to \mathbb{R}\) for \(i = 1, \ldots, 4\) satisfy

\[\frac{f_i(u)}{u} \geq 1, \quad u \in \mathbb{R}\setminus\{0\}.\]

We study nonoscillatory solutions of (S) and we state asymptotic properties of solutions which lead to establishing sufficient conditions for the system to have weak property B and property B.

References


On topological invariants of Brouwer flows

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We study topological properties of Brouwer flows, i.e. flows of the plane which have no fixed points. For each Brouwer flow we have a decomposition of the plane into parallelizable regions with the transition maps between parallelizing homeomorphisms of these regions. We divide the set of all Brouwer flows into classes by the relation of topological equivalence of flows and for each of these classes we take a common index set for the considered decompositions. This allows us to compare the transition maps of Brouwer flows belonging to the same class. The main result gives a sufficient condition for topologically equivalent Brouwer flows to be topologically conjugate. The condition describes the relations between the transition maps of Brouwer flows contained in the same class. This result generalizes a theorem describing conjugacy classes of Reeb flows.

References


Recent advances in global stability of monotone maps: 
application to population dynamics

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In a previous work [2, 3, 4], the authors established global stability for a certain class of models. Based in these results, we introduce and develop in a forthcoming paper [1], a new notion of normal monotonicity of higher dimensional models defined on Euclidean spaces $\mathbb{R}^k$. Under certain conditions, we determine the global stability of normally monotone maps, i.e., if the map has a unique interior fixed point, then it must be globally asymptotically stable.

In this talk we will present the main results of our work and show the effectiveness of our tools providing detailed proofs of the global stability of two important competition models in population dynamics: the Leslie-Gower model and the Ricker competition model.

References


Discrete fractional Cucker–Smale optimal control problem

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In this work, we propose and study discrete fractional Cucker–Smale optimal control problem with Grunwald–Letnikov derivatives defined in the sense of Caputo. Necessary conditions of optimality are given and the numerical treatment to some particular problems is proposed.

References


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There has been an increasing interest in recent years in the analysis of multi–agent systems where agents interact accordingly to some local rules. Speaking about consensus we need to imagine a group of individuals who need to act together as a team or committee. An extensive analysis for the models introduced by Krause in [1] or sometimes referred to as the Hegelsmann–Krause model were given in [2] and [3]. In investigations we use interactions between opinions defined like in Hegselmann–Krause models but with included memory by fractional–order operator on the left side. We use the Grünwald–Letnikov–type difference operator. In the paper we investigate various models for the dynamics of discrete-time fractional order opinions by analytical methods and by computer simulations.

References


Exploration of combinatorial emergence in coupled boolean network systems

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We consider the following system of difference equations which describes state transition of a set of $N$ binary variables $x_i \in \{0, 1\}$:

$$x_i(t+1) = f_i(x_1(t), x_2(t), \ldots, x_n(t)), \quad (1)$$

where function $f_i : \{0, 1\} \to \{0, 1\}$ represents one of logical functions such as AND, OR, XOR and NOT. Boolean network model (1) proposed by S.A. Kauffman in 1969 [1] was proposed to describe random dynamics of gene regulatory network as crude but useful simplification of real gene regulatory network. Boolean network models have been used to understand regulatory dynamics of transcription factors which activate or suppress expression of various genes [2]. It is known that gene expression pattern changes when distinct cells are co-cultured, which could be typically observed for immune cells. Although several patterns exhibited by a boolean network model such as cycling and steady states qualitatively explain observable real patterns of gene expression dynamics, expected dynamical patterns exhibited by a coupled state of two different cell types have not been fully understood yet. In this talk, we consider a coupled boolean network system to investigate the possibility of combinatorial emergence: an emergent dynamical behavior that is given risen from coupling of two different dynamical systems. Potential biological implications are further discussed based on numerical simulation results.

References


Stability of a logistic equation with multiple delays

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We discuss stability of a logistic difference equation with multiple delays. Global stability conditions have been studied in papers e.g. [1, 4, 5]. We review the studies and introduce a new global stability condition obtained in [2]. We then visualize stability conditions in a parameter space performing linearized stability analysis [3]. Examples that delay can stabilize the equilibrium will be presented. A part of this talk is based on a collaboration work with Prof. Emiko Ishiwata and Naoyuki Yatsuda.

References


Set Invariance for Delay Difference Equations

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In set-theory, the notion of positive invariance is used to characterize the properties of dynamical systems. A positive invariant set is defined as a collection of initial conditions generating trajectories in forward time within the same set.

In this talk, set invariance properties for linear time-delay systems are addressed. More precisely, the first goal is to review known necessary and/or sufficient conditions for the existence of invariant sets with respect to dynamical systems described by linear discrete time-delay difference equations (dDDEs) of the form:

\[ x(k + 1) = \sum_{i=0}^{d} A_i x(k - i) \]  

where \( x(k) \in \mathbb{R}^n \) is the state vector at the time \( k \in \mathbb{Z}_+ \), \( d \in \mathbb{Z}_+ \) is the maximal fixed time-delay, the matrices \( A_i \in \mathbb{R}^{n \times n} \), for \( i \in \mathbb{Z}_{[0,d]} \) and the initial conditions are considered to be given by \( x(-i) = x_{-i} \in \mathbb{R}^n \), for \( i \in \mathbb{Z}_{[0,d]} \). Secondly, the construction of invariant sets in the original state space, also called \( \mathcal{D} \)-invariant sets, by exploiting the forward mappings is addressed. The notion of \( \mathcal{D} \)-invariance is appealing since it provides a region of attraction, which is difficult to obtain for time-delay systems without taking into account the delayed states in some appropriate extended state space model.

In this talk we will discuss recent results related to sufficient conditions for the existence of ellipsoidal \( \mathcal{D} \)-contractive sets for dDDEs, and necessary and sufficient conditions for the existence of \( \mathcal{D} \)-invariant sets with respect to linear time-varying dDDE stability. Another interesting point is the clarification of the relationship between convexity (convex hull operation) and \( \mathcal{D} \)-invariance of linear dDDEs. In short, it is shown that the convex hull of the union of two or more \( \mathcal{D} \)-invariant sets is not necessarily \( \mathcal{D} \)-invariant, while the convex hull of a non-convex \( \mathcal{D} \)-invariant set is \( \mathcal{D} \)-invariant.

References

On the Hyers-Ulam stability of a first-order linear difference equation

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In 1998, C. Alsina and R. Ger [1] investigated the Hyers-Ulam stability of the linear differential equation

\[ x' = x, \quad t \in I, \]

where the prime denotes the derivative with respect to \( t \); \( I \) is a nonempty open interval of \( \mathbb{R} \). To be precise, they proved that if a differentiable function \( \phi : I \rightarrow \mathbb{R} \) satisfies

\[ |\phi'(t) - \phi(t)| \leq \varepsilon \]

for all \( t \in I \), then there exists a differentiable function \( x : I \rightarrow \mathbb{R} \) such that \( x'(t) = x(t) \) and

\[ |\phi(t) - x(t)| \leq 3\varepsilon \]

for all \( t \in I \), where \( \varepsilon \) is a given non-negative constant. When this fact is satisfied, we say \( x' = x \) has the “Hyers-Ulam stability”. Moreover, we call the constant 3 “Hyers-Ulam stability constant (HUS constant)” for the differential equation \( x' = x \).

In this talk, we consider the first-order linear difference equation

\[ \Delta_h x(t) = x(t), \quad t \in h\mathbb{Z}, \tag{1} \]

where

\[ \Delta_h x(t) = \frac{x(t + h) - x(t)}{h}, \quad h > 0; \]

and \( h\mathbb{Z} = \{hk | k \in \mathbb{Z}\} \). The aim of this talk is to clarify that difference equation (1) has the Hyers-Ulam stability with HUS constant 3.

References


The growth of positive solutions of difference equations with applications to delay differential equations

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In this talk, we first recall our previous result on the growth rates of positive solutions of a system of difference equations [2]. Then we show how this discrete result can be used to determine the growth rates of the positive solutions of a class of delay differential equations.

References


Boundedness of Solutions in Almost Linear Volterra Difference Equations Using Fixed Point Theory and Lyapunov Functionals

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In this talk we consider the almost linear Volterra difference equation

\[ \Delta x(n) = a(n)h(x(n)) + \sum_{k=0}^{n-1} c(n, k)g(x(k)) \quad (1) \]

and obtain conditions under which all solutions are bounded, using Krasnoselskii’s fixed point theorem. Also, we will display a Lyapunov functional that yields boundedness of solutions and compare both methods through examples.

References


Integral stability for dynamic systems on time scales

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We consider the dynamic system in a Banach space on unbounded above and below time scales:

\[
\begin{align*}
    x^\Delta &= A(t)x + f(t, x, y), \\
    y^\Delta &= B(t)y + g(t, x, y).
\end{align*}
\]

(1)

This system satisfies the conditions of integral separation with the separation constant \(\nu\), the integral contraction with the integral contraction constant \(\mu\), nonlinear terms are \(\varepsilon\)-Lipshitz, and the system has a trivial solution. We prove the theorem of asymptotic phase. Using this result and the centre manifold theorem we reduce the investigation of integral stability of the trivial solution of (1) to investigation of integral stability of the trivial solution of the reduced dynamic system

\[
x^\Delta = A(t)x + f(t, x, u(t, x)).
\]

References


This work was partially supported by the grant No. 345/2012 of the Latvian Council of Science.
Bounded solution of dynamic system on time scale

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We consider the dynamic equation in a Banach space on unbounded above and below time scales $\mathbb{T}$:

$$x^\Delta = A(t)x + f(t, x), \tag{1}$$

with $rd$-continuous, regressive right hand side, nonlinear term satisfy the Lipschitz condition

$$|f(t, x) - f(t, x')| \leq \varepsilon(t)|x - x'|,$$

and the estimate

$$|f(t, 0)| \leq N(t) < +\infty.$$  

where $N: \mathbb{T} \to \mathbb{R}_+$ and $\varepsilon: \mathbb{T} \to \mathbb{R}_+$ are integrable scalar functions. Using Green type mapping [1] we find sufficient condition for the existence of bounded solution and investigate it’s properties. We give an example in the case of the nonuniform exponential dichotomy.

References


This work was partially supported by the grant Nr. 345/2012 of the Latvian Council of Science
Applications of non-autonomous discrete dynamical systems into nonlinear consensus problems

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Historically, an idea of reaching consensus through repeated averaging was introduced by DeGroot (see [1, 3]) for a structured \textit{time-invariant} and synchronous environment. Since that time, the consensus which is the most ubiquitous phenomenon of multi-agent systems becomes popular in various scientific communities, such as biology, physics, control engineering and social science. Roughly speaking, a trajectory of a row-stochastic matrix presents DeGroot’s model of the structured \textit{time-invariant} synchronous environment. In [2], Chatterjee and Seneta considered a generalization of DeGroot’s model for the structured \textit{time-varying} synchronous environment. A trajectory of a sequence of row-stochastic matrices (a non-homogeneous Markov chain) presents the Chatterjee-Seneta model of the structured \textit{time-varying} synchronous environment.

In this paper, we shall consider a \textit{nonlinear model of the structured time-varying synchronous environment} which generalizes both DeGroot’s and the Chatterjee-Seneta models. Namely, by means of multidimensional stochastic hypermatrices, we present an opinion sharing dynamics of the multi-agent system as a trajectory of non-autonomous polynomial stochastic operators (nonlinear Markov operators). We show that the multi-agent system eventually reaches to a consensus under suitable conditions.

References


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On the Stability of an SIR epidemic discrete model with a delay

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A model for the spread of disease-causing is treated with some mathematical epidemic discrete equation with a delay. In this talk, we consider the asymptotic stability of a discrete SIR epidemic discrete model with a delay by applying the luxury Liapunov functional.

References


Converse theorems on globally asymptotic stability of solutions for nonlinear difference equations

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In this talk we consider initial value problems

\[ x(n+1) = f(n, x(n)), \quad x(n_0) = x_0 \]

where \( k \in \mathbb{Z}_+ = \{0, 1, 2, \ldots \}, k \geq 1, n_0 \in \mathbb{Z}_+, n \in \mathbb{Z}_+, x_0 \in \mathbb{R}^k, x \in \mathbb{R}^k \) and \( f(n, x) \) is continuous in \( x \in \mathbb{R}^k \) for each \( n \in \mathbb{Z}_+ \) with a unique equilibrium point \( x_e = f(n, x_e) \) for \( n \in \mathbb{Z}_+ \). In the same way as in T. Yoshizawa [2] we give converse theorems in case that the equilibrium \( x_e \) of the above equation is globally asymptotic stability (see definitions in [1]). And also their applications of the converse theorems are dealt with to perturbed equations.

References


Equations with five variables give the second Feigenbaum constant

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Feigenbaum constant is an universal value between simple chaotic models and fractals [1]. A series expansion for the constant is not known yet. It is just found in almost two thousands digits in Briggs’ thesis [2].

An universal function $g(x)$ which is required for calculation of the constant, has following properties [3, 4],

1. $g(x)$ is an even function.

2. $g(\alpha x)/\alpha = g(g(x))$

3. $\alpha = 1/g(1)$

4. $g(0) = 1$

We propose the equations with five variables by linearizing above properties. These equations may be calculated by some types of greedy algorithm, that is a set of difference equations.

References


[4] M. Campanino et al., On Feigenbaum’s Functional Equation $g \circ g(\lambda x) + \lambda g(x) = 0$ Topology 21 (1982) 125–129.

Nonoscillation theorems for second-order linear difference equations via the Riccati-type transformation

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In this talk, nonoscillation problem is dealt for the second-order linear difference equation

\[ c_n x_{n+1} + c_{n-1} x_{n-1} = b_n x_n, \]

where \( \{b_n\} \) and \( \{c_n\} \) are positive sequences. For all sufficiently large \( n \in \mathbb{N} \), the ratios \( c_n / c_{n-1} \) and \( c_{n-1} / b_n \) play an important role in the results obtained. To be precise, our nonoscillation criteria are described in terms of the sequence

\[ q_n = \frac{c_{n-1}}{b_n} \frac{c_n}{c_{n-1}} \frac{c_{n-1}}{b_{n+1}} = \frac{c_{n-1}^2}{b_n b_{n+1}}. \]

These criteria are compared with those that have been reported in previous researches by using some specific examples. Figures are attached to facilitate understanding of the concrete examples.

References


An evolutionary game model of families’ voluntary provision of public goods

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We consider a two-stage voluntary provision model where individuals in a family contribute to a pure public good and/or a household public good, and an altruistic parent makes a non-negative income transfer to his or her child. The subgame perfect equilibrium derived in the model is analyzed using two evolutionary dynamics games (i.e., replicator dynamics and best response dynamics). As a result, the equilibria with ex-post transfers and pre-committed transfers coexist, and are unstable in the settings of replicator dynamics as well as best response dynamics, whereas the monomorphic states (i.e., all families undertake either ex-post or pre-committed transfers) are stable. An income redistribution policy does not alter the real allocations in the settings of both evolutionary dynamics games, because the resulting real allocations depend on only the total income of society and not on the distribution of individual income.

References


Prime period 4 behavior of certain piecewise linear system of difference equations where initial condition are some points in positive x-axis

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Recently the authors have been working on a comprehensive project examining the global behavior of a family of systems of piecewise linear difference equations. In this presentation we will share the results from a specific system:

\[ x_{n+1} = |x_n| - y_n - 1 \]
\[ y_{n+1} = x_n + |y_n| - 1 \]

where initial conditions \((x_0, y_0)\) is such that \(x_0\) is an arbitrary non-negative real value, and \(y_0\) is an arbitrary real value. We will show that every solution of this system is either one of two prime period-3 solutions, or one of two prime period-4 solutions or the unique equilibrium solution. We will also share the sufficient conditions for the prime period-4 solutions.

References

[1] E. A. Grove, E. Lapierre and W. Tikjha, *On the global behavior of* \(x_{n+1} = |x_n| - y_n - 1 \) and \(y_{n+1} = x_n + |y_n| - 1\), *Cubo*. 14 (2012) 125–166.


This talk is concerned with the stability of traveling wave fronts for delayed monostable lattice differential equations given by

\[ \dot{x}_j(t) = G(x_{j-n}(t-\tau_n), \ldots, x_{j-1}(t-\tau_1), x_j(t), x_{j+1}(t-\tau_1), \ldots, x_{j+n}(t-\tau_n)), \]  

where \( j \in \mathbb{Z} \); the positive constants \( \tau_{\pm k} \) for \( k = 1, \ldots, n \) are discrete time delays and the spatially independent nonlinearity \( G(u_{-n}, \ldots, u_0, \ldots, u_n) : \mathbb{R}^{2n+1} \to \mathbb{R} \) is a \( C^2 \) function. We study the stability of a traveling wave front by using comparison principles for the Cauchy problem and initial-boundary value problem of the lattice differential equations, respectively. We show that any solution of the Cauchy problem converges exponentially to a traveling wave front provided the initial perturbation around the traveling wave front is restricted in the weighted space whose asymptotic exponential rate at \(-\infty\) (in moving coordinate) is greater than that of the traveling wave front.

References


Regular iterations connected with an initial value problem of a nonlinear difference equation

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Let $f$ be an increasing homeomorphism of $[0, \infty)$ onto itself with no non-zero fixed point such that $d := f'(0)$ exists and $0 < d < 1$. Let $U : \mathbb{N} \to C[0, \infty)$ satisfy the difference equation $f \circ U(n + 1) = U(n) \circ f$ with the initial condition $U(0)(x) = \alpha x$, where $\alpha > 0$. The purpose of this talk is a presentation of the properties of asymptotic solutions of the above equation in a dependence on the parameter $\alpha$, that is the properties of the limits

$$f_{\alpha, \infty}(x) := \lim_{n \to \infty} f^{-n}(\alpha(f^n(x)))$$

and

$$\limsup_{n \to \infty} f^{-n}(\alpha(f^n(x))) = \liminf_{n \to \infty} f^{-n}(\alpha(f^n(x)))$$

if the last equality holds.

Put $N_\alpha := \{ \alpha > 0 : f_{\alpha, \infty}(a) = \lim_{n \to \infty} f^{-n}(\alpha(f^n(x))) \}$. We prove that for every (some) $\alpha > 0$ set $\mathbb{R}^+ \setminus N_\alpha$ is at most countable and the map $\alpha \to f_{\alpha, \infty}(a)$ is injective if and only if the Schröder equation $\sigma(f(x)) = d \sigma(x)$ has a regularly varying solution. If $N_\alpha = \mathbb{R}^+$ for an $x > 0$ then the family $\{f_{\alpha, \infty}, t > 0\}$ stands a regular multiplicative iteration group, that is

$$f_{\alpha, \infty} \circ f_{\beta, \infty} = f_{\alpha \beta, \infty}, \quad \alpha, \beta > 0$$

and $f_{\alpha, \infty}$ are differentiable at zero. Moreover, $f_{d, \infty} = f$ and $f'_{\alpha, \infty}(0) = \alpha$ for $\alpha > 0$. If $f$ is of class $C^1$ and $f'(x) = d + O(x^\rho)$ or $f$ is convex or concave then $N_\alpha = \mathbb{R}^+$. Several others properties of $f_{\alpha, \infty}$ and $\alpha_{\alpha, \infty}$ will be presented.

References


Self-adjoint extensions of minimal linear relation associated with discrete symplectic system

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In this talk we discuss self-adjoint extensions of the minimal linear relation associated with the (time reversed) discrete symplectic system

\[ z_k(\lambda) = S_k(\lambda) z_{k+1}(\lambda), \quad S_k(\lambda) := S_k + \lambda V_k, \quad (S_\lambda) \]

where \( \lambda \in \mathbb{C} \) is the spectral parameter and the \( 2n \times 2n \) complex-valued matrices \( S_k \) and \( V_k \) are such that

\[ S_k^* J S_k = J, \quad V_k^* J V_k \text{ is Hermitian}, \quad V_k^* J V_k = 0, \quad \Psi_k := J S_k J V_k^* J \geq 0 \quad (1) \]

with the skew-symmetric \( 2n \times 2n \) matrix \( J := \begin{pmatrix} 0 & I \\ -I & 0 \end{pmatrix} \), the superscript * denoting the conjugate transpose, and \( k \) belonging to a discrete interval, which is finite or unbounded above. Especially, we emphasize that the matrix \( S_k \) is (conjugate) symplectic according to the first identity in (1). The talk is based on a joint research with S. L. Clark, see [1, 2].

References


Tempered exponential dichotomy describes nonuniform hyperbolicity for linear random dynamical systems. In this talk, we present a result on the roughness of the tempered exponential dichotomy. The result is given in Banach spaces without assuming the invertibility and the integrability condition of the Multiplicative Ergodic Theorem. Moreover, the approach we used gives an explicit estimate for perturbations and an explicit form for the exponent and the bound of the tempered exponential dichotomy. This is a joint work with Kening Lu and Weinian Zhang.

References


Non-commutative symmetries for generalized Davey-Stewartson equations

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The purpose of this talk is to introduce an analog and reveal the Lie-algebraic structure symmetries [3] of the generalized Davey-Stewartson (GDS) system of equations [1, 2] in a non-commutative setting [6]. In particular, we show that the symmetries in the non-commutative case [4, 6] are related to two copies of the Poisson bracket continual Lie algebra over a non-commutative field [5, 7]. Examples and further development is also provided.

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