The Tenth International Scientific Conference on Physics and Control

PhysCon2021

4-8 October

Fudan University

Shanghai, China

Keynote Talk

Day 1, October 4, 2021

14:30-15:30 (Time in Beijing UTC+8)

Dynamics-based data science

Speaker: Prof. Luonan Chen

(Chinese Academy of Sciences)

Abstract

In this talk, I will present a new concept "dynamics-based data science" and its approaches for studying dynamical processes, including dynamical network biomarkers (DNB) for providing early-warning signals of diseases, spatio-temporal information (STI) transformation for predicting short-term time series, and partical cross-mapping (PCM) for inferring causal relations between variables only based on the observed data. These methods are all data-driven or model-free approaches but based on the theoretical frameworks of nonlinear dynamics. We show the principles and advantages of dynamics-based data-driven approaches as explicable, quantifiable, and generalizable. In particular, dynamics-based data science approaches exploit the essential features of dynamical systems in terms of data, e.g. strong fluctuations near a bifurcation point, low-dimensionality of a center manifold or an attractor, and phase-space reconstruction from a single variable by delay embedding theorem, and thus are able to provide different or additional information to the traditional approaches, i.e. statistics-based data science approaches. The dynamical-based data science approaches will further play an important role in the systematical research of various fields in future.

Keynote Talk

Day 1, October 4, 2021

15:40-16:40 (Time in Beijing UTC+8)

Peculiarities of relay synchronization in heterogeneous multiplex networks of nonlinear oscillators

Speaker: Prof. Galina Strelkova

(Saratov State University)

Abstract

We discuss peculiarities of relay synchronization of complex spatiotemporal structures in heterogeneous three-layer networks of discrete- and continuous-time nonlinear systems. The studied networks consist of a relay layer and two remote layers which are not directly coupled but interact via the relay layer. The spatiotemporal dynamics of the relay layer is completely different from that of the outer layers. The first part of the talk is devoted to relay and complete synchronization of amplitude and phase chimeras and solitary states in a three-layer network of rings of nonlocally coupled chaotic maps. We consider the cases when the individual elements of the relay layer and of the outer layers are described by Lozi maps and Henon maps, respectively, and vice versa. We also analyze the role of the relay layer structure in the resulted synchronous patterns. The results are illustrated by diagrams of desynchronized and synchronous regimes in the "inter-layer coupling-intra-layer coupling of the relay layer" parameter planes.

In the second part of the talk we present numerical results for relay synchronization of wave structures in a heterogeneous three-layer network of coupled two-dimensional (2D) lattices of continuous-time systems. Remote layers consist of coupled van der Pol oscillators, while the relay layer is described by a lattice of interacting FitzHugh-Nagumo neurons. We show for the first time that already for weak inter-layer coupling, anti-phase relay synchronization of target wave patterns occurs in the considered network. This is a novel effect which can be observed in multiplex networks of interacting 2D lattices of oscillatory systems. Our numerical studies indicate that strong inter-layer coupling leads to in-phase synchronization of spatio-coherent structures in the network layers. We also analyze the impact of inter-layer coupling ranges in the relay and the remote layers on the relay synchronization effect.

Keynote Talk

Day 2, October 5, 2021

09:00-10:00 (Time in Beijing UTC+8)

Predicting critical transition and system collapse with machine learning

Speaker: Prof. Ying-Cheng Lai

(Arizona State University)

Abstract

To predict a critical transition due to parameter drift based on data is an outstanding problem in complex dynamics and applied fields. A closely related problem is to predict whether the system is already in or if the system will be in a transient state preceding its collapse. A model free, machine-learning solution to both problems will be presented. The idea is to develop a parameter-cognizant machine-learning framework based on reservoir computing. When the machine is trained only with data from the normal functioning regime with oscillatory dynamics (i.e., before the critical transition), the transition point can be predicted accurately. Remarkably, for a parameter drift through the critical point, the machine is able to predict not only that the system will be in a transient state, but also the average transient time before the final collapse. Applications to electrical power and ecological systems will be demonstrated. The machine-learning framework can also be extended to predicting transient chaos and intermittency as well as synchronization transition and amplitude death in coupled nonlinear systems.

Keynote Talk

Day 2, October 5, 2021

10:10-11:10 (Time in Beijing UTC+8)

Nonlinear and network dynamical systems for a better connected world

Speaker: Prof. Jie Sun

(Hong Kong Research Center)

Abstract

Nonlinear and network dynamics plays a critical role in a broad range of industrial applications. Centering around communication systems and networks, we discuss several important problems, ranging from real-time signal processing to large-scale control and optimization, and how they can potentially benefit from emerging theory and algorithms in modern dynamical systems and network science, ultimately leading to a better connected world.

Keynote Talk

Day 3, October 6, 2021

14:30-15:30 (Time in Beijing UTC+8)

Transient chaos in complex systems

Speaker: Prof. Ulrike Feudel

(University of Oldenburg)

Abstract

The dynamics of many complex dynamical systems is dominated by very long chaotic transients. Such transient dynamics occurs often in systems which possess multistability, i.e. the co-existence of different stable long-term states for a given set of control parameters or dynamical systems which are characterized by a large number of interacting components such as spatial systems or complex networks. Transient chaos is frequently related to the existence of chaotic saddles either within the basin of attraction of one stable long-term state or attractor or embedded in the basin boundaries of a multistable system. In both cases, the consequences for the overall dynamics are manifold. Particularly, we discuss the response of complex systems with respect to perturbations which can be either large shock perturbations applied at a specific time instant or slow changes of a control parameter occurring on a certain time interval. We show that the existence of chaotic transients makes a system extremely vulnerable with respect to shock perturbations. This applies particularly to the vulnerability of the synchronized state in a complex network, in which the perturbation could lead to a complete or partial desynchronization [1, 2, 3, 4]. Moreover, the outcome of the shock can depend on where and/or when the shock perturbation is applied. We demonstrate these dynamics using different examples like the Duffing oscillator and the Henon map [1, 2], an electronic circuit [3] or the power grid of Great Britain [4]. Furthermore, we show, that chaotic transients can be obstructions to observe critical transitions, i.e. transitions from one stable long-term state to another in multistable systems, when a control parameter is varied [5]. Instead of those critical transitions, also called bifurcation tippings, one observes only chaotic transients with new tipping phenomena occurring [6].

[1] Medeiros ES, Medrano-T RO, Caldas IL, Feudel U (2018): The boundaries of synchronization in oscillator networks. Phys. Rev. E **98**, 030201.

[2] Medeiros E, Medrano-T RO, Caldas IL, Tel T, Feudel U (2019) State-dependent vulnerability of synchronized states, Phys. Rev. E **100**, 052201.

[3] Medeiros ES, Medrano-T RO, Caldas IL, Feudel U (2021): The impact of chaotic saddles on the synchronization of complex networks of discrete time units. J. Phys. Complex. **2**, 035002.

[4] Halekotte L, Vanselow A, Feudel U (2021): Transient chaos enforces uncertainty in the British power grid. J. Phys. Complex. **2**, 035015.

[5] Kaszas B, Feudel U, Tel T (2016): Death and revival of chaos. Phys. Rev. E **94**, 062221.

[6] Kaszas B, Feudel U, Tel T (2019): Tipping phenomena in typical dynamical systems subjected to parameter drift. Scientific Reports **9**, 8654.

Keynote Talk

Day 2, October 5, 2021

15:40-16:40 (Time in Beijing UTC+8)

Control of tipping points in stochastic ecological networks

Speaker: Prof. Celso Grebogi

(University of Aberdeen)

Abstract

A challenging and outstanding problem in interdisciplinary research is to understand the interplay between transients and stochasticity in high-dimensional dynamical systems. Focusing on the tipping-point dynamics in complex mutualistic networks of pollinators and plants in ecology constructed from empirical data, I will examine the phenomena of noise-induced collapse and noise-induced recovery. I will discuss control strategies that delay the extinction and advances the recovery by controlling the decay rate of pollinators in a stochastic mutualistic complex network, whose control strategies are affected by environmental (Gaussian white) and state-dependent demographic noises. By comparing the empirical network with random and scale-free networks, I will also look at the influence of the topological structure on the control effect. Remarkably, the investigation of the dynamics of tipping point in multilayer ecological networks supported by mutualism uncovers a natural mechanism that can postpone the occurrence of a tipping point: multiplexity. In particular, for a double-layer mutualistic system, coupling between the network layers naturally occurs when there is migration of certain pollinator species from one layer to another. Multiplexity is induced as the migrating species have a simultaneous presence in both layers. I will argue that the new mutualistic links established by the migrating species with the residence species have some fundamental benefits to the well-being of the ecosystem such as delaying the tipping point and facilitating species recovery. The implication is that articulating and implementing control mechanisms to induce multiplexity can be of significant value to sustaining various ecosystems that are or will be in danger of extinction as the result of environmental changes.

Data based identification and prediction of nonlinear and complex dynamical systems, W.-X. Wang, Y.-C. Lai, and C. Grebogi, Physics Reports **644,** 1-76 (2016)

Predicting tipping points in Mutualistic Networks through dimension reduction, J. Jiang, Z.-G. Huang, T.P. Seager, W. Lin, C. Grebogi, A. Hastings, and Y.-C. Lai, PNAS (Proc. Nat. Acad. Sci.) **115,** E639-E647 (2018)

Noise-enabled species recovery in the aftermath of a tipping point, Y. Meng, J. Jiang, C. Grebogi, and Y.-C. Lai, Phys. Rev. E **101**, 012206 (2020)

Tipping Point and Noise-induced Transients in Ecological Networks, Y. Meng, Y.-C. Lai, and C. Grebogi, J. Royal Soc. Interface **17**, 20200645 (2020)

Control of Tipping Points in Stochastic Mutualistic Complex Networks, Y. Meng and C. Grebogi, Chaos **31**, 023118(1-9) (2021)

The Fundamental Benefits of multiplexity in Ecological Networks, Y. Meng, C. Grebogi, and Y. C. Lai, submitted for publication

Topic 1
Control Theory
Day 1, October 4, 2021
18:00-21:10 (Time in Beijing, UTC+8)

Talk 1
18:00-18:30

Controllability properties for multi-agent linear systems: a geometric approach

Contributor(s): Dr. M. Isabel Garcia-Planas
Speaker: Dr. M. Isabel Garcia-Planas

Abstract

This contribution addresses the controllability of a class of multi-agent linear systems that they are interconnected via communication channels. Multiagent systems have attracted much attention because they have great applicability in multiple areas, such as power grids, bioinformatics, sensor networks, vehicles, robotics and neuroscience, for example. Consequently, they have been widely studied by scientists in different fields specially in the field of control theory. Recently has taken interest to analyze the control properties as consensus controllability of multi-agent dynamical systems motivated by the fact that the architecture of communication network in engineering multi-agent systems is usually adjustable. In this talk, the control condition is analyzed under geometrical point of view, in the case of multiagent linear systems that can be described by k agents with dynamics $\dot{x}^i = A_i x^i + B_i u^i, i = 1, \dots, k$.

Talk 2

18:30-19:00

Nonlinear regulators in the orientation problems of a rigid body rotating around a fixed point

Contributor(s): Prof. Aleksandr Andreev & Prof. Olga Peregudova
Speaker: Prof. Olga Peregudova

Abstract

In this contribution, the application of regulators of a new type in solving the problems on one- and three-axis orientation of a rigid body rotating around a fixed point with respect to inertial and non-inertial coordinate frames is considered. Moreover, in the case of an inertial frame these problems are solved without measuring the angular velocity of the body.

Talk 3

19:00-19:30

On the stability of a nonlinear automatic control system with a delayed feedback

Contributor(s): Prof. Jumanazar Khusanov & Prof. Azizbek Akhmatov
Speaker: Prof. Jumanazar Khusanov

Abstract

In this contribution, the asymptotic stability problem of a nonlinear automatic control system with a delay in the feedback structure is considered by using Lyapunov functions method. In order to obtain the asymptotic stability property of the closed loop system we use the transformation formula of B.S. Razumikhin, hence we get the restrictions on the maximum value of the delay in the system feedback.

Talk 4

19:40-20:10

On global trajectory tracking control of robot manipulators with a delayed feedback

Contributor(s): Prof. Aleksandr Andreev & Prof. Olga Peregudova
Speaker: Prof. Aleksandr Andreev

Abstract

In this contribution, the trajectory tracking control problem of a robot manipulator with cylindrical joints is considered by means of a nonlinear PD controller taking into account the delayed feedback structure. The conclusion about stability of a closed-loop system is obtained on the basis of the development of the direct Lyapunov method in the study of the stability property for a non-autonomous functional differential equation by constructing a Lyapunov functional with a semidefinite time derivative.

Talk 5

20:10-20:40

On the solution of the initial-boundary value problem for the Hamilton-Jacobi equation

Contributor(s): Dr. Lyubov Shagalova
Speaker: Dr. Lyubov Shagalova

Abstract

Let time moment $T > 0$ and value $x^* \in R$ be given. In the region $G^+ = \{(t,x)|\, 0 < t < T, x > x^*\}$ the following Hamilton-Jacobi equation is considered

$$\frac{\partial u}{\partial t} + H\left(x, \frac{\partial u}{\partial x}\right) = 0, \tag{1}$$

where the Hamiltonian has the form

$$H(x,p) = f(x)e^p. \tag{2}$$

Here $f(\cdot)$ is continuously differentiable increasing function such that $f(x^*) > 0$. Also continuously differentiable function $u_0 : R \to R$ and subdifferential function $\varphi: [0,T] \to R$ are given, such that the left derivative $\varphi'_-(0)$ of function φ at the point 0 exists, and the following equalities hold

$$\varphi(0) = u_0(x^*), \qquad \varphi'_-(0) = u'_0(x^*). \tag{3}$$

It is required to construct a viscosity solution [M.G. Crandall & P.L. Lions, Trans. Amer. Math. Soc. (1983)] $u(\cdot,\cdot)$ of the equation (1) which is continuous in the closure of the domain G^+ and such that the following initial and boundary conditions are satisfied

$$u(0,x) = u_0(x), \quad x \in R, \ \ x \geq x^*, \tag{4}$$

$$u(t,0) = \varphi(t), \qquad t \in [0,T]. \tag{5}$$

It is proved that a continuous viscosity solution to the initial-boundary value problem (1)-(5) exists. Also, sufficient conditions are indicated under which such a solution is unique. The process of solving the problem under consideration is based on the minimax approach [A.I. Subbotin, Boston: Birkhauser(1995)], the method of generalized characteristics [N.N. Subbotina, Modern Math. and its Appl. (2004)], as well as solutions of variational problems with moving ends.

Talk 6

20:40-21:10

Beams monitoring and control by charged particles beams stochastic optics methods

Contributor(s): Dr. Vyacheslav Kurakin
Speaker: Dr. Vyacheslav Kurakin

Abstract

Charged particles beam behaves itself similar to the light ray while falling on incline plane border that separates vacuum and some material medium. Namely it changes the direction of motion and partial beam reflection takes place, that is like in light case refraction and refraction take place. To explain this phenomenon the distribution function for multiple Coulomb scattering in infinite medium had been attracted. To calculate the angles of reflected as well as refracted beams the model of conventional liquid flow had been built based on properties of distribution function. Such an approach allows anybody to explain the phenomena taking place at the border of scattering medium-vacuum qualitatively and to calculate the direction of motions of reflected and refracted parts of the beam after interaction with medium. This method allows also calculating reflection coefficients. The fact that reflection coefficient is particle energy and incident angle dependent while it's thin plate traversing may be used for beam energy monitoring. On the other hand, the reflection angle of the beam falling on incline border of scattering medium does not depend on beam energy and this might be served for achromatic beam rotation. An example of beam formation from isotropic positron source is discussed in this contribution.

Topic 2
Nonlinear System and Control

Day 2, October 5, 2021

14:00-16:10 (Time in Beijing, UTC+8)

Talk 1

14:00-14:30

Relay synchronization scenarios in three-layer networks

Contributor(s): Dr. Jakub Sawicki
Speaker: Dr. Jakub Sawicki

Abstract

Relay synchronization is a dynamical phenomenon occurring in various complex networks and is characterized by the synchronization of remote parts of the network due to their interaction via a relay. This phenomenon has been observed in neural networks, lasers, and electronic circuits. In multilayer networks, distant layers that are not connected directly can synchronize due to signal propagation via relay layers [J. Sawicki *et al.*, Phys. Rev. E (2018)]. We study the influence of time delay in the inter-layer coupling on the partial synchronization of chimera states, complex patterns of coexisting coherent and incoherent domains. We demonstrate that three-layer structure of the network allows for synchronization of coherent domains of chimera state in the first layer with its counterpart in the third layer, whereas the incoherent domains are desynchronized [F. Drauschke *et al.*, Chaos (2020)]. Moreover, we study various relay synchronization scenarios in a three-layer network, where the middle (relay) layer is a single node, i.e. a hub [J. Sawicki *et al.*, Chaos (2021)]. The two remote layers consist of non-locally coupled rings of FitzHugh-Nagumo oscillators modeling neuronal dynamics. All nodes of the remote layers are connected to the hub. The role of the hub and its importance for the existence of chimera states is investigated in dependence on the inter-layer coupling strength and inter-layer time delay. Tongue-like regions in the parameter plane exhibiting double chimeras, i.e., chimera states in the remote layers whose coherent cores are synchronized with each other, and salt-and-pepper states are found. At very low intra-layer coupling strength, when chimera states do not exist in single layers, these may be induced by the hub.

Talk 2

14:30-15:00

Nonlinear dynamics of autonomous spacecraft control system in initial orientation

Contributor(s): Prof. Yevgeny Somov, Dr. Sergey Butyrin & Eng. Sergey Somov
Speaker: Prof. Yevgeny Somov

Abstract

The problems of autonomous digital control of the information satellites and space robots in the initial orientation modes are considered. Autonomous angular guidance and modularly limited vector digital control using a vector of the modified Rodrigues parameters are applying to bring the spacecraft's orientation from completely arbitrary to the required one. The developed methods, algorithms and simulation results for a mini-satellite in a sun-synchronous orbit are presented.

Talk 3

15:10-15:40

Keeping the vessel on a given trajectory in conditions of uncertainty

Contributor(s): Dr. Aliya Imangazieva
Speaker: Dr. Aliya Imangazieva

Abstract

A solution to the problem of keeping the vessel on a given trajectory under conditions of uncertainty, the action of external disturbances is proposed. The model of the vessel takes into account external disturbances: the moment of wind action, the angle of the wave slope, independent, generating white noise; measurement errors, as well as kinematic relations. The motion of the vessel in the horizontal plane is considered, taking into account the lateral deviation from the trajectory. The robust ship course control law is constructed using the auxiliary loop method and two Khalil observers. The simulation results illustrate the effectiveness of the proposed robust control law.

Talk 4

15:40-16:10

Self-reproduction of chaotic bursting in Hindmarsh-Rose neuron

Contributor(s): Dr. Chunbiao Li, Mr. Yicheng Jiang & Ms. Xu Ma

Speaker: Dr. Chunbiao Li

Abstract

Hindmarsh-Rose neural model exhibits a unique multi-time-scaled burst-rest behavior, a phenomenon which has attracted great attention in neuroscience. In this system, periodic function introducing may lead to chaotic busting self-reproducing. However, mismatched amplitude, phase and frequency will destroy the inherent burst-rest behavior. In this contribution, some discussion on self-reproduction of chaotic bursting in Hindmarsh-Rose neuron is given for better understanding of multi-time-scaled dynamics.

Topic 3

Collective Dynamics on Networks

Day 2, October 5, 2021

18:00-20:40 (Time in Beijing, UTC+8)

Talk 1

18:00-18:30

Variance and covariance of distributions on graphs

Contributor(s): Prof. Renaud Lambiotte

Speaker: Prof. Renaud Lambiotte

Abstract

We develop a theory to measure the variance and covariance of probability distributions defined on the nodes of a graph, which takes into account the distance between nodes. Our approach generalizes the usual (co)variance to the setting of weighted graphs and retains many of its intuitive and desired properties. Interestingly, we find that a number of famous concepts in graph theory and network science can be reinterpreted in this setting as variances and covariances of particular distributions. As a particular application, we define the maximum variance problem on graphs with respect to the effective resistance distance, and characterize the solutions to this problem both numerically and theoretically. We show how the maximum variance distribution is concentrated on the boundary of the graph, and illustrate this in the case of random geometric graphs. Our theoretical results are supported by a number of experiments on a network of mathematical concepts, where we use the variance and covariance as analytical tools to study the (co-)occurrence of concepts in scientific papers with respect to the (network) relations between these concepts.

Talk 2

18:30-19:00

Signal propagation in complex networks

Contributor(s): Dr. Chittaranjan Hens
Speaker: Dr. Chittaranjan Hens

Abstract

Recent advances in network theory enable us to study the interplay between the topological structure and the intrinsic dynamic states of all nodes. We here analytically derive the response propagation, obtaining its dependence on the degree distribution, the distance from the perturbation and the intrinsic dynamics of each network. Our results uncover a deep universality in the propagation patterns crossing domains of inquiry, from ecological system to gene regulatory dynamics. More specifically we uncover how disease spread in arbitrary complex networks [C. Hens *et al.*, Nat. Phys. (2019); S. Ghosh *et al.*, Chaos (2021)].

Talk 3

19:10-19:40

Predicting dynamical processes in complex networks: a machine learning approach

Contributor(s): Prof. Francisco A. Rodrigues

Speaker: Prof. Francisco A. Rodrigues

Abstract

Estimating the outcome of a given dynamical process from structural features is a key unsolved challenge in network science. The goal is hindered by difficulties associated to nonlinearities, correlations and feedbacks between the structure and dynamics of complex systems. In this talk, we will present an approach based on machine learning algorithms that is shown to provide an answer to the previous challenge. Specifically, we show that it is possible to estimate the outbreak size of a disease starting from a single node as well as the degree of synchronicity of a system made up of Kuramoto oscillators. Also, we show which topological features of the network are key for this estimation, and provide a rank of the importance of network metrics with higher accuracy than previously done. Our approach is general and can be applied to any dynamical process running on top of complex networks.

Talk 4

19:40-20:10

Non-equilibrium critical dynamics of cortical activity as fundamental characteristic of sleep and wake micro-architecture

Contributor(s): Dr. Xiyun Zhang
Speaker: Dr. Xiyun Zhang

Abstract

Physiological states and cognitive functions are considered to associate with different dynamical states of cortex. Therefore, investigating dynamical stability of neuronal networks becomes a fundamental approach to understand the working mechanism of the brain. However, this paradigm based on equilibrium and stationary dynamics cannot explain observations of transient physiological behaviors, such as sleep in mammals. Continuous sleep exhibits intermittent transitions among sleep stages, including short awakenings and arousals, constitute a challenge to the current homeostatic framework for sleep regulation, focusing on factors modulating sleep over large time scales. Here we propose that the complex micro-architecture characterizing the sleep-wake cycle results from an underlying non-equilibrium critical dynamics, bridging collective behaviors across spatio-temporal scales. We investigate θ and δ wave dynamics in control rats and in rats with lesions of sleep-promoting neurons in the parafacial zone. We demonstrate that intermittent bursts in θ and δ rhythms exhibit a complex temporal organization, with long-range power-law correlations and a robust duality of power law (θ-bursts, active phase) and exponential-like (δ-bursts, quiescent phase) duration distributions, typical features of non-equilibrium systems self-organizing at criticality. Crucially, such temporal organization relates to anti-correlated coupling between θ- and δ-bursts, and is independent of the dominant physiologic state and lesions, a solid indication of a basic principle in sleep dynamics.

Talk 5

20:10-20:40

Personalized Brain Network Models in Clinical Translation

Contributor(s): Dr. Spase Petkoski
Speaker: Dr. Spase Petkoski

Topic 4

Adaption and Machine Learning in Physical Systems

Day 3, October 6, 2021

18:00-21:10 (Time in Beijing, UTC+8)

Talk 1

18:00-18:30

History of adaptation and machine learning

Contributor(s): Prof. Alexander Fradkov

Speaker: Prof. Alexander Fradkov

Abstract

Machine learning and artificial intelligence (AI) are attracting a lot of attention during recent years. They are applied to various new problems in science and engineering. Both media and scientific journals are full of exciting reports on AI in physics, AI in mechanics, AI in chemistry, etc. However not many people know that there exist strong historical links between machine learning and classical adaptation methods which may be useful for understanding new ideas. In this talk a brief overview of historical evolution of the machine learning field and its relations to adaptation, optimization and adaptive control are discussed. A number of little-known facts published in hard-to-reach sources are presented.

REFERENCES

[1] Alexander L. Fradkov. Early History of Machine Learning. IFAC-PapersOnLine, **53**, 1385-1390 (2020). DOI: 10.1016/j.ifacol.2020.12.1882

[2] Anuradha M. Annaswamy and Alexander L. Fradkov. A Historical Perspective of Adaptive Control and Learning. https://arxiv.org/abs/2108.11336 [math.OC] 24 Aug 2021.

Talk 2

18:30-19:00

Detection and control of epileptiform regime in the Hodgkin-Huxley artificial neural networks via quantum algorithms

Contributor(s): Dr. Sergey Borisenok
Speaker: Dr. Sergey Borisenok

Abstract

The Hodgkin-Huxley (HH) elements connected to an artificial neural network (ANN) demonstrate variety of their behavior such as resting, singular spikes and spike trains and bursts. This dynamical richness can cause an epileptiform regime originated in the hyper-synchronization of the neuron outcomes. Our model covers the detection and suppression of pre-ictal and ictal behavior in a small population of HH cells. The model follows our general approach (Borisenok, Çatmabacak, Ünal, 2018) for neuron driving the collective neural bursting, but here we use a quantum paradigm-based algorithm emulated with the pair of HH neurons. Such emulation becomes possible due to the complexity of the individual 4D HH dynamics (Borisenok, 2021). The linear chain of two HH neurons is connected to the rest of ANN and works autonomously. The first neuron plays a role of the detecting element for the hyper-synchronization in the ANN and the quantum algorithm emulator; while the second one works as a measuring element (emulation of the quantum measurement converting the signals into the classical domain) and the trigger for the feedback suppressing the epileptiform regime. We cover few alternative approaches for the detecting/suppressing HH pair (gradient feedback, target attractor feedback), and discuss their pros and cons to compare with our classical model of the epileptiform suppression.

Talk 3

19:00-19:30

Energy synchronization in a network of conservative Hamiltonian systems

Contributor(s): Ms. Galina Reneva & Prof. Alexander Fradkov
Speaker: Ms. Galina Reneva

Abstract

The problem of energy synchronization in a network of conservative Hamiltonian systems with a given topology is considered. We investigate the possibility of applying the Speed-Gradient Method to achieve the control goal. The theoretical results are illustrated with computer simulation of a pendulum system.

Talk 4

19:40-20:10

Neural network based synchronization control of the two-rotor vibration setup

Contributor(s): Dr. Oleg Shagniev
Speaker: Dr. Oleg Shagniev

Abstract

A solution to the problem of keeping the vessel on a given trajectory under conditions of uncertainty, the action of external disturbances is proposed. The model of the vessel takes into account external disturbances: the moment of wind action, the angle of the wave slope, independent, generating white noise; measurement errors, as well as kinematic relations. The motion of the vessel in the horizontal plane is considered, taking into account the lateral deviation from the trajectory. The robust ship course control law is constructed using the auxiliary loop method and two Khalil observers. The simulation results illustrate the effectiveness of the proposed robust control law.

Talk 5

20:10-20:40

A toolkit for gamma rhythm processing, analysis and adaptive modeling

Contributor(s): Ms. Evgeniia Sevasteeva & Dr. Sergei Plotnikov

Speaker: Ms. Evgeniia Sevasteeva

Abstract

Neural oscillations are electrical activities of the brain measurable at different frequencies. This paper studies the interaction between the fast and slow processes in the brain. We analyze electrocorticogram (ECoG) signals from the simple Wistar rats with developed tools application: low-pass and bandpass zero-phase filters to separate slow and fast components and envelope extraction to determine gamma-amplitude bursts and attenuations. Then we compute the correlation between the gamma rhythm envelope and a low-frequency ECoG signal. The analysis shows that the low-frequency signal (identified as delta rhythm) modulates the gamma rhythm with an approximately half-second time delay.

Talk 6

20:40-21:10

Synchronization in the complex heterogeneous networks of Hindmarsh-Rose neurons via adaptive coupling

Contributor(s): Mr. Danila Semenov

Speaker: Mr. Danila Semenov

Abstract

This talk is devoted to the adaptive synchronization problem in the heterogeneous Hindmarsh-Rose neuronal networks. Heterogeneity is a natural property of biological neuronal networks, as each neuron has its own physiological characteristics, which may differ from other neurons within the population. Therefore, the study of the effect of heterogeneity on the synchronization in the biological neuronal network is an important problem. In order to solve this problem, the ultimate boundedness property of the network trajectories is used. Based on the boundedness analysis and the Speed Gradient method, the adaptive algorithm for adjusting the coupling strength is developed. It is proved mathematically that the developed algorithm provides synchronization in the network under study. The obtained theoretical results are confirmed by the simulations.

Topic 5

Control of Power Grids

Day 4, October 7, 2021

14:00-16:40 & 18:00-22:10 (Time in Beijing, UTC+8)

Talk 1

14:00-14:30

What adaptive neuronal networks teach us about power grids

Contributor(s): Prof. Eckehard Schöll
Speaker: Prof. Eckehard Schöll

Abstract

Power grids, as well as neuronal networks with synaptic plasticity, describe real-world systems of tremendous importance for our daily life. The investigation of these seemingly unrelated types of dynamical networks has attracted increasing attention over the last decade. This contribution provides a new perspective on power grids by demonstrating that they can be viewed as a special class of adaptive networks, where the coupling weights are continuously adapted by feedback of the dynamics, and both the local dynamics and the coupling weights evolve in time as co-evolutionary processes [R. Berner *et al.*, Phys. Rev. E (2021)]. Such adaptive networks are very common in neural networks with synaptic plasticity. In terms of power grids, the power flow into the network nodes from other nodes represent pseudo coupling weights. This modelling approach allows one to transfer methods and results from neural networks, in particular the emergence of multifrequency clusters [R. Berner *et al.*, SIAM J. Appl. Dyn. Syst. (2019); R. Berner *et al.*, Chaos (2019); R. Berner *et al.*, Phys. Rev. Lett. (2021)], which may form in a hierarchical way and destabilize the desirable completely synchronized operating state of the power grid. In this work, the relation between these two types of networks, in particular the model of Kuramoto-Sakaguchi phase oscillators with inertia (swing equation for power grids) and the model of phase oscillators with adaptivity, is used to gain insights into the dynamical properties of multifrequency clusters in power grid networks. This relation holds even for more general classes of power grid models that include voltage dynamics. Moreover, the phenomenon of cascading line failure in power grids is translated into an adaptive neuronal network. Building on this relation between phase oscillators with inertia and adaptive networks, a new perspective on solitary states in power grid networks [H. Taher *et al.*, Phys. Rev. E (2019); F. Hellmann *et al.*, Nat. Commun. (2020)] and their influence on network stability is provided and illustrated by the ultrahigh-voltage power grid of Germany.

Talk 2

14:30-15:00

PMU-based dynamic state and parameter estimation in multi-machine power systems

Contributor(s): Prof. Johannes Schiffer
Speaker: Prof. Johannes Schiffer

Abstract

Situational awareness of the transient dynamics of power systems is becoming increasingly relevant as these systems undergo major changes due to the massive introduction of power-electronics-interfaced equipment, growing transit power flows and fluctuating (renewable) generation. These developments render the steady-state assumptions used in traditional static state estimation questionable. Thus, the deployment of methods for dynamic state estimation (DSE) is gaining increasing importance for power system control and protection. A key enabler for DSE is the growing availability of phasor measurement units (PMUs). By exploiting the huge potential provided by PMUs, in the present contribution a decentralized mixed algebraic and dynamic state observation approach is introduced, which is suitable for multi-machine power systems with unknown inputs and partially known parameters. The effectiveness of the proposed DSE technique is demonstrated in extensive simulations based on the New England IEEE-39 bus system as well as via real-world PMU measurement data.

Talk 3

15:00-15:30

NetworkDynamics.jl -- Simulating complex network dynamics in Julia

Contributor(s): Mr. Michael Lindner
Speaker: Mr. Michael Lindner

Abstract

NetworkDynamics.jl is an easy-to-use and computationally efficient package for working with heterogeneous dynamical systems on complex networks, written in Julia. By combining state of the art solver algorithms from DifferentialEquations.jl with efficient data structures, NetworkDynamics.jl achieves top performance while supporting advanced features like events, algebraic constraints, time-delays, noise terms and automatic differentiation. NetworkDynamics.jl is the computational backend of PowerDynamics.jl which facilitates dynamical simulation and control of power grid models.

Talk 4

15:40-16:10

Fault detection and probing in high-voltage power networks

Contributor(s): Dr. Melvyn Tyloo

Speaker: Dr. Melvyn Tyloo

Abstract

A wide variety of natural and human-made systems consist of a large set of dynamical units coupled into a complex structure. Breakdown of such systems can have a dramatic impact, as in the case of neurons in the brain or lines in an electric grid, to name but a few. Preventing such catastrophic events requires in particular to know as much as possible about the system of interest and to be able to detect and locate the source of disturbances as fast as possible. First, we propose a simple method to identify and locate disturbances in networks of coupled dynamical agents, relying only on time series measurements and on the knowledge of the (possibly Kronreduced) network structure. The strength and the appeal of the present approach lies in its simplicity paired with the ability to precisely locate disturbances and even to differentiate between line and node disturbances. If we have access to measurement at only a subset of nodes, our method is still able to identify the location of the disturbance if the disturbed nodes are measured. If not, we manage to identify the region of the network where the disturbance occurs. Second, we discuss recent probing methods that allow to infer network characteristics such as the coupling between the nodes and the total number of nodes in the grid. The latter methods give information about the power network that help in order to optimally control the system.

Talk 5

16:10-16:40

Solitary and splay states in the Kuramoto model with inertia

Contributor(s): Dr. Serhiy Yanchuk, Dr. Rico Berner & Prof. Eckehard Schöll
Speaker: Dr. Serhiy Yanchuk

Abstract

It has recently been shown that there is a fundamental relationship between power grid networks and adaptive dynamical networks. More specifically, simple models for power grids, such as coupled phase oscillators with inertia or coupled swing equations with voltage dynamics, can be represented as a special class of adaptive networks. As a direct consequence of this relationship, the properties and phenomenology of adaptive networks can be transferred to the above-mentioned power grid models. In this way, new classes of multi-cluster states for phase oscillators with inertia have been shown. In this contribution, we discuss other possible classes of solutions that may be relevant for power grids: splay states and solitary states as well as the synchronized state and its stability.

Talk 6

18:00-18:30

Controlling arbitrage on the energy market by price policies

Contributor(s): Dr. Tim Ritmeester & Prof. Hildegard Meyer-Ortmanns

Speaker: Prof. Hildegard Meyer-Ortmanns

Abstract

As a consequence of the energy transition, the energy market is reorganized towards more decentralized structures. Retailers on local markets try to optimize their own profit while possibly losing track of the physical grid stability. The physical stability of the German grid was actually endangered in 2019, when the reserve energy was almost completely exhausted due to strong fluctuations in renewable energy, so that drastic changes in the price for reserve energy were very likely abused by arbitrageurs. Usually the price for reserve energy is higher than the price on the intraday energy market. Caused by deviations from forecasts it may occasionally happen that the relation between both prices gets inverted. In such a situation, arbitrageurs may buy reserve energy at a lower price than they can sell energy on the intraday market; this way they exploit the option for arbitrage by short selling reserve energy. To make profit from such behavior, arbitrageurs must amount to a minority of the retailers. Therefore, we model their actions as a minority game with strategies, depending on the success of their actions in hindsight, chosen out of a repertoire of P options. We determine the average arbitrage over the number of players and over a certain period of time, and focus particularly on its fluctuations, as large fluctuations in arbitrage may destabilize the grid. The fluctuations depend non-monotonously on a parameter that is the ratio of P, a measure for the complexity of available information, and the number N of arbitrageurs. The value of the ratio for which the fluctuations are minimal signals the occurrence of a phase transition that has a counterpart in spin glasses, where it is known under the name of replica symmetry breaking. The phase with broken symmetry is characterized by large outliers of fluctuations, stronger than induced by a random choice of strategies. In our case, such outliers may lead to a complete exhaustion of reserve energy. Depending on the choice of parameters, the fluctuations may grow even proportional to N. When other external fluctuations are included to represent uncertainties in the weather forecast or the consumption behavior, their combination with a nonlinear price function may actually reduce the arbitrage and effectively stabilize the grid. We also analyze the impact of risk aversion of arbitrageurs. Here it turns out that it is favorable to penalize the few parties which contribute a large fraction of arbitrage rather than the many ones with a small contribution, to make them risk averse. Remarkably, even if we use the real data from 2019 for short selling energy on the German energy market, we see remnants of the phase transition as the control parameter P/N is varied. Based on our results we propose economic and statutory measures to control and reduce the amount of arbitrage below a tolerable low threshold. Our results complement those obtained from an economic perspective, as we deal with collective effects, manifest in signatures of an underlying phase transition, and with the interplay of nonlinear price functions with stochastic fluctuations. This understanding supports, for example, decisions regarding an optimal choice of the market size in terms of the number of retailers. The relative size of the fluctuations in arbitrage does not necessarily decrease with the system size, as we have shown. In ongoing work, we analyze by means of the cavity method from statistical physics how the different sources of uncertainties interact and evolve in the course of time: the external noise leading to fluctuations in reserve and intra-day prices, the fluctuating information available in the market, and the choice of strategies of the retailers.

Talk 7

18:30-19:00

Using batteries for frequency control in power grids

Contributor(s): Dr. Giulia Ruzzene, Dr. Damià Gomila & Prof. Pere Colet
Speaker: Dr. Giulia Ruzzene

Abstract

The transition to more sustainable energy production brings many challenges among which there is the high variability of the energy output of renewable energy resources, such as wind and sun. One solution is to install energy storage systems (such as batteries) in the grid to increase its stability measured in terms of frequency fluctuations. In this study we model the effects of introducing a battery in a scenario where we have conventional generation and high wind penetration. We use a model of a conventional power plant with primary and secondary control and we couple it to two different models of battery usage. One is based on an optimization technique known as model predictive control and is aimed at smoothing wind power, the other uses the battery as an additional primary and secondary control. We simulate the dynamics of the system frequency using demand and wind production data of Gran Canaria, Spain. We show how both methods reduce frequency fluctuations and we compare their performance.

Talk 8

19:00-19:30

Control of synchronization in two-layer power grids

Contributor(s): Dr. Simona Olmi, Dr. Carl H. Totz & Prof. Eckehard Schöll
Speaker: Dr. Simona Olmi,

Abstract

In this contribution, we suggest to model the dynamics of power grids in terms of a two-layer network, and use the Italian high voltage power grid as a proof-of-principle example. The first layer in our model represents the power grid consisting of generators and consumers, while the second layer represents a dynamic communication network that serves as a controller of the first layer. In particular, the dynamics of the power grid is modelled by the Kuramoto model with inertia, while the communication layer provides a control signal P_i^c for each generator to improve frequency synchronization within the power grid. We propose different realizations of the communication layer topology and different ways to calculate the control signal. Then, we conduct a systematic survey of the two-layer system against a multitude of different realistic perturbation scenarios, such as disconnecting generators, increasing demand of consumers, or generators with stochastic power output. When using a control topology that allows all generators to exchange information, we find that a control scheme aimed to minimize the frequency difference between adjacent nodes operates very efficiently even against the worst scenarios with the strongest perturbations.

Talk 9

19:40-20:10

Resilience and efficiency of the power grid with high penetration of renewable energy sources: the Balearic Islands as a case study

Contributor(s): Prof. Benjamín A. Carreras, Prof. Pere Colet,
Dr. José M. Reynolds-Barredo & Dr. Damià Gomila
Speaker: Prof. Pere Colet

Abstract

We analyze the resilience and efficiency of the power grid with a high penetration of renewable energy sources (RES) using the ORNL-PSERC-Alaska (OPA) model. In particular we use the power grid of the Balearic Islands with a high share of solar photovoltaic power as a case study. The day-to-day fluctuations of the solar energy and the use of storage is included in the model and their effects on the security of the supply are analyzed. The potential of wind energy is also discussed. We find that dismantling conventional power plants to be replaced with renewable energies with an equivalent average power increases considerable the risk of failures for RES fractions above 30%. It is possible to achieve producing 75% or more of the total consumption with RES, while keeping the risk similar to the one obtained with 100% conventional generation, by source redundancy, i.e. oversizing the installed solar power by a factor 2.5. Above 80% of RES production, the amount of necessary installed power becomes unreasonably high. Therefore at least a 20% backup of controllable power sources is necessary.

Talk 10

20:10-20:40

Hierarchically coordinated power flow control for enhancing rotor angle and frequency stability with demand-side flexibility

Contributor(s): Dr. Chao Duan
Speaker: Dr. Chao Duan

Abstract

Large-scale integration of renewables in power systems gives rise to new challenges for keeping synchronization and frequency stability in volatile and uncertain power flow states. To ensure safety of the operation, the system must maintain adequate disturbance rejection capability at the time scales of both rotor angle and system frequency dynamics. This calls for flexibility to be exploited on both the generation and demand sides, compensating volatility and ensuring stability at the two separate time scales. This contribution proposes a hierarchical power flow control architecture that involves both transmission and distribution networks as well as individual buildings to enhance both small-signal rotor angle stability and frequency stability of the transmission network. The proposed architecture consists of a transmission-level optimizer enhancing system damping ratios, a distribution-level controller following transmission commands and providing frequency support, and a building-level scheduler accounting for quality of service and following the distribution-level targets. We validate the feasibility and performance of the whole control architecture through real-time hardware-in-loop tests involving real-world transmission and distribution network models along with real devices at the Stone Edge Farm Microgrid. We also report on a real-time demand response experiment with 100 controllable devices. The experiment reveals several key challenges in the deployment of a real-time demand response program, including time delays, uncertainties, characterization errors, multiple timescales, and nonlinearity, which have been largely ignored in previous studies.

Talk 11

20:40-21:10

Evaluating and optimizing the robustness of high voltage power grids under power outages and fluctuations

Contributor(s): Prof. Philippe Jacquod
Speaker: Prof. Philippe Jacquod

Abstract

In complex network-coupled dynamical systems, two questions of central importance are how to identify the most vulnerable components and how to devise a network making the overall system more robust to external perturbations. These issues are becoming crucial for high voltage power grids, whose operational state becomes more and more subject to uncontrolled power fluctuations. This talk will be devoted to the analysis of local and global disturbances affecting large-scale power systems. I will discuss the propagation of frequency disturbances following power outages and fluctuations, and how the resulting perturbation can be optimally mitigated by the spatial redistribution of ancillary services such as droop/primary control and inertia. I will argue that in many instances, strong perturbations are carried by large wavelength, slow modes that split the network into coherently oscillating areas. Identifying these areas allows one to optimally damp inter-area modes, thereby enhancing grid stability.

Talk 12

21:10-21:40

Predicting risks in fluctuation driven power grids

Contributor(s): Dr. Xiaozhu Zhang & Prof. Marc Timme

Speaker: Dr. Xiaozhu Zhang

Abstract

Increasing renewable energy supply imply that power grid dynamics is increasingly driven by fluctuating inputs. Previous work [Zhang *et al.*, Sci. Adv. (2019); Gorjão *et al.*, Nat. Commun. (2020)] showed that strongly heterogeneous response patterns emerge that especially include distributed resonances. How to estimate or mitigate risks due to such non-local, network-wide dynamical responses remains unknown to date. In this talk we present: i) a condition on the power spectrum of the fluctuation signal that determines the heterogeneity and the stationarity of power grid responses, and ii) an easy-to-compute dynamic vulnerability index that identifies those nodes most vulnerable to stochastic perturbations [Zhang *et al.*, Chaos (2020)]. These findings might help to evaluate the potential systemic risks in power grids induced by fluctuating inputs and to design control schemes to mitigate such risks.

Talk 13

21:40-22:10

Predicting power grid frequency dynamics

Contributor(s): Dr. Benjamin Schäfer, Dr. Leonardo Rydin Gorjão, Dr. Johannes Kruse & Dr. Dirk Witthaut

Speaker: Dr. Benjamin Schäfer

Abstract

The power grid frequency is the central observable in power system control, as it measures the balance of electrical supply and demand. We require a better understanding of fluctuations and external influences to facilitate rapid control actions and improve power system stability.

In this contribution, I stress the need for more openly shared data and point to a recently established open data base for power grid frequency measurements https://power-grid-frequency.org/

Next, I discuss how methods from statistical physics as well as machine learning can be used to quantify power grid fluctuations and obtain forecasts of future trajectories. Analyzing the spatio-temporal dynamics, I will reveal inter-area oscillations and determine the time-to-bulk, i.e. the time it takes for far-away points in the power grid to synchronize. Furthermore, I will show how explainable Artificial Intelligence (XAI) may be used to reveal the drivers of large RoCoF (rate of change of frequency) events or DFDs (deterministic frequency deviations).

Topic 6

Computational Algorithms and Methods

Day 5, October 8, 2021

14:00-16:40 (Time in Beijing, UTC+8)

Talk 1

14:00-14:30

Modeling the control processes of the size population of microorganisms using modulated microwave radiation

Contributor(s): Dr. Alexander Oschepkov

Speaker: Dr. Alexander Oschepkov

Abstract

A mathematical model of a control system for the size population of microorganisms using modulated microwave radiation of non-thermal power has been built. The model is implemented in the dynamic environment MATLAB+Simulink, the areas of optimal values of the impact parameters are found. An algorithm for automatic tuning of the modulation frequency during the experiment has been developed. The efficiency of the algorithm is shown with the help of computer simulation.

Talk 2

14:30-15:00

Method of forming a conflict-free 4D trajectory of a low-flying vehicle, taking into account the parameters of observed conflict objects motion

Contributor(s): Dr. Vladimir Nebylov, Dr. Alexander Knyazhsky & Dr. Alexander Nebylov
Speaker: Dr. Vladimir Nebylov

Talk 3

15:00-15:30

Genetic stochastic method of global extremum search for multivariable function

Contributor(s): Prof. Sergej Ermakov, Dr. Liudmila Vladimirova,
Dr. Irina Rubtsova & Mr. Alexey Rubanik
Speaker: Dr. Irina Rubtsova

Abstract

The contribution is devoted to the development of stochastic methods of global extremum search. The modification of the annealing simulation method [S.M. Ermakov *et al.*, Vestnik St. Petersburg University, Mathematics (2017)] is combined with the covariance matrix adaptation method [S.M. Ermakov *et al.*, Automation and Computer Engineering (in Russian 1977)]. In this case, an effective computational method [S.M. Ermakov *et al.*, Communications in Statistics-Simulation and Computation (2019)] is used for modeling the multivariate normal distribution. The special methods of covariance matrices adaptation are suggested to avoid the obtaining a local extremum instead of a global one. The methods proposed are successfully applied to the problem of nonlinear regression parameters calculation. This problem often arises in physics and mathematics and may be reduced to global extremum search. In particular case considered the extremum of rather complex function of 14 variables was found.

Talk 4

15:40-16:10

Free fock parafermions in the tight-binding model with dissipation

Contributor(s): Ms. Alena Mastiukova, Dr. Vladimir Gritsev,
Dr. Denis Kurlov & Dr. Aleksey Fedorov
Speaker: Ms. Alena Mastiukova

Abstract

Exotic excitations of quasiparticles are now one of the leading research topics of fundamentally important and complex problems. A significant attention was attracted by anyons that demonstrate richer exchange statistics. Their possible applications are associated with the use of quantum information for topologically protected processing. Parafermions that generalize fermions are interacting quasi-particles. Although many attempts to develop models with non-interacting parafermions have been undertaken. Here we present a way for the realization of free Fock parafermions (FPF) in the tight-binding model with dissipation of a very simple form. We demonstrate a 1D model with free FPF with dissipation. Including dissipation of a very simple form transform an originally non-integrable model of FPF to an exactly-solvable one by natural cancelling the Hermitian conjugate part of the Baxter Hamiltonian. We also discuss possible experimental realizations of the suggested model based on solid-state realization and programmable quantum simulators either by controlling n-level quantum system nor spatially-ordered states with z_n symmetries.

Talk 5

16:10-16:40

Global variables control of a Josephson junctions array

Contributor(s): Eng. Nikolay Litvinov
Speaker: Eng. Nikolay Litvinov

Abstract

In this contribution, a way to solve an LQ-problem for a Josephson junction array with a common LRC-load is proposed. The cases of identical and non-identical Josephson junctions are considered. The solution ensures phase stabilization of Josephson current in every junction. The results are obtained using computer modelling in Jupyter Notebook and MATLAB.

Topic 7

Dynamical System and its Analytical Analysis

Day 5, October 8, 2021

18:00-21:10 (Time in Beijing, UTC+8)

Talk 1

18:00-18:30

Integrable homogeneous dissipative dynamical systems with four degrees of freedom

Contributor(s): Prof. Maxim Shamolin
Speaker: Prof. Maxim Shamolin

Abstract

In many problems of dynamics, there appear mechanical systems with four-dimensional manifolds as position spaces. Tangent bundles of such manifolds naturally become phase spaces of such systems. For example, study of a five-dimensional generalized spherical pendulum in a nonconservative force field leads to a dynamic system on the tangent bundle of a four-dimensional sphere, and the metric of special form on it is induced by an additional symmetry group [M.V. Shamolin, J. Math. Sci. (2003); M.V. Shamolin, J. Math. Sci. (2009)]. In this case, dynamic systems describing the motion of such a pendulum possess alternating dissipation and the complete list of first integrals consists of transcendental functions that can be expressed in terms of a finite combination of elementary functions [M.V. Shamolin, J. Math. Sci. (2009); V.V. Trofimov & M.V. Shamolin, J. Math. Sci. (2012)].

Talk 2

18:30-19:00

Bifurcation analysis of the pilot-vehicle systems with an actuator saturation

Contributor(s): Prof. Boris Andrievsky, Ms. Iuliia Zaitceva & Prof. Nikolay Kuznetsov

Speaker: Ms. Iuliia Zaitceva

Abstract

Saturation nonlinearity of actuator is a common problem in the airspace field. The saturation-induced events may lead to so-called pilot-induced oscillations. It is often associated with unfavorable interaction between the pilot and the aircraft, which may tend to uncontrollable dangerous excursions in aircraft attitude and flight path. It is known that a pseudo-linear correcting device embedded in the actuator control loop able to prevent these oscillations. This event is accompanied by a change in the parameters of the pilot model and actuator rate. Analysis of the stability of nonlinear time-varying systems is a non-trivial task. In this connection, this contribution proposes a comparative numerical analysis of the pilot-vehicle system behavior with and without correction to identify the parameters, initiating a qualitative change in the system. As a result, bifurcation diagrams are presented illustrating parameters areas of possible cliff-like behavior and oscillatory mode. Also, the measure of the excitability of a pilot-vehicle system is calculated.

Talk 3

19:00-19:30

Global dynamics of a planar polynomial mechanical system

Contributor(s): Dr. Valery A. Gaiko
Speaker: Dr. Valery A. Gaiko

Abstract

In this contribution, using a bifurcational geometric approach, we study the global dynamics and solve the problem on the maximum number and distribution of limit cycles in a planar polynomial Euler–Lagrange–Li´enard type mechanical system.

Talk 4

19:40-20:10

Emergency of beta oscillations in a resonance model for parkinson's disease

Contributor(s): Dr. Yaqian Chen & Prof. Yan-Mei Kang
Speaker: Dr. Yaqian Chen

Abstract

In Parkinson’s disease, the excess of beta oscillations (13-30Hz) in cortical-basal ganglia (BG) circuits has been correlated with normal movement suppression. However, how these abnormal oscillations are generated remains unknown. In this paper, a physiologically resonance model, generalizing an earlier model of subthalamic nucleus-globus pallidus (STN-GP) circuit is employed to analyze critical dynamics of the occurrence of beta oscillations, which correspond to the Hopf bifurcation. With the experimentally measured parameters, conditions for the occurrence of the Hopf bifurcation with time delay are deduced by means of linear stability analysis, center manifold theorem and normal form analysis. It is found that beta oscillations can be induced by increasing synaptic transmission delay. Furthermore, it is revealed that the oscillations originate from interaction among different synaptic connections. Our analytical results are consistent with the previous experimental and simulating findings, thus may provide a more systematic insight into the mechanisms underlying the transient beta bursts.

Talk 5

20:10-20:40

Characterization of linear Hamiltonian systems using linear algebra techniques: A review

Contributor(s): Prof. M. Isabel Garcia-Planas & Dr. A. Chanes-Espigares
Speaker: Prof. M. Isabel Garcia-Planas

Talk 6

20:40-21:10

Investigation of dynamics and stability of elastic elements of wing profiles

Contributor(s): Dr. Petr Velmisov & Dr. Andrey V. Ankilov
Speaker: Dr. Andrey V. Ankilov

Abstract

The dynamics and stability of the elastic elements of the wing profiles, flown around by the stream of an incompressible medium (gas or liquid), are investigated. To study the dynamics of elastic elements and a gas-liquid medium, both linear and nonlinear models of the mechanics of a solid deformable body, and linear models of the mechanics of liquid and gas are used. Several models of profiles are considered. Based on the constructed functionals for partial differential equations, the sufficient stability conditions are obtained. The conditions impose restrictions on the parameters of mechanical systems.