Chaotic Modeling &
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Book of Abstracts

Plenary and Keynote Talks

Applying a Kernel PCA Method to Reveal Coexisting Attractors within a Generalized Lorenz Model

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Based on recent studies that reveal the coexistence of chaotic and nonchaotic solutions using a generalized Lorenz model (GLM), a revised view on the dual nature of weather has been proposed (Shen 2019a, b; Shen et al. 2019, 2020a, b), as follows: the entirety of weather is a superset consisting of both chaotic and non-chaotic processes. Since better predictability for non-chaotic processes can be expected, an effective detection of regular or chaotic solutions can improve our confidence in numerical weather and climate predictions. In this study, by performing a kernel principle component analysis of coexisting attractors obtained from the GLM, we illustrate that the time evolution of the first eigenvector of the kernel matrix, referred to as the first kernel principle component (K-PC), is effective for the classification of chaotic and non-chaotic orbits. The spatial distribution of the first K-PC within a two-dimensional phase space can depict the shape of a decision boundary that separates the chaotic and non-chaotic orbits. We additionally present how a large number (e.g., 128 or 256) of K-PCs can be used for the reconstruction of data in order to illustrate the different portions of the phase space occupied by chaotic and non-chaotic orbits, respectively.
In this talk, we will additionally analyze the KPCA from a perspective of singular value decomposition. When a matrix A is constructed for the transformed data, a small matrix (A^T A) represents a multiplication of the covariance matrix by a constant n, and a large matrix AA^T signifies the kernel matrix. The right and left eigenvectors of A are indeed the eigenvectors of the covariance and kernel matrices, respectively. An important relationship between the covariance and kernel matrices that provides the foundation for the KPCA is that the

eigenvectors of the kernel matrix represent the normalized projections of transformed data onto the eigenvectors of the covariance matrix. Applying the so-called kernel trick to choose a kernel function, a kernel matrix can be constructed using raw data without explicitly generating the transformed data matrix, A. The eigenvalues and the eigenvectors of the kernel matrix are then analyzed for classification.

Keywords: K-PCA, Chaos, Coexisting Attractors, Decision Boundary, Generalized Lorenz Model

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Cryptocurrencies Portfolio Synthesis by Max Entropy Principle

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A Cryptocurrency is a digital medium of exchanges but also an attractive unique asset on investor alternatives. In this paper the max entropy

principle is applied to Cryptocurrencies portfolio synthesis problem. In contract to classical Mean-Variance approach of Markowitz, equal weights or 1/N portfolios resulting from Max Entropy approach, lately demonstrated that is superior to investors' interest. Applying the max entropy principle of portfolio cryptocurrencies weights subject to expected return, resulting a max entropy curve on a Return-Entropy chart. This is an efficient frontier of portfolio Return-Entropy. Mathematically is the solution of non-linear constrained optimization, solved step by step, starting from the simple equal weights' global maximum of entropy. In this efficient frontier is possible to maximize the investor utility by using an appropriate Entropic Return Index, like the Sharpe ratio in Mean-Variance portfolio approach. The relation with Mean-Variance approach is presented in detail using illustrative examples of portfolios with 5-10-15-20 cryptocurrencies. The performance of proposed portfolio synthesis approach with naïve equal weights (1/N) and M-V min risk discussed in the framework of Jaynes max entropy principle distributions.
KEYWORDS: Cryptocurrency, Portfolio Synthesis, Max Entropy Principle, Mean-Variance Portfolio, (1/N) Equal Weights Portfolio, Nonlinear Constrained Optimization.

Interacting Populations: Dynamics and Viability in Bounded Domains under Uncertainty

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We study the nonlinear dynamical control systems which describe the dynamics of the interactions of predators and their preys under assumption of uncertainty in related initial conditions. It is assumed that the interaction of populations occurs in limited areas, estimated by corresponding ellipsoids. The possible presence of uncertainty or errors in determining the parameters of these ellipsoids and the uncertainty in the initial conditions of the moving objects and also in some parameters of dynamical systems are also taken into account. Procedures and algorithms for evaluating the movements of upper estimates of reachable sets of the system under indicated conditions of uncertainty are proposed. The research is based on the approach [1,2] and continues the studies [3,4]. Numerical simulation results related to the proposed techniques and illustrating the results are also included.
Acknowledgement: The research is supported by the Research and Education Center of IMM UB of RAS in the framework of the Ural Mathematical Center (Project "Set-Valued Dynamics in Control and Estimation Problems forDynamical Systems with Uncertainty").

Keywords: Nonlinear control systems, Set-membership uncertainty, Ellipsoidal calculus, Viability, State estimation

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Vector difference equations, Gerschgorin's theorem, and design of multi-networks to reduce spread of epidemics

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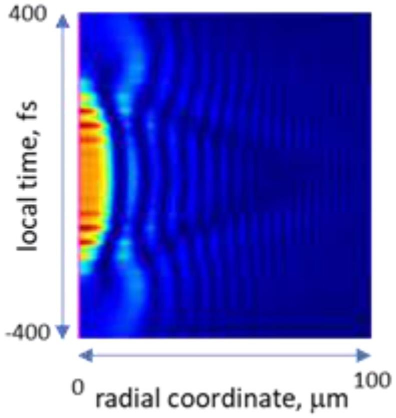
We start with the SIR model (susceptible, infected, removed) on a network. Since the goal is to make I = 0 a (Lyapunov) stable equilibrium, we linearize the discrete-time SIR model to obtain difference equations of the form Inew = I(1 + aS - b) at each node before including infections derived from other nodes. We assume S equal to its initial value at that node. Here a depends upon the infectivity and contact rate, b = 1/(duration of infectivity) and the traditional Rt = aS/b (Rt < 1 corresponds to aS < b). This yields a vector difference equation Inew = MI. Since all entries in M are assumed non-negative, one expects that the maximum row sum is a relatively tight bound on the maximum eigenvalue by the Gerschgorin circle theorem. Interpretation: for 0 to be a stable equilibrium (the infection dies out), the total flow into any node must be less than the value of aS - b at that node. The entries of M may vary in time, even discontinuously as flows between nodes are turned on and off. This may yield useful design constraints for a multi-network composed of weak and strong interactions between pairs of nodes representing interactions within and among cities.

Keywords: Epidemiology, SIR model, Lyapunov stability, pandemics



Spatiotemporal Turbulence in a Multimode Fiber Laser

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We demonstrate the occurrence of spatial mode-cleaning in a normal dispersion regime, provided by graded-dissipation in a multimode fiber. It was found that the contribution of excited "internal soliton modes" in the soliton destabilization process becomes crucial when the dissipative soliton energy scales higher (see the Figure, presenting the contour plot of laser field intensity: the wavelength is of 1.03 mm, the pulse power is of 100 kW, the Gaussian beam size is of 10 mm, the input pulse width is of 150 fs, the propagation length is of 1.5 cm). We consider such a mode-cleaning enforced by spatially graded and spectral dissipation, as a realization of distributed Kerr-lens mode-locking in a multimode fiber laser, where the turbulent dynamics can be suppressed by the adjustment of dissipative factors. The proposed photonic devices could provide an efficient tool for metaphorical modeling of strongly localized coherent structures, emerging in nonlinear nonequilibrium dissipative systems, e.g., in a Bose-Einstein condensate in the weakly-dissipative limit.

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Keywords: Dissipative spatiotemporal solitons, Turbulent dynamics, Multimode fiber lasers, metaphorical modeling, weakly-dissipative Bose-Einstein condensate.

Pattern Formation of Limit Cycles for 2-D Generalized Logistic Maps

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The pattern formation of discrete limit cycles with chaotic dynamics is considered, for two-dimensional (2-D) generalized logistic maps. Firstly, the time-dependent chaos function with an amplitude function is proposed, and a 1-D generalized logistic map is derived for population growth. In particular, the number of newly infected people, due to the COVID-19, is modeled by the 1-D logistic map. Secondly, 2-D generalized logistic maps with a system parameter and amplitude functions are derived by extending the 1-D logistic map, and stable limit cycles with entrainment and synchronization are numerically calculated. Finally, the pattern formation of limit cycles is discussed for the 2-D generalized logistic maps, which are restricted by the system parameter and amplitude functions, as non-equilibrium open systems.
Keywords: Logistic map, 2-D logistic map, Time-dependent chaos function, Population growth, Limit cycle, Pattern formation, Non-equilibrium open system

Chaos identification of a colliding constraint body on a moving belt

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The main aim of this paper is to introduce a new mechanical system modeled by a non-autonomous system of ordinary differential equations and to detect its movement character using a combination of the 0-1 test for chaos and approximate entropy instead of the standard Lyapunov exponent treatment. The investigated system consists of a cylinder hanging on a flexible rope, and a moving belt. Such a system with impacts and dry friction is illustrative of many industrial applications, such as stones falling on a moving conveyor belt. The mathematical model of the system has three degrees of freedom, from which two correspond to the position of the cylinder centre and the last one to its angular rotation. The studied system was excited by a slider moving in the vertical direction, and by impacts between the cylinder and the belt. Consequently, the cylinder exhibits movement with both regular (periodic) and irregular (chaotic) patterns depending on the excitation amplitude and frequency. The goal of the research was to qualify and quantify the movement character. For this purpose, the 0-1 test for chaos together with approximate entropy was applied to find regions of parameters for which chaos or regularity was observed.
Keywords: Inteaction between a body and a moving belt, Collisions, 0-1 test for chaos, Approximate entropy, Bifurcation

Chaotic behavior of dynamical systems associated with dynamic traffic assignment in transportation

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Dynamic traffic assignment is a fundamental problem in transportation planning and management. But it is difficult to solve, and constitutes the object of very active researches. (refer for instance to Wang et al 2018).
In a dynamic traffic assignment problem, the total demand for trips, the origins, the destinations, and the desired arrival times in the transportation network constitute the data of the problem. The object of the assignment problem is to determine how this demand is distributed between paths and between departure times. As more travelers choose an option (departure time, path), the resulting congestion reduces the attractivity of this option. Thus the assignment problem can be viewed as an equilibrium problem. From the travelers' point of view, it is a Nash equilibrium, with each traveler choosing the option with minimum cost (travel time plus penalty for not arriving exactly at the desired arrival time). The equilibrium points of a dynamic assignment problem need not be unique (the multimodal case for instance, see Iryo and Watling 2019) nor need they be stable.
Traditionally two categories of assignment must be distinguished (Papageorgiou 1990): reactive and predictive. In reactive assignment travelers respond in real time to information (internet, operators, etc). In predictive assignment they base their decision on their knowledge of the network.
It is possible to associate to a dynamic assignment problem a field which has the same equilibria as the dynamic assignment problem. In the reactive case, the dynamical system associated to the field emulates the learning process of travelers. In discretized form it could represent the day-to-day learning process: how travelers adjust their decision by traveling each day through the network. Several such fields have been proposed, for instance Smith 1984, Nagurney and Zhang 1997, Jin 2007, Lebacque et al 2009, Smith and Watlin 2016.
In this paper we will consider a simplified network transportation model, the "bathtub model" (Jin 2020). In a nutshell the demand is disaggregated per trip length and desired arrival time Speed in the network is a decreasing function of the total number of travelers in the network. The dynamics of traffic in the network are described by an infinite dimensional dynamical system. The relative simplicity of the model allows us to include departure time choice into the analysis of assignment.

The travel demand must be distributed between departure times. The field used to analyze the assignment process (we choose the Nagurney field for simplicity) operates on the space of the distribution of travel demand.

The distribution of demand is adjusted progressively along field lines until an equilibrium is reached. Considering the multiplicity of equilibria as well as the possibility of unstable equilibria, chaotic behavior can occur, in the predictive case but also in the reactive case, in which real-time information is liable to affect aversely the network equilibrium (Khoshyaran Lebacque 2020). Such effects have been observed on networks where internet/social network information providers have a significant impact on assignment.

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Keywords: Nonlinear dynamical systems, infinite dymensional systems, fixed points, stability, network equilibrium, bathtub model, assignment field, day-to-day process

Mechanism of Formation of Fluctuation Phenomena

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At the present time, there is no theory explaining the mechanism of formation of fluctuation phenomena. A new model is proposed based on the combined action of force and moment of force on the formation of fluctuations in the mechanics of a continuous medium. Until now, the laws of equilibrium for forces and moments of forces were built without taking into account the distributed moment per force. As a result, a symmetric stress tensor was obtained, which does not allow mathematical description of some physical phenomena. In statistical physics, this meant the exclusion of a change in the position of the center of inertia of an elementary volume during the thermal motion of molecules. Taking such a motion into account leads to a change in the speed of particles and their number. These changes can be essential for calculating the equation of state (virial coefficients). The above issues are discussed in the report.

Maximally Chaotic Dynamical Systems

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The maximally chaotic dynamical K-systems are the systems which have nonzero Kolmogorov entropy. The Anosov C-condition defines a reach class of hyperbolic dynamical systems that have exponential instability of their phase trajectories and positive Kolmogorov entropy and are therefore maximally chaotic. The interest in Anosov-Kolmogorov systems is associated with the attempts to understand the relaxation phenomena, the foundation of the statistical physics, the appearance of turbulence in fluid dynamics, the non-linear dynamics of the Yang-Mills field, the N-body system in Newtonian gravity and the relaxation phenomena in stellar systems and the Black hole thermodynamics. The classical- and quantum-mechanical properties of maximally chaotic dynamical systems, the application of the C-K theory to the investigation of the Yang-Mills dynamics and gravitational systems as well as their application in the Monte Carlo method will be presented. e-Print: 2001.04902 [hep-th]
Keywords: Classical and Quantum Chaos, Kolmogorov-Sinae entropy, Anosov hyperbolic systems, Yang-Mills gauge systems, gravity and N-body systems, Monte-Carlo method, Instability of fluid hydrodynamic.

Generalizing of Attractor Notion for Spherical Pendulum Systems

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The nonideal spherical pendulum system which is described by nonlinear system of differential equations of 5-th order is considered [1, 2]. The existence of so-called maximal attractor is established. It is argued that general term «attractor» is not applicable in this system. It is shown that such maximal attractor consists of infinitely many limit sets (similarly to fact that attractor in general sense may consist of infinitely many trajectories) and all limit sets inherit all properties of maximal attractor and vice versa. The possibility of maximal attractor to be localized in the three dimensional space (namely, representative limit set of maximal attractor) is shown. The various scenarios of transition to chaos of maximal attractor (and consequently all limit sets of it) are described.
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Keywords: Spherical Pendulum, Generalized Attractor, Chaotic Maximal Attractor, Regular Maximal Attractor

How the unsolved problem of finding the Healthy Life Expectancy (HLE) in the far past was resolved: The case of Sweden (1751-2016) with forecasts to 2060 and comparisons with HALE

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Healthy Life Expectancy (HLE) estimates are achieved after systematic work of a large group of researchers all over the world during last decades. The most successful estimate was termed as HALE and is provided by the World Health Organization (WHO) in the related website.

Having established a methodology of data collection and handling the HLE can be estimated and provided to researchers and policy makers.
However, it remains an unexplored period of the last few centuries where, LE data exists along with the appropriate life tables, but not enough information for HLE estimates is collected and stored. The problem is now solved following a methodology of estimating the HLE from the life tables after the Healthy Life Years Lost (HLYL) estimation.
Our methodology on a Direct HLYL estimation from Life Tables, is tested and verified via a series of additional methods including a Weibull parameter test, a Gompertz parameter alternative and of course a comparison with HALE estimates from WHO. The complete methodology and estimation methods are published in the book on "Demography of Population Health, Aging and Health Expenditures" of Volume 50 of the Springer Series on Demographic Methods and Population Analysis.
https://www.springer.com/gp/book/9783030446949 ,
https://doi.org/10.1007/978-3-030-44695-6
https://osf.io/preprints/socarxiv/akf8v/

Keywords: Life Expectancy, Healthy Life Expectancy, HALE, Logistic model, forecasts, Life Tables

The equations of nature and the nature of equations

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We need tools to explain why some networks are robust to perturbations, but others are vulnerable. Differential equations and graph theory has been used as ubiquitous tools by scientists in the studying a vast group of networks. Even though there is an extensive literature available on studying linear system of equations using graphs and matrices, the interactions between network members in most cases are nonlinear.
We began this investigation to understand ecological networks. There was much more written about stability of ecosystems than about the question of whether the ecosystem had a robust equilibrium.
Some ecological networks can have a steady state that depends on the system improbably being perfectly balanced, where arbitrarily small changes result in the absence of a steady state.
We find that some networks can have robust steady states and others cannot and we can tell what the difference independent of the actual details of the equations. We do not address the question of stability of robust solutions, but our theory opens the door to such investigations.
To understand this problem, we had to attack a much broader question: How do we know if a system of N equations in N unknowns, $F(X) = C$ has a robust solution. That is, if some X and C satisfy the equation and arbitrarily small changes in C still have solutions. It is surprising to us how general our solution is that we came up with.

Symposium

Nonlinear Dynamics and chaos for energy harvesting and diagnostics

Virtual session

Symposium organizers:
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Scope and Rationale

Currently, increasing research activity is observed in the field of distributed energy harvesting from ambient vibrations, leading to the development of complex systems using multi-field devices with piezoelectric, electrostatic, and electromagnetic transducers. The low efficiency of these devices are compensated by the high availability of vibration sources. Systems with linear transducers operate efficiently when in resonance with the source frequencies, while complex nonlinear devices can be made efficient in a broader spectrum by leveraging the effects of sub- and super-harmonics in the response as well as possible chaos. On the other hand, diagnostics of the specific device or phenomenon can be performed by the filters basing on nonlinear models with similar appearance of multiple solutions. Various solutions appearing in the systems can be stabilized or destabilized informing about the examined state or dynamical process.

Keywords: Energy harvesting, nonlinear dynamics, simulations of smart material, multiple responses, chaos identification, nonlinear methods in diagnostics

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The Papers of the Symposium

Energy harvesting from flow induced vibrations in a flexible flapper

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This study investigates the energy harvesting characteristics from flows using a vortex induced vibration (VIV) based energy harvester. The harvester comprises of a bluff body and a detached flapper made up of a thin flexible plate placed in its downstream. The study focuses on developing a high fidelity FSI framework comprising of an incompressible Navier-Stokes (NS) solver, coupled with an elastic structural model. The incompressible NS equation has been cast into arbitrary Lagrangian Eulerian formulation on a moving grid with a Laplacian mesh moving strategy. The flow solver uses a second order accurate spatial discretization and the temporal discretization is performed using a second order implicit backward differencing scheme. A variable time stepping technique based on a maximal Courant number has been adopted. The pressure velocity coupling is implemented through PISO (Pressure Implicit with Splitting of Operator) algorithm. The absolute error tolerance criteria for pressure and velocity are set to predefined thresholds. The flexible flapper was modelled as an elastic continuum with its leading edge restrained as a fixed support. The structural behaviour has been analysed through a large strain elastic stress analysis solver based on Lagrangian displacement formulation. A quasi-Newton coupling algorithm, with an approximation for the inverse of the residual's Jacobian matrix from a least-square model (IQN-ILS), has been adopted in the strong coupling method. The strong coupling scheme demands solving the subsystems multiple times until the convergence criterion at the interface is satisfied. The FSI model has been coupled in one way coupling with the energy equation. Essentially the composite structure with the MFC generates strain, which is spatio-temporally varying. Voltage output of the flapper is dependent upon the strain rate time history integrated over the length of the beam, which is computed from the FSI part of the solver. Simulations have been carried out considering different gaps and locations of the flapper, as well as with different shapes for the bluff body, to compare its FSI behavior while interacting with oncoming wake vortices. Depending on the configuration, it has been observed that the flapper exhibits either 1st mode oscillations, period 2 oscillations with weak quasi-periodic signature, mixed mode oscillations or aperiodic broadband behaviour.

The quantum of power harvested undergoes significant changes for different configurations of the VIV based energy harvester.
Keywords: Vortex induced vibrations, Energy harvesting, Fluid-structure interactions, Navier Stokes solver, nonlinear response

Effects of additive noise on the energy harvesting characteristics of a base excited double pendulum

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It has been observed in the literature that energy harvested from ambient sources provides a better broadband efficiency under chaotic motion. This happens at a low amplitude of power. A trade-off between power harvester and the frequency band has led to many designs of energy harvesters. This study focusses on a recently reported base excited double pendulum [1] to generate electricity in small scale but through a noisy environment.
The system consists of two pendulums attached in series with rigid massless links. The masses are assumed to be concentrated at the bobs. The tip of the second pendulum contains a magnetic mass which when moves over a series of equally spaced coils placed near the arc of the trajectory of the magnet generates power at small scale. This study will look into the thresholds on statistics of noisy signal that will provide enough energy input to drive the system into chaos. It will also investigate effect of signal to noise ratio to the harvested power and its frequency band. This study with benefit the usage of the system in uncertain noisy environment.
Keywords: Double pendulum, Nonlinear energy harvester, Fluctuating magnetic field, Chaos, Poincare plots.
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Dynamical responses of a bistable energy harvester with hysteresis

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The nonlinear bistable energy harvester with a hysteresis is studied numerically. For the analysis, the nonlinear piezoelectric energy harvesting system based on cantilever elastic beam is applied to harvest kinetic energy of the moving frame. We used a double well potential induced by permanent magnets for a ferromagnetic beam resonator. A piezoelectric patch attached along the beam was used as a transducer of the mechanical into electrical energy. It occurs that the system can work in a wide interval of frequency beyond the linear resonance. Among various solution there are various subharmonic and chaotic ones. To classify them we study their voltage output time series using nonlinear **methods.**
Keywords: energy harvestin, nonlinear vibrations, chaos identification

Dynamical responses of an energy harvester with impacts

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The nonlinear energy harvester with impacts is studied. Our nonlinear piezoelectric energy harvesting system based on cantilever elastic beam is applied to harvest kinetic energy of the moving frame. The harvester consists of a nonlinear resonator with impacts and a piezoelectric transducer. It occurs that the system can work in a wide interval of frequency beyond the linear resonance. The system shows complex responses including chaotic ones. We study their voltage output time series using nonlinear methods.
Keywords: energy harvestin, nonlinear vibrations, chaos identification, impacts

On identifying flow over separation characteristics of aerofoil using cross recurrence quantification analysis.

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Aerofoils are unique curved surfaces designed to produce favorable lift to drag ratios in several engineering applications like airplane wings, wind turbine blades, propellers, marine rudders, and so on. In this study, we explore the nonlinear surface flow behavior and identify the flow separation characteristics inflow over the aerofoil by using cross-recurrence quantification analysis (CRQA). CRQA quantifies the patterns of the co-visitation of neighboring flow over the aerofoil and also assesses the correlation between two time series data. The qualitative behavior of flow over separation is studied with the help of various quantification measures like recurrence rate, determinism, laminarity, and average diagonal lengths from CRQA. The study of surface pressure and identifying flow separation statistically can help the future designers to design an efficient aerofoil with or without active or passive flow controls, which leads to better aerodynamic performances.
Keywords: Aerofoil, recurrence, aircraft, pressure, time-series data, flow separation

Effects of additive noise on the energy harvesting characteristics of a base excited double pendulum

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It has been observed in the literature that energy harvested from ambient sources provides a better broadband efficiency under chaotic motion. This happens at a low amplitude of power. A trade-off between power harvester and the frequency band has led to many designs of energy harvesters. This study focusses on a recently reported base excited double pendulum [1] to generate electricity in small scale but through a noisy environment.

The system consists of two pendulums attached in series with rigid massless links. The masses are assumed to be concentrated at the

bobs. The tip of the second pendulum contains a magnetic mass which when moves over a series of equally spaced coils placed near the arc of the trajectory of the magnet generates power at small scale. This study will look into the thresholds on statistics of noisy signal that will provide enough energy input to drive the system into chaos. It will also investigate effect of signal to noise ratio to the harvested power and its frequency band. This study with benefit the usage of the system in uncertain noisy environment.
Keywords: Double pendulum, Nonlinear energy harvester, Fluctuating magnetic field, Chaos, Poincare plots.
[1] R. Kumar, S. Gupta, S. F. Ali, Energy harvesting from chaos in base excited double pendulum, Mechanical Systems and Signal Processing 124 (2019) 49–64

Contributed Papers

Nanofluids in oscillatory natural convection :Scenario to chaos

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We studied numerically the transient laminar natural convection in an horizontal cavity containing nanofluid. The fluid is water and the nanofluid is copper oxide (CuO).The horizontal walls are adiabatic and the vertical walls are composed of the two regions of the same size maintained at different temperatures. Transfer equations are resolved using the (stream function-vorticity formulation). We analyzed the effect of Rayleigh number on heat transfer and on the roads to chaos borrowed by the system. The first Hopf bifurcation were observed and the systems are determinist. As the Rayleigh increased, multiplicity solutions are represented by attractors in spaces of phases. We compared results obtained for three concentrations of nanofluids.
Keywords: Natural convection, Bifurcation, Attractor, Nanofluid

Behaviour of Solutions of a Neuron Model

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We consider a discrete-time network of a single neuron as the discrete dynamical system xn+1=βxn−g(xn), n=0,1,..., where β is positive and an internal decay rate and g is a step signal function given by a piecewise constant function which consists of five steps.The considered model is quite simple as a mathematical expression, but with complex dynamics of its solutions. The model is highly sensitive to initial conditions and parameters. Small differences in an initial value and parameters yield widely diverging outcomes for the model, giving a great amount of different periodic orbits, more precisely, arbitrarily small differences of an initial value and parameters may lead to significantly different future behaviour and density of periodic orbits of the difference equation. Periodic orbits have been discussed according to the different rage of

parameter β. In the situation with parameter β greater than one we can find some values of parameters such our considered model has the chaotic behaviour.

Keywords: Nonlinear difference equation, discrete dynamical system, periodic orbits, chaotic maps.

Discrete Rotation-Translation Sequences on Closed Loops

Bernd Binder

Consider an ordered sequence of operations given by a rotation, a translation, and a reflection. Repeating this sequence operating on an initial discrete point cloud provides for characteristic spatial density patterns in the plane. A wide variety of interesting chaotic point clouds emerge if the rotation angle is a monotonic decreasing function of distance from a rotation singularity. In this way C. Skiadas generated complex structures resembling familiar chaotic flow patterns. Adding a periodic boundary condition, wave-like patterns can emerge (B. Binder) on the sphere and in the plane. We focus on closed loop conditions, where the point cloud evolves toward a sine wave attractor independent of initial conditions. As a key boundary condition, the rotation-translation loop sequence generates a highly nonlinear extra geometric phase gap controlling the pattern type with chaotic patterns at stronger rotations.
Keywords: Chaotic modeling, Rotation, Discrete, Translation, Reflection, Closed Loop, Quantum, Chaotic Attractors, Patterns, Simulation, Commutation, Operator, Geometric Phase.

Mathematical models for the chemical damage of built heritage

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Here we present an interdisciplinary work on chemical aggression of stone artifacts. We study different problems connected to the chemical damage of stone artifacts: sodium sulphate crystallization inside porous stone (masonry brick), the formation of iron precipitates - the so-called Liesegang rings - in Lecce stones in contact with iron source, the corrosion of stones determined by carbonic acid caused by the presence of CO2 in the air and the consolidation of stone artifacts with protective products.

Most of the proposed models are validated against laboratory data produced by chemists.
Keywords: porous stones, mathematical modelling, numerical simulations, stone protection, predictive models

Dynamical properties of a non-smooth model with different closed curve equilibria

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The main aim of this paper is to analyze the dynamical properties of a model with a closed curve equilibrium. The corresponding three-variable model is given as a set of nonlinear ordinary differential equations containing non-smooth functions. The dynamics of the model are studied depending on three parameters. For this purpose, new methods, as the 0-1 test for chaos and approximate entropy, are applied. Using these tools, the dynamics are quantified and qualified. It is shown that depending on the system's parameters, the system exhibits both irregular (chaotic) and regular (periodic) character.
Keywords: non-smooth model, closed curve equilibrium, bifurcation, approximate entropy, 0-1 test for chaos

Finite Element Method for Solving Lorenz Chaotic Model

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In this work, we study the Lorenz chaotic model analytically and numerically. The finite element method (FEM) is the most largely used method for solving problems of engineering and mathematical models as Lorenz chaotic model. Next we present results of comparing FEM-ALGO's output to both CC and the MATLAB
Keywords: Finite difference method, finite element method, Lorenz chaotic model, discretization, Simulation, Chaotic simulation

Multi-Grid Method to Simulate Growing Dynamical Systems: Codes in Matlab

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In this work we shows how to solve a system of differential equations controlling the development of a dynamical system based on multi-grid method (MGM). Our algorithm leads to solve a linear system of equations by propagating the flow. In the end of this work we give some codes in Matlab and we present some numerical and graphical results.
Keywords: Finite element method, Multi-grid method, Chaotic modeling, Simulation, Propagation theflow, Chaotic simulation.

A digital receiver for an analog transmitter

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Indubitadebly, private communication is a necessity of modern times. Chaos-based cryptography does not have a standardized robustness evaluation as classical ciphers like Advanced Encryption Standard have. Nevertheless, chaos-based ciphers have proved for decades, since the ‘70s, to be competitive due to the pseudo-randomness engendered by chaotic maps and flows. When analog circuitry is used as transmitter the pseudo-randomness is increased. The present work uses Matlab and Simulink to implement a high-order sliding mode estimator to recover the dynamics of the analog transmitter and, eventually, the private message embedded in its dynamics.
Keywords: Chaos-based private communication, Cryptography, Estimation, High-order sliding-mode observers, Simulink implementation

Heat transfer by sea water to air and environment's impacts

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In the aquatic environment, thermal transfer is understood as a result of any process that changes ambient water temperature. In oceans, such change in water temperature that goes beyond the natural range of temperature variation may be caused by discharged heated water coming from different areas of Globe (Sea Gulf Streams, sea districts around Equator, or districts near Arctic and Antarctic create waves of heat emission that is depended on solar radiation and climatic conditions in any sea area. We are aware that relatively small changes in natural ambient temperature might create substantial environmental problems; for instance, they may influence the dissolved oxygen concentration (Rajwa-Kuligiewicz et al. 2015), population of fish and other aquatic organisms and plants (Brett 1956; Coutant 1999; Currie et al. 1998; Murray 2002). The list of potential environmental impacts of thermal transfer to air is very long and widely discussed in the literature Therefore, the prediction of possible water temperature increase and assessment of its environmental impact, for example, before constructing human facilities become mandatory.

While trying to predict the potential increase of natural water temperature below the heated water discharge, one might have problems with making assumptions and relevant simplifications to obtain a desirable solution. Heat transport models generally consist of nonlinear differential equations with no analytical solutions under real conditions, and therefore, they must be solved numerically. Choosing a proper solution to a problem is a challenge. It requires not only a compromise between the computation time and cost needed to obtain the results and the desired accuracy of the solution but also depends on the availability of input data and their accuracy. The most obvious simplifications of the general three-dimensional (3D) problem pertain to the reduction of the dimension to the two- (2D) or even one-dimensional (1D) problem. That corresponds to the description of so-called near-field (3D); mid-field (2D); or far-field region (1D) (see Table 1). In each, particular region, vertical, horizontal and longitudinal mixing prevails, respectively. While the vertical mixing is relatively fast, the transverse mixing may continue far away from the discharge point. Therefore, the mid-field region is very important from the environmental point of view. To describe the heat transport in the 2D case in the mid-field region, the 2D depth-averaged equation has to be used (see, e.g., Kalinowska and Rowinski 2015; Kalinowska and Rowiński 2008; Rutherford 1994; Szymkiewicz 2010).

Further simplifications of heat transport equation are associated with different equation terms. Those terms are often difficult to estimate like, for example, the dispersion tensor components (see, e.g., Kalinowska and Rowiński 2008; Rowinski and Kalinowska 2006) in 2D equation, longitudinal dispersion coefficient (see, e.g., Guymer 1998; Piotrowski et al. 2006; Rowiński et al. 2005; Wallis and Manson 2004) in 1D equation or source functions that may include the information on heat exchange between river water and its surrounding.

Distributional chaos of type 2 via IP families applied to Nash equilibrium

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In this work, we introduce a DC2 system via Furstenberg families, which it has Nash equilibrium points for families containing IP sets. Moreover, we compare results for systems with Li Yorke chaos, through simulations; use to compare the level of chaoticity for particular dynamic games. Finally, we construct a game, which are Li-Yorke, DC and strongly DC2 for a system with Nash equilibrium points as a scrambled pair of the system.

Discovery Hidden Bifurcation Cells inGrid Multiscroll Chaotic Attractors Generated by Saturated Function Series

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The Procedure of analytical-numerical for localization of hidden attractors and the applied bifurcation theory together discover a new technique for analysis of control systems, this technique named hidden bifurcations. In this paper, we studied Discovery Hidden Bifurcation cells in Grid multi scroll chaotic attractors generated by saturated function series are pathfinder. We check numerically our technique to get hidden bifurcation cells, where the number of scrolls is 24.

Keywords: localization, hiddenbifurcations, Saturated Function Series.

Sensitivity of Dynamics of Toxoplasma Gondii and Host Immune Response

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Epidemiology is essential to understand the reason of spreading the disease, its outburst and control of the various diseases. Toxoplasmosis is a protozoan parasite that can infects all warm blood vertebrates, including mammals and birds. Approximately *20%* human population in US and *30%* world-wide are infected by protozoan parasite. It is happen mainly due to single cell parasite T. Gondii. The present study exhibits the mathematical modeling of interaction between Toxoplasma Gondii invasion dynamics and host immune responses through simple ODE system. To observe the impact of parameters on the reproduction number, sensitivity analysis has been done. The analytic and numerical simulations are carried out to understand that the impact of Holling type II functional response and observed that it enhanced the effector cells of host's immune response.
Keywords: Toxoplasma Gondii, neurological disorders, sensitivity, immune system

A fractional order model of the cardiac function

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In 2015, 17.9 million people died around the world caused by a cardiovascular disease and rose by 12.5% between 2005 and 2015 with a specific increase of ischemic heart disease by 16.6%. Even though heart transplantation is considered as the best therapy for patients with end-stage congestive heart failure, it is usually a delayed process that could last around 300 days or more on the average for potential recipients. For this reason, the medical community has increased emphasis on the use of ventricular assist devices that can enhance the function of the natural heart while patients wait for a heart transplantation. The use of such devices implies a need for an accurate mathematical model that facilitates the use of optimal control techniques. To address this issue, this work explores the use of Fractional Calculus in a nonlinear mathematical model which consistently solves the myocyte contraction, electric activity and ventricle pressure-volume relation at the organ level at the same time over multiple cardiac cycles. In particular, we study the effect of fractional-order operators on chaotic dynamics (e.g. arrhythmia) in the cardiovascular system.
Keywords: Cardiovascular system modeling, Fractional-order dynamics, Chaos, arrhythmia, nonlinear dynamics

Prediction After a Horizon of Predictability: Non-Predictable Points and Partial Multi-Step Prediction for Chaotic Time Series

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The paper discusses several novel strategies for multi-step prediction of chaotic time series. Generalized z-vectors (irregular embeddings), comprising non-successive observations, make it possible to obtain for each point to be predicted, a fairly large set of possible predicted values. If one examines such a set, one may ascertain whether it is possible to produce a unified predicted value for it or not (whether the point is predictable or non-predictable), and determine this unified value, if it exists. With non-predictable points, one may state the partial multi-step prediction problem as a two-objective problem. The first functional minimizes the number of non-predictable points, the second, average error for predictable ones. The main difference of strategies designed for such statements from their classical counterparts is non-predictable points and, consequently, an ability not to account for ! predictions at intermediate positions that are clearly erroneous. It appears that for such algorithms the number of non-predictable points grows exponentially with a prediction horizon, but an average error for predictable points remains constant and rather small up to a horizon of predictability and even farther for benchmark and real-world time series.

Keywords. Chaotic time series, multi-step prediction, predictive clustering, predictable and non-predictable points, a horizon of predictability.

Spectral analysis and invariant measure in studies of the dynamics of the Krebs cycle

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This work continues the study of a mathematical model of the Krebs cycle. With the help of spectral analysis of the kinetics of the process obtained at the variation in a small parameter, the scenario of changes in the cyclicity and the appearance of a strange attractor in the metabolic process of the Krebs cycle is found. The projections of a phase portrait and the histograms of projections of the invariant measure of a strange attractor are constructed. Some conclusions on the connection between

the functional state of a cell and the self-organization in the Krebs cycle are presented.
Keywords: Krebs cycle, self-organization, strange attractor, Fourier series, invariant measure, bifurcation.

Dynamics of cardiac cell

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Proper propagation of electrical signals across the heart muscle is a very complex process. Any cell involved in this process can jeopardize the proper functioning of that muscle and cause a condition that is no longer compatible with life. Therefore, to properly understand the electrophysiology of the cardiac muscle, it is necessary to properly understand the functioning of one cell. This study examines the dynamic properties of a mathematical model describing the electrophysiology of the heart cell. The model is stimulated by regular stimulation and its responses for different combinations of amplitude and frequency of pacing are investigated. Using classical and modern methods, regular and chaotic responses of this model are identified and described.
Keywords: dynamical systems; cardiac cell; chaos

Pseudo-random bit generator based on 2D chaotic map and its application in image encryption

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Chaos theory studies chaotic dynamic systems. Chaotic systems are nonlinear dynamic systems that are very sensitive to initial conditions. A small change in the initial conditions of such systems will cause many changes in the future. An important feature that has made this phenomenon so important for cryptography is the system's definability as well as its quasi-random behavior, which makes the system output appear random, which is very important in cryptography.

In this paper, the image encryption algorithm by using a chaotic two-dimensional map introduced.
We have study the dynamical property of introduced chaotic maps, to determine its capability in cryptography. We have specified the chaotic range to generate the quasi-random numbers. Finally, we have introduced an algorithm for image encryption. Then the generated quasi-random numbers have been used to encode the image (as a plaintext).
Based on the simulation results, and referring to the performed tests, it is possible to realize the high resistance against brute force and statistical attacks.
Keywords: 2‐D chaotic map, image encryption, pseudo-random number

Modelling mechano-electric feedback and arrhythmia in a simplified multiscale cardiac model

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Mechano-electric feedback (MEF) is the mechanism by which mechanical changes in cardiac muscles influence the electrical excitation of the heart (and vice-versa). It is a fundamental feedback process in normal behaviour, helping to maintain the hearts response to the demands placed on it. Indeed, a disruption to the pattern of electrical signals triggered by pathological conditions in the mechanical environment, can lead to cardiac alternans and arrhythmia.
In this paper, MEF is investigated using a low-order, lumped-parameter model which incorporates the mechanical, electrical and chemical action across both sarcomere (cardiac muscle fibres) and heart scales. Feedback is simulated by coupling the mechanical model to both the fast and slow variables of the electrical activity, thereby allowing the effects of mechanical stress and stretch on electrical patterns to be observed. Although simple, the model allows significant qualitative behaviour to be observed without significant cost.
It is found that disruption to the MEF causes interesting bifurcations in the mechanical-electrical system, leading to various pathological conditions such as periodic doubling in heart beats, irregular (quasi-periodic) frequencies
Keywords: Nonlinear dynamics; Multiscale model; cardiac cycle; mechano-electric effect; arrhythmias; feedback; lumped-parameter model; biological complexity; self-organization

The Hidden Architecture of Meaning in Languages

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Conventions in the study of linguistics ignore, or consider arbitrary, any relation or connection between the sounds that make up a word (and by extension the letters that represent those sounds) and its meaning. This conclusion likely stems from a comparison of the forms and meanings of individual words and, at this level of abstraction, the conclusion seems fully justified. How could the word o-n-i-o-n, for example, be related to the thing 'onion'? It seems far-fetched to suggest that it might be. However, appearances can be deceptive and so it proves in the domain of languages.

This paper postulates that, notwithstanding appearances, every language has embedded in it a heretofore unexplored underlying structure or architecture grounded in Meaning. This latent, inner architecture is not apparent at the level of words because words reference characteristic traits or qualities of things, not the things themselves. As a result, the certainty that there is a purposeful relationship between the form of a word and its meaning only becomes apparent when understood in the context of how Meaning is distributed in the architecture of a language.

The paper explores how Meaning is built into words and into the Meaning System of the English language as a whole. It identifies three key embedded design features in particular for analysis: Abstraction of Meaning (AOM); Fields of Meaning (FOM); and Polarity of Meaning (POM). I point out the evidence supporting the existence of these hidden structures and show how they combine to produce a system-wide, Meaning-based architecture.

When we assimilate this knowledge into our thinking, languages are shown to be a great deal more than the sum of their disparate parts. They are no longer simply a means of communication; they are complex networks of Meaning with a definite beginning, a traceable growth trajectory and a self-similar architecture that gives rise to the emergent phenomenon of consciousness. The implications of this understanding are profound, as some of the greatest mysteries of our time, including the so-called hard problem of consciousness, the origin of languages and how information is stored in the brain, depend on it for their resolution.

Keywords: Languages and Meaning, Architecture of Meaning, Meaning Networks, Models of Meaning, Meaning Maps, Polarity of Meaning, Emergent properties, Consciousness.

Prediction of qualitative dynamics in population models through Holling's functional responses

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Abstract: Natural ecosystems are complex network of biotic and abiotic interactions of species and their biological, physical and chemical constituents. Over the century, mathematical models have played primary roles in understanding the mystery behind the ecosystems processes and interesting dynamics of natural ecosystems. The di-trophic predator-prey interactions are the basic building blocks for complex food web models (multiple trophic interactions). The pioneering work of Lotka-Volterra (1926), explaining the abrupt deviations in species abundance and existence of oscillations in a simple predator-prey interaction. Studies in previous decades, it has been assumed that the functional responses are the main cause for chaotic and non-chaotic behavior. In this paper, we investigate how functional responses affect the system dynamics by using its different combinations in a simple two prey-one predator population model. Based on our present investigation, we concluded that stabilizing properties of functional responses dominate oscillatory behavior.
Keyboard: Controlling Limit cycles, Two parameter bifurcation comparison, Leslie Gower model, Holling type Functional Responses, stabilizing property, dominating oscillatory property.

Chaos and Anderson Localisation in Disordered Classical Chains: Hertzian vs FPUT models

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We numerically investigate the dynamics of a one-dimensional disordered lattice using the Hertzian model, describing a granular chain, and the $\alpha + \beta$ Fermi-Pasta-Ulam-Tsingou model (FPUT). The most profound difference between the two systems is the discontinuous nonlinearity of the granular chain appearing whenever neighboring particles are detached. We therefore sought to unravel the role of these discontinuities in the destruction of Anderson localization and their

influence on the system's chaotic dynamics. Our results show that both models exhibit an energy range where localization coexists with chaos. However, the discontinuous nonlinearity is found to be capable of triggering energy spreading of initially localized modes, at lower energies than the FPUT model. A transition from Anderson localization to chaotic dynamics and energy equipartition is found for the granular chain and is associated with the "propagation" of the discontinuous nonlinearity in the chain. On the contrary, the FPUT chain exhibits an alternate behavior between localized and delocalized chaotic behavior which is strongly dependent on the initial energy of excitation.
Keywords: Anderson localization, Chaos, equipartition, granular chains, FPUT, discontinuous nonlinearity

Modified RQA analysis of the γ-ray Variability in Blazars

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Linear time series analysis, mainly the Fourier transform based methods, has been quite successful in extracting information contained in the ever-modulating light curves (Lcs) of active galactic nuclei, and thereby contribute in characterizing the general features of supermassive black hole systems. In particular, the statistical properties of γ-ray variability of blazars are found to be fairly represented by flicker noise in the temporal frequency domain. However, these conventional methods have not been able to fully encapsulate the richness and the complexity displayed in the light curves of the sources.

In this work, to complement our previous study on the similar topic, we perform non-linear time series analysis of the decade-long Fermi/LAT observations of 20 γ-ray bright blazars. The study is motivated to address one of the most relevant queries that whether the dominant dynamical processes leading to the observed γ-ray variability are of deterministic or stochastic nature. For the purpose, we perform Recurrence Quantification Analysis of the blazars and directly measure the quantities which suggest that the dynamical processes are mostly of deterministic nature. The result with possible implication of strong disk-jet connection in blazars could prove to be significantly useful in constructing models that can explain the rich and complex multi-wavelength observational features in active galactic nuclei.

In addition, we estimate the dynamical timescales, that re-occur often in the system, in the order of a few weeks.
Keywords: RQA, accretion disks — radiation mechanisms: non-thermal, γ-ray — galaxies: active — galaxies: jets, method: non-linear time series analysis

A study of supergranulation

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Solar convection through supergranulation is examined through its various physical phenomena. Interrelationships amongst the parameters characterizing supergranular cells namely size, horizontal flow field, lifetime and physical dimensions of the cells and the fractal dimension deduced from the size data can reveal a wealth of information regarding its chaotic and turbulent aspects.
The findings are supportive of Kolmogorov's theory of turbulence.
Kodaikanal and SoHO data are used to study these parameters in the Solar maximum and Solar minimum phases respectively and the analysis mode is visual inspection and manual processing.

Chaotic brain extracellular matrix dynamics in the presence of periodically changing neuronal firing rate

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Modeling neuronal processes is a rather difficult task that requires extensive observations of a real biological object. It is known from recent experiments that the brain extracellular matrix (ECM) can influence synaptic plasticity and memory processes [1]. As a basis, we took a model with feedback from the neuron [2, 3]. An analysis of the dynamics with periodically changing neural activity was carried out. Changing the parameters affecting the level of neural activity and the amplitude of its oscillations, complex chaotic modes were observed, as well as the coexistence of regular and chaotic attractors. We have investigated the mechanisms leading to the onset of chaos, identified the regions of parameters where various types of dynamical regimes are observed.
Keywords: Chaos, Brain extracellular matrix, Multistability.

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Modeling the dynamics of information representations of an individual based on the apparatus of quantum potential wells

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This paper discusses the possible approaches to modeling the cognitive activity of the human brain using the mathematical apparatus of quantum mechanics (primarily – potential wells) in terms of the theory of information representations. The article briefly describes the proposed theory of information representations, draws analogies, and identifies common features of information representations of the human mind and Feynman's virtual particles. The human mind is represented as a one-dimensional potential well with finite walls of different sizes and internal potential barrier simulating the boundary between consciousness and subconsciousness. This creates a foundation for a mathematical apparatus that can make it possible to forecast particular cognitive functions of the human brain.
Keywords: cognitive activity, virtual particles, information representations, Schrödinger equation, potential well.

Simple inductor-free chaotic generator: design, research and computer modelling

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Circuit realization of the generator that demonstrates chaotic behavior is presented. This circuit contains three operational amplifiers, three capacitors, one diode, eight resistors, and one voltage source. The system's behavior was investigated through numerical simulations, by using well-known tools of nonlinear theory, such as phase portrait, chaotic attractor and time distributions of two chaotic system-variables.

This proposed circuit of chaotic generator can be used as a main part of modern systems transmitting and receiving information for masking and decryption of an information carrier.
Keywords: Chaos, Inductor-free, MultiSim

Spiral Break up due to Core Expansion and its Elimination

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We present an investigation into the dynamics of spiral waves and the onset of spatiotemporal chaos or irregularity due to spiral waves breakup following their core expansion. It aims at offering a further demonstration of the core expansion in two dimensions and to study the theory of non-local effects in such excitable systems that display self-oscillatory recovery. We use the Barkley's reaction-diffusion model to provide an observation of the core expansion which will be a caricature model for fibrillation. The resonant drift method will be applied to extinguish the spiral waves as a possible tool against cardiac problems.

Estimating Lyapunov exponents from noise-contaminated time-series data

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Chaos theory has been hailed as a revolution of thoughts and attracting ever increasing attention of many scientists from diverse disciplines. Chaotic systems are nonlinear deterministic dynamic systems which can behave like an erratic and apparently random motion. A relevant field inside chaos theory is the detection of a chaotic behavior from empirical time-series data. One of the main features of chaos is the well-known initial-value sensitivity property. Methods and techniques related to test the hypothesis of chaos try to quantify the initial-value sensitive property estimating the so-called Lyapunov exponents. Nowadays quantifying chaos from time-series data through this kind of quantitative measure in a rigorous fashion is far from being a trivial exercise and poses a number of theoretical and practical challenges. This paper describes the main estimation methods of the Lyapunov exponent from time-series data. We apply such methods to several noise-contaminated time series coming from different data generating processes. The results show that the

jacobian indirect methods provide better results than the direct methods for both clean and noisy time series. Moreover, the jacobian-based methods that use local polynomial kernel regression provide more robust and accurate fit than those using neural networks considering both clean and noise-contaminated time-series data.
Keywords: Chaotic time series, Lyapunov exponent, Jacobian indirect method, Neural net model, Polynomial kernel model.

Stability and Symmetry Analysis of Coupled Map Lattices

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In this work we investigate the dynamical behavior of coupled logistic map lattices (CMLs) with respect to the transient geometry and the dynamical stability. The largest eigenvalue Lyapunov Exponent have been applied to detect instability. We also review the Gradient Pattern Analysis (GPA) and introduce to the most recent technique of the second gradient moment, in order to detect whether the spatial symmetry breaks. The phase diagram of the Largest Eigenvalue Lyapunov Exponent and the second gradient moment indicates that the system coupling can diminish the chaotic dynamic. Moreover, our analysis indicates that low coupling systems with chaotic parameters distant to the non-chaotic boundaries can lead to a period-2 synchronization. The synchronization is probably caused by a locally stable parameters, such as logistic map with r = 3.84, which are magnified by the system coupling.
Keywords: Coupled Map Lattice, Lyapunov Exponent, Gradient PatternAnalysis, Synchronization

Experimental investigation of turbulent structures in a supersonic boundary layer

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Turbulence in the supersonic airflows with Mach numbers up to 1.6 was investigated experimentally on a shock tube with a discharge section. The radiation of a distributed surface sliding discharge with a duration of 500 ns and a size of 10x3 cm2 was used as a visualizing method. The distribution of the discharge radiation intensity indicates the instantaneous density distribution due to the strong dependence of the intensity on the reduced electric field E/N. Processed result of the obtained experimental photographic images using a mathematical numerical computational program showed that the spatial scales of structural elements of turbulence in the direction of the flow can reach 1.7-5.9 mm.

Keywords: supersonic flow, boundary layer, turbulence, surface sliding discharge

Universal Cosmology and Short-Range/Long-Range Theories

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Universalization of knowledge by means of increasing the level of phenomena abstraction up to the achievement of the highest initial Universe's Axiom, for the first time, allows us to obtain the single initial Universal Meta-Formalism that radically develops a general scientific paradigm and, in particular, deduces the new Universal Cosmology that is fundamentally different from the generally accepted Big Bang hypothesis. The Universe is infinite in Space, Time and Matter and naturally develops from non-living to living phenomena Classes with the strengthening of harmonising properties up to the Supreme Mind, traditionally associated with the concept of God, which for the first time receives a formal definition and becomes a full-fledged object of scientific study. The research was carried out according to the universal scheme of a Conditioned Reflex extended by the Method of Sequential Consistent Concretization of Hypotheses that, in principle, allows complete cognition when making the assumption about the hypothetical character of knowledge, but reveals subsequent contradictions. It is exclusively the volume of the achieved consistent system of concepts that becomes the main criterion of a truth. The Universal Theory, that uses suitable formalisms of the modern science, provides the largest dimensions of this volume. Such a relevant problem is a contradiction between 1) the Class predestination of the Supreme Mind to harmonise the Space-Time-Matter- (STM-) Complex of the Universe into the state of the Harmon and 2) the uncontrollability of the Universe as an infinite unitary whole, according to the existing dogmatic assumptions of short-range and long-range action. The observable dimensions of the Universe of approximately tens of billions of light years are comparable with estimates of its age and fundamentally do not allow intellectual short-range action in the final stage of the Universe evolution and therefore effective access to it. The mechanisms of long-range action are unknown and the well-substantiated ideas of overcoming this problem within the framework of dogmatization are absent. Therefore, the universalization of the problem is the goal of this work. In [A. V. Sosnitsky, A. I. Shevchenko. The Universe Multiphase Meta-Reduction: The Harmon

(Mandala), Continuum (Prana), Discretization, Formalization, Knowledge, Cognition, Condensation and Absolute Nothing. Chaotic Modeling and Simulation. In print.], the multi-phase structure of the Universe of 12 coexisting phases between the initial and final states of the Harmon is substantiated. The Harmon is internally unstable and in case of absence of Time instantly disintegrates into the STM-Complex with internal Time, dividing into separate Complexes of Space, Time and Matter. These separate Complexes are continuously increasing due to the disharmonisation of the Harmon, presumably keeping the balance of $-\partial H = \partial S + \partial T + \partial M$, where symbols "+/-" mean the structural connectedness/disconnectedness of the Complexes, $-\partial H$ is the Harmon's harmony consumption to increase the Complexes. Supposing there is a constant mutual ratio of the growth of the Complexes, the partial mutual derivatives of the Complexes must be constant. Therefore, $\partial S/\partial T = c$ is presumably the well-known, always constant speed of light in a vacuum, which generates an insuperable short-range action of phenomena and an insolvable problem of controllability of the Universe within the framework of the STM-Complex. However, the Universe simultaneously coexists in all phases, starting with the Harmon, all parts of which, by definition, are directly and completely interconnected in the absence of Time and innately support an absolute short-range action. Therefore, the transition between the STM-Complex and Harmon completely solves the long-range problem. In addition, the phases have loose intersecting boundaries and smoothly mutually transform properties. Therefore, the limited long-range action of the Harmon in the Prana phase can be combined perfectly well with an inchoate weak Time and its partial short-range action, which is a compromise weakening of the problem. The above-mentioned mechanisms serve as a basis for the universal formalization of short-range/long-range theories with the further development of Universal Cosmology.
Keywords: Universal Theory, Universal Cosmology, short-range, long-range, the multi-phase Universe, Big Bang hypothesis

Examination of Sudden Jumps in the Time Course of Approximate and Sample Entropy Values of Supercomputer Power Consumption

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This work deals with the investigation of the origin of sudden jumps in the values of Approximate and Sample Entropy of discrete-valued time series, such as the supercomputer power consumption. These sudden jumps are not continuous and it is clear that they do not reflect real

changes in the degree of complexity of the observed complex time series, which may cause erroneous detection of changes in the monitored complex system. The content of this contribution is a detailed explanation of the mechanism of this phenomenon and also several proposals for measures to prevent its occurrence.
Keywords: Nonlinear time series analysis, Entropy, Time series complexity degree, Complex systems, Complex time series, Sample Entropy, Approximate Entropy, Sudden jumps, Phenomenon examination, Discrete-valued time series

Sequence of PRN's from elliptic curves over $Z_{\{p^m\}}$

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Let p>3 be a positive number and let E_m be an elliptic curve defined over finite ring $\mathbf{Z_{\{p^m\}}}$, given by the affine Weierstass equation of the form y2={x}^{3}+ax+b (mod p^m)
for some a, $\mathbf{Z_{\{p^m\}}}$, where -3a is quadratic non-residue modulo p.
We construct the sequence of points (x_n, y_n), n=0,1,2,…, on the curve E_m such that the sequence {y_n}/{p_m} measure up of pseudorandomness on the interval [0,1). Among other things, we deduce the bound for discrepancy D^s of the points {y_n}/{p_m}, {y_{n+1}}/{p_m},…, {y_{n+s-1}}/{p_m}, n=0,1,…,N-1<p^m,
D^sll{N^{-1}}$p^{\{m/2\}}$(log{p^m})^s,,,,s=1,2,3,4,
with absolute constant in symbol "ll"
Keywords: elliptic curves, pseudorandom numbers, discrepancy

Finite-time synchronization of multi-scroll chaotic systems with sigmoid nonlinearity and uncertain terms

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In this article, the finite-time synchronization of multi-scroll chaotic systems with sigmoid nonlinearity in presence of uncertain parameters has been studied. In real-time it has many applications such as chaos-based communication, image and voice encryption. In the present chaotic system scrolls up to five are incorporated with the help of hyperbolic tangent functions (sigmoid nonlinearity), but there is no limit of multi-scroll in the chaotic system. Finite-time synchronization is achieved

using the Lyapunov stability theory with the help of some lemmas and definitions. The Lyapunov exponents are also calculated for multi-scroll chaotic systems with uncertainties, and it confirms that the multi-scroll system is chaotic. The main objective of this article is to investigate the finite-time synchronization of multi-scroll chaotic systems with uncertain parameters, where the multi-scrolls are generated by nonlinear functions.
Keywords: Finite-time synchronization, Chaotic system, Sigmoid function, Lyapunov exponent, Lyapunov stability theory

Time series analysis of GDP scaling and dynamical regimes

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It is known the GDP of the largest ~25 economies (nations, EU) follows a power law GDP ~ 1/rank (c.f. Garlaschelli et al. 2007). Reed and Hughes (2002) show how power law behavior can arise if "stochastic processes with exponential growth in expectation are killed (or observed) randomly," while Montroll and Shlesinger (1982) suggest a basic lognormal distribution as a consequence of multiplying many independent random variables, with a power law high-end tail because "the very wealthy generally achieve their superwealth through amplification processes that are not available to most." Here we consider empirically observed GDP scaling over time, finding stable regimes including a high-end power law tail, a middle scaling region where GDP decreases exponentially with rank, and a more rapidly decaying low-end tail, exponentially with rank squared (Hastings and Young-Taft 2020), over the 40 year period from 1980 to date. We create an inter-temporal surface across time, and track displacement over time of individual countries with respect to development variables. We cluster possibly related development variables relative to movement across and within scaling regimes, and test hypotheses with respect to shape of curve over time and trends of movement on curves across nations across time (spaghetti plot). Additionally, we develop tests relative to hypotheses of tripartite scaling division given path of break point and change of parameters (including scaling coefficients and intercept) relative to log-normal hypotheses, including non-parametric cumulative distributional and maximum entropy tests, consider correlation across time relative to Kolmogorov-Smirnov tests (Smirnov 1948), and consider empirical dynamical modeling considering deterministic chaos across lags (Sugihara and May 1990) and nonlinear causation (Sugihara *et al*. 2012) among GDP and related development variable combinations (Ye and Sugihara 2016).

Keywords: Economic models, Scaling regions, Ensemble prediction, Spaghetti plot, Empirical dynamic modeling.

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Computational method for solving systems of linear and nonlinear fredholm integral equations

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In this paper, a computational method based on hybrid of Quadratic functions and block-pulse functions is proposed to solve system of linear and special nonlinear Fredholm integral equations of the second kind. Numerical examples are given to illustrate the efficiency of the method.
Keywords: Hybrid, Quadratic functions, Block-pulse functions, Fredholm integral equations, Fixed-point iteration method.

Best Trapezoidal Approximation Solution of fuzzy nonlinear equations

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Fuzzy logic is powerful tool for modeling uncertainties associated with human cognition, thinking and perception, which has been successfully applied in various fields such as neural network and financial time series. The models lead to a nonlinear system.
In this paper, we propose a method for finding trapezoidal approximation of solution of fuzzy nonlinear equations using the metric (distance) between two fuzzy numbers. Numerical test is given to state efficiency of the proposed method. The proposed method is compared to Newton's method for a fuzzy nonlinear equation
Keywords: Fuzzy distance; Fuzzy number; Fuzzy nonlinear equation.

Some remarks on the Corona-virus pandemic in Europe

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The coronavirus "Severe-Acute Respiratory Syndrome-SARS-CoV-2 was initially reported in China by the late 2019 and rapidly spread across the world. In the 11th of March 2020 the World Health Organization declared the situation as a worldwide pandemic. By the late April 2020 there were 2.475.440 confirmed cases and 170.069 deaths worldwide, whereas 164.656 fatal cases out of the total were reported in Europe. In response to the pandemic, the primary objectives of European countries were a) to limit the spread of the virus, b) to protect the most vulnerable populations and health workers, c) to provide a clear quantification of the virus's process. However, there are major inconsistencies between countries concerning the adoption of protocols and measures towards the above goals. The installation of measurements such as the restriction of public gatherings, lockdowns, and the shutdown of educational institutes, workplaces etc. took place in different times and scales. In parallel, there are various problematics and restriction concerning the so far epidemiological data we possess, a fact that holds back the study of this pandemic.