DTU Technical University of Denmark

UNIVERSITY OF COPENHAGEN

Oscillations, Transients and Fluctuations in Complex Networks (OTFCN)

International Workshop, Copenhagen, July 1-3, 2019

Organizers:

Erik Andreas Martens, DTU
Mads Peter Sørensen, DTU
Susanne Ditlevsen, UCPH
Mogens Høgh Jensen, UCPH

Conference website:

http://eam.webhop.net/index_OTFCN.php5

Version
July 1, 2019

Sponsor:

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PROGRAMME

MONDAY

08.50	E. A. Martens	Welcome
09.00	C. Bick	Intermittent interactions: dynamics of oscillator networks with dead zones
09.45	A. Daffertshofer	Mean fields and neural masses - how close can we go?
10.30	Coffee break	
11.00	K. Tsaneva-Atanasova	Noise-induced escapes in oscillatory network dynamics
11.30	P. Słowiński	Epileptogenesis – network perspective
12.00	H. Lindén	Pattern generation and multi-functionalism in motor networks with balanced excitation and inhibition
12.30	LUNCH	
14.00	Canceled: ~~J. Ottesen~~	~~Intracranial pressure and cerebral blood flow~~;
14.45	E. Feliu	Algebraic approaches to determine and preclude Hopf bifurcations in reaction networks
15.30	Coffee break	
16.00	M. Yamakou	Transitions between two weak-noise-induced resonance phenomena in a slow-fast dynamical system
16.30	C. Poignard	Impacts of structural perturbations on the synchronizability of diffusive networks
17.00	Posters & Reception	
18.30	Free social activities, independent dinner	

TUESDAY

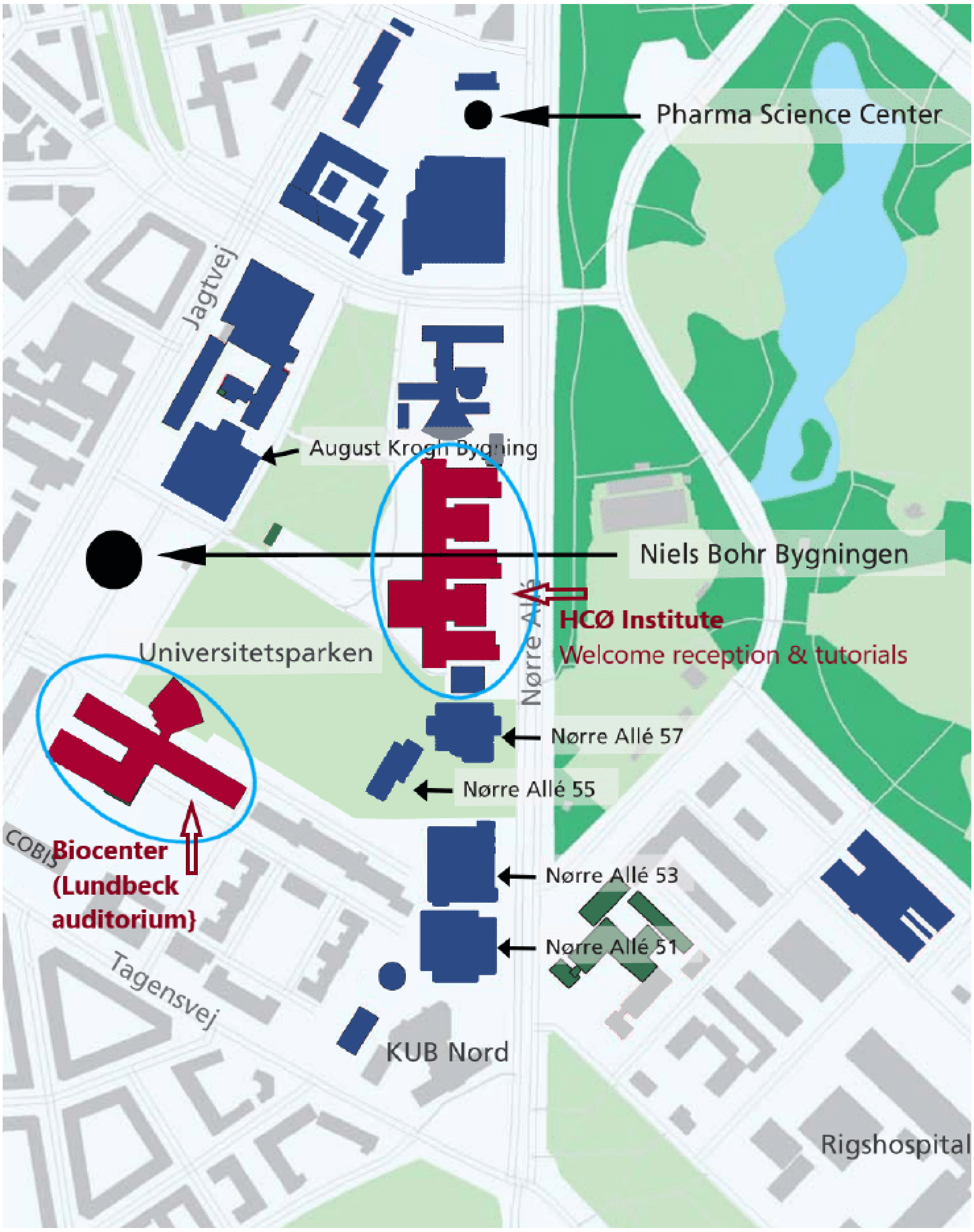
09.00	A. Ustinov	Experimental study of collective modes in SQUID metamaterials
09.45	F. Hellmann	Lossy couplings and fluctuation response in power grids
10.30	Coffee break	
11.00	J. Hindes	Network desynchronization by non-Gaussian fluctuations
11.30	H. Hong	Synchronization of coupled oscillators and its thermodynamic cost
12.00	H. True	Oscillations and transients in railway vehicle dynamics
12.30	LUNCH	
14.00	M. H. Jensen	Coupled oscillators and chaos in gene regulation
14.45	J.G. Caputo	Source detection in a fluid network
15.30	Coffee break	
16.00	N. Grønbech Jensen	Time-Step independent statistics in simulated Langevin systems
16.45	P. Ditlevsen	Entangling the complex dynamics of the climate from a time series: The case of tipping points
17.30	Free time	
18.30	Conference Dinner	

WEDNESDAY

09.00	K. Sneppen	Cyclic replacements in collapse-driven population dynamics
09.45	N. Mitarai	Bacteria vs. phages: the art of war among the unseen majority
10.30	Coffee break	
11.00	S. Krishna	Hysteretic oscillations in a well-mixed population of budding yeast
11.30	K. Klemm	Stucture of adaptive flow networks under load fluctuations
12.00	C. Xu	Classification and Dynamics of continuous time Markov chains with applications in reaction networks
12.30	LUNCH	
	End of workshop. Independent social activities, ...	

MAPS

See also the interactive Google Map with more locations.
You may also find this via the conference website:
http://evo.ds.mpg.de/erik/index_OTFCN.php5?page=otfcompnet_venue



Lunch / Auditorium:
University of Copenhagen North Campus

LOCATIONS AND PRACTICAL INFO

Venue and talk location

The conference venue is in the North Campus of the University of Copenhagen.
All talks will be held at **H. C. Ørsted Institute, Auditorium 4**.

Address:
H. C. Ørsted Institute
Universitetsparken 5
2100 Copenhagen Ø

The H. C. Ørsted Institute is located in the North Campus of the University of Copenhagen and is within a 5 minutes walk from the Biocenter.

Lunch

Lunch will be served in the cafeteria in the Biocenter.

Poster Session & Reception

The poster session and welcome reception will be hosted right next to Auditorium 4. Posters will be attached to the wall using sticky tags (provided), thus no specific poster size formats are demanded.

Conference dinner

The conference dinner will be held at Nørrebro Bryghus, Ryesgade 3, 2200 Copenhagen, approximately 1.5 km away from the conference venue in the direction towards the city center.

Address:
Nørrebro Bryghus
Ryesgade 3
2200 Copenhagen N

Internet

The University of Copenhagen is covered by Eduroam and by KU Guest wireless networks.

Eduroam You can log on if you already have access to Eduroam from your home university.

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Useful cell phone numbers for emergent problems

Organizers:

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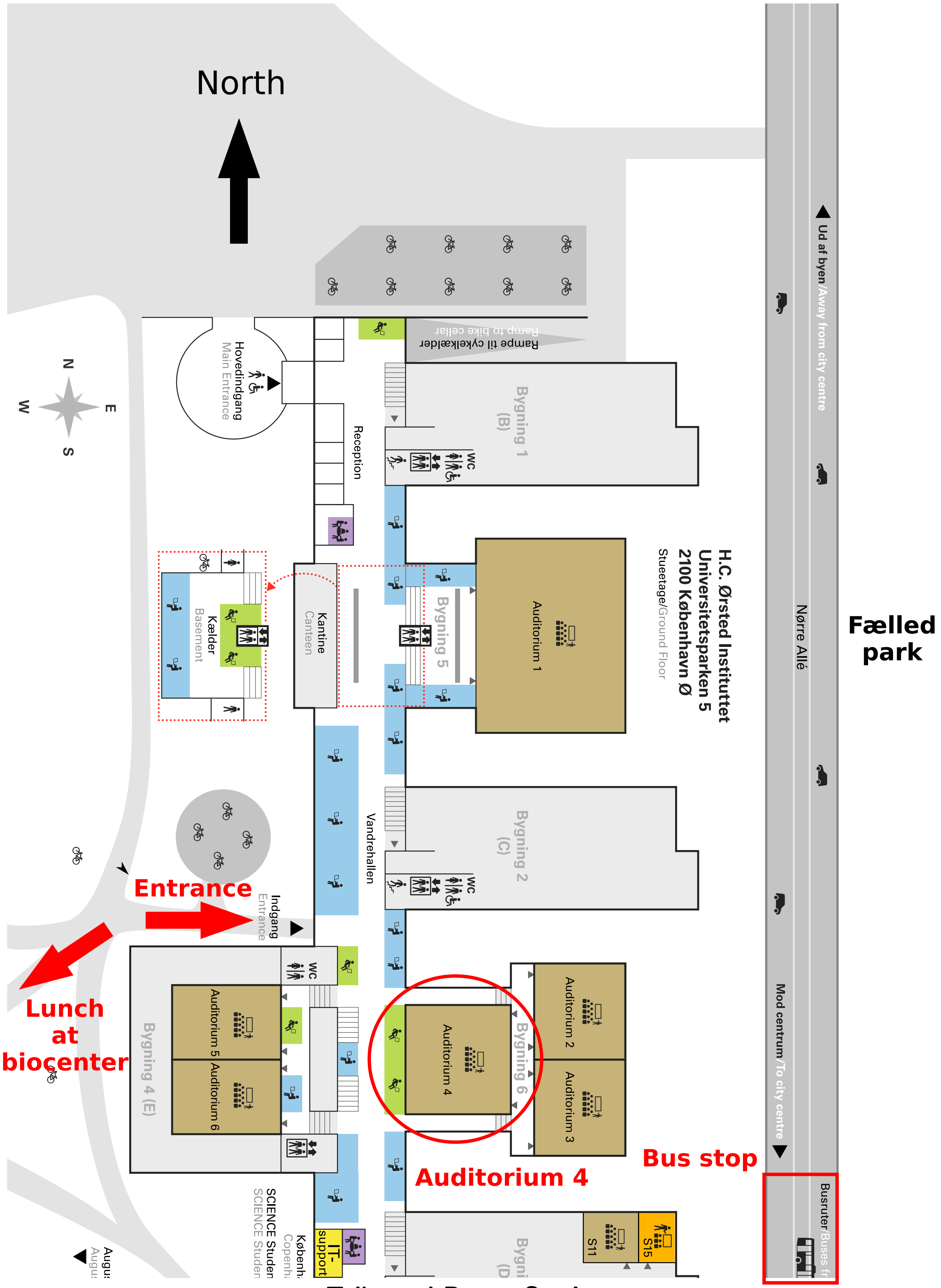
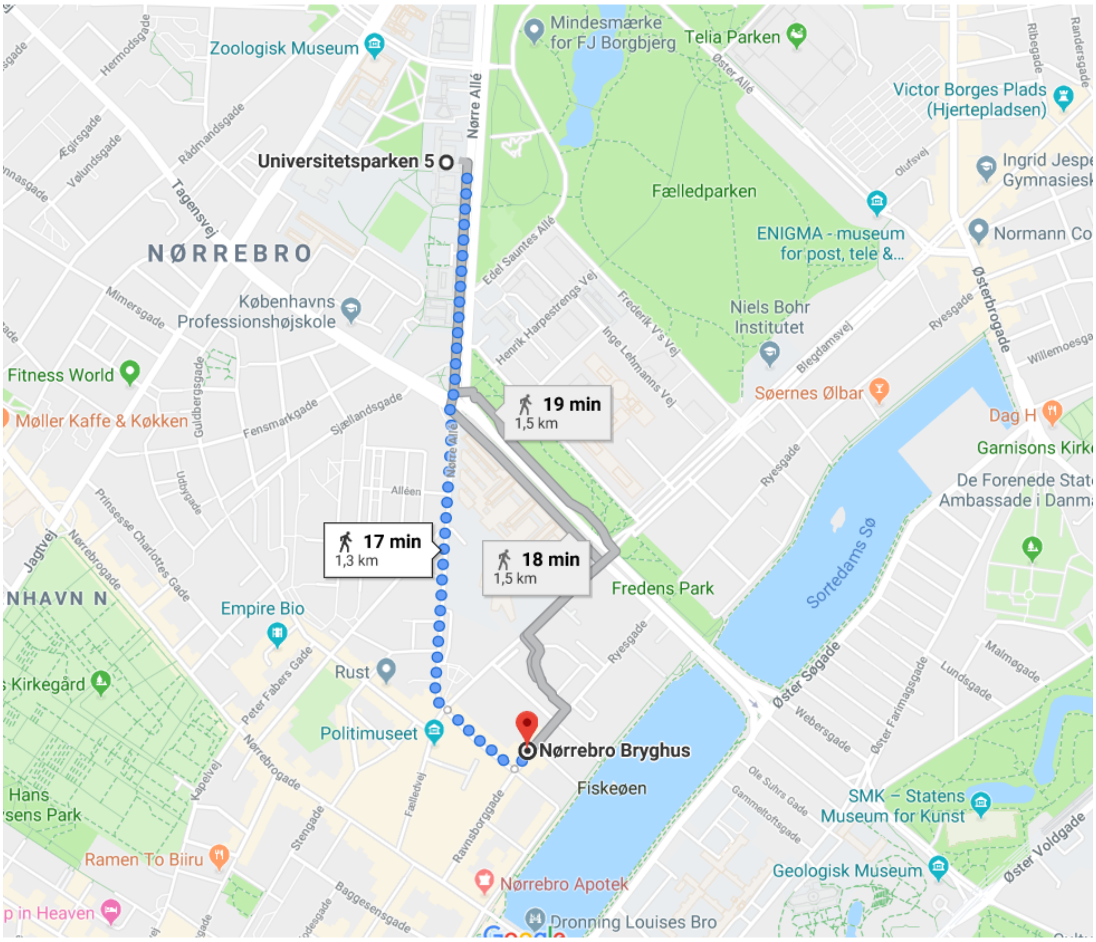


Talks and Poster Session:

Auditorium 4, H. C. Ørsted Institute, Universitetsparken 5, ground floor

NOTE: Entrance door will generally be locked during summer period. On Monday morning, we will be there to open doors latest 8.30 (guaranteed) – hopefully earlier.

If you are late to get in: please text/call one of the organizers on cell phone numbers listed above.



Conference Dinner:
Nørrebro Bryghus, Ryesgade 3, 2200 Copenhagen

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TALKS

Intermittent interactions: dynamics of oscillator networks with dead zones

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Abstract: Whether two nodes in a network of dynamical units interact may depend on their states. For example, after a spike, neurons typically have a refractory period where they are desensitized to further input before they can produce another action potential. We investigate the dynamics of coupled oscillator networks where the coupling functions have "dead zones" (regions without interaction). These induce an effective coupling structure that depends on the state of the network. We analyze the interplay between dynamics and the evolving coupling structure and find solutions where units continuously decouple and recouple. These state-dependent dynamical systems relate to "asynchronous networks," a framework to describe dynamical systems with time-varying connectivity. (This is joint work with P. Ashwin, M. Field, C. Poignard.)

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Mean fields and neural masses - how close can we go?

Author(s): Andreas Daffertshofer

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Abstract: The dynamics of neural populations are often cast in so-called neural mass models. Although neural mass models are of based on heuristic arguments, they have been proven useful to describe self-sustained, meso- and macroscopic oscillations and phenomena like local and distant synchronization. Since derivations of such models often lack mathematical rigor, one may rightfully ask to extent they really resemble the full dynamical spectrum of the neural population under study. To trigger discussion, first, paradigm will be sketched briefly, in which the neural mass dynamics can be derived given a specific albeit non-trivial nodal dynamics in network with arguably trivial connectivity. Next, the nodal dynamics is simplified to ease averaging procedures but connectivity / adjacency is considered to be less trivial. As will be shown, there the conventional mean-field approximations can yield arbitrarily large deviations from the population dynamics, with the latter being determined through numerics, which is here considered as 'ground truth'. In this specific case, it appears that the deviations are due to the presence of (partial) synchronization causes. Finally, potential implications of these findings for the interpretation of neural mass models will be discussed.

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Noise-induced escapes in oscillatory network dynamics

Author(s): Krasimira Tsaneva-Atanasova, Jennifer Creaser, Peter Ashwin

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Abstract: Mathematical models of excitable cells, such as neurones, are often characterised by different dynamic regimes, such as alternating excited and rest states. The transient dynamics responsible for the transition between dynamic states are not well understood. However, it is well known that the addition of noise in a multi-stable system can induce random transitions between stable states where the rate of transition can be characterised in terms of the properties of the noise-free system and the added noise: for potential systems in the presence of asymptotically low noise the well-known Kramers' escape time gives an expression for the mean escape time. We focus on the case of sequential escapes: we assume that one of the stable states is only marginally stable and we start with all nodes in the marginally stable state. After escape, we assume that the transitions back are astronomically large by comparison and there will typically be a sequence of noise-induced escapes. We quantify and characterize the resulting sequences of noise-induced escapes. For weak enough coupling we show that a master equation approach gives a good quantitative understanding of sequential escapes, but for strong coupling this description breaks down.

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Epileptogenesis – network perspective

Author(s): Piotr Słowiński

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Abstract: Large-scale brain networks are increasingly recognized as important for the generation of seizures in epilepsy. However, how a network evolves from a healthy state through the process of epileptogenesis remains unclear. Here we provide the first description of how functional connectivity and network dynamics inferred from background EEG evolve during epileptogenesis. We show that network dynamics inferred by means of computational modeling are different at early and later stages of epileptogenesis. Numerical results are consistent with experimental observations and can be used to model outcomes of localised pharmacological suppression of epileptiform activity in individual animals.

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Pattern generation and multi-functionalism in motor networks with balanced excitation and inhibition

Author(s): Henrik Lindén

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Abstract: Networks of neurons in the spinal cord are responsible for the precise execution of movements, such as walking, running or swimming. Despite over a century of research it still remains controversial how spinal neuronal networks achieve this and how the dynamical properties of this network should be described. In the classical half-centre model, rhythms are generated in an oscillatory central core and muscles coordination is achieved by the interplay between discrete neuronal populations in a fixed modular organization. It is, however, unclear how such a network can generate multiple distinct behaviours using the same neuronal populations. Here, we take a different approach and study rhythmic pattern generation in an unstructured (random) network with balanced excitation and inhibition. We show that slow rhythmic motor coordination can be generated in a rate-based network with strong synaptic weights by stimulation of one or several eigenmodes while the overall network activity is in a stable regime. By properly adjusting the weights of a linear readout, as an analogue of muscle nerve activity, we show that one realization of such a network can display distinct modes of activity, illustrating a minimal model of multi-functional motor networks.

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Intracranial pressure and cerebral blood flow

Author(s): Johnny T. Ottesen and Peter Reinstrup, Lund University Hospital

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Abstract: Head injury is a common form of trauma and is a significant cause of death and disability (especially in young males) and is associated with raised intracranial pressure (ICP). ICP is a result of alterations in craniospinal volume due to differences in edema (swelling), blood inflow and blood outflow, and the ability of e.g. the craniospinal compartment to accommodate added volume. The craniospinal system is essentially a system of partially closed 'boxes' in the skull with both viscous and elastic properties. The elastic (inverse compliant) properties of the compartments will determine what added volume can be absorbed while intracranial pressure begins to rise. So an understanding of raised ICP encompasses an analysis of both intracranial volume and craniospinal compliance.

Unique data over a single heart cycle for 10 patient measured in Lund gave the possibility of modelling the relationship between ICP and blood flows to and away from the brain region for intensive care patients with head trauma. ICP shows unexplained nonlinear oscillations having various peaks characteristics. A lumped model is capable of, for the first time, accurately fit most of the observed ICP pattern given the measured inflow and outflow, thus increasing the physiologically understanding of the system.

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Algebraic approaches to determine and preclude Hopf bifurcations in reaction networks

Author(s): Elisenda Feliu

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Abstract: Polynomial systems of ordinary differential equations arise in modeling the concentration of the species in a reaction network under the assumption of mass-action kinetics. These systems have numerous parameters, encoding the reaction rate constants and the total amounts of kinase, substrate etc.
Theoretically, the study of the sign and vanishing set of the so-called Hurwitz determinants can be employed to address whether a network admits, for some choice of parameter values, a Hopf bifurcation, which in turn will lead to oscillations. In practice, these determinants are huge, with millions of terms, and its computation and analysis is not straightforward. Some recent progress on the understanding on how to operate with these polynomials have shed some light into how to put this approach in practice. In this talk I will review the strategy, and show how it is used to study Hopf bifurcations in two systems of biological relevance.
The first result is the discovery of oscillations in a simple two-layer cascade with a simple phosphorylation cycle at each layer, without the presence of any feedback (joint work with A. Torres). The second result is the preclusion of Hopf bifurcations in a double phosphorylation cycle (joint work with C. Conradi and M. Mincheva). Previously, oscillations had been reported in a two-layer cascade where the first layer is a simple phosphorylation cycle but the second layer is a double phosphorylation cycle. Therefore, our results show that while the second layer alone cannot be responsible for the emergence of oscillations in this system, the cascade structure alone already gives rise to oscillations.

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Transitions between two weak-noise-induced resonance phenomena in a slow-fast dynamical system

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Abstract: We consider a singularly perturbed stochastic nonlinear dynamical system derived from computational neuroscience. First, we will independently understand the mechanisms that underlie two very different forms of weak-noise-induced resonance phenomena, namely: self-induced stochastic resonance (SISR) and inverse stochastic resonance (ISR). We will then show that SISR and ISR are in fact mathematically related via the relative geometric positioning (and stability) of the fixed point and the generic folded singularity of the critical manifold of the dynamical system. This result could explain the experimental observation where real biological neurons having similar physiological features and synaptic input encode very different information.

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Impacts of Structural Perturbations on the Synchronizability of diffusive networks

Author(s): Camille Poignard[(1)], Jan Philipp Pade[(2)], Tiago Pereira[(3)]

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Abstract: We study how the synchronizability of a diffusive network increases or decreases when we add some links in its underlying graph. This work has led to the article [2] below. Motivations come from the context of power grid networks where people want to prevent from having blackouts, or from neural networks where synchronization is responsible of many diseases such as Parkinson. Thanks to structural genericity properties for Laplacian matrices on connected graphs (see [1]), we deduce some classification results telling which links added increase the Synchronizability and which links added decrease it. Contrary to the common belief we particularly show that adding links which reinforce strongly the structure of a network, can possibly lead to a hindrance or loss of synchronization. We do this in two settings: in the context of connected undirected

networks where the links added are directed, and in the context of directed networks presenting a master-slave configuration.

Keywords: diffusively coupled networks, Laplacian matrices, spectral graphs properties, perturbations of eigenvalues theory.

- Spectra of Laplacian matrices of weighted graphs: structural genericity properties, C. Poignard, T. Pereira, J. P. Pade. SIAM Journal on Applied Mathematics (2018).
- The effects of Structural Perturbations on the Synchronizability of diffusive networks, C. Poignard, J.P Pade, T. Pereira. Journal of Nonlinear Science (2019).

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Experimental study of collective modes in SQUID metamaterials

Author(s): A. P. Zhuravel, S. Bae, A. Averkin, S. M. Anlage, and A. V. Ustinov

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Abstract: We examine the collective behavior of two-dimensional nonlinear superconducting metamaterials using a novel imaging technique. The metamaterial is made up of self-resonating microwave oscillators in a strongly coupled 27 x 27 planar array of Superconducting QUantum Interference Devices (SQUIDs). By using low-temperature laser scanning microscopy we image microwave currents in the SQUIDs and identify the clustering and uniformity of like-oscillating meta-atoms. We follow the rearrangement of coherent patterns due to meta-atom resonant frequency tuning as a function of external dc and rf magnetic flux bias. We find that the rf current distribution across the SQUID array at zero dc flux and small rf flux reveals a low degree of coherence. By contrast, the spatial coherence heals upon increasing of rf flux amplitude. We will discuss the possible origins of such coherence variations.

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Lossy couplings and fluctuation response in power grids

Author(s): Frank Hellmann

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Abstract: I discuss recent results on the spreading of fluctuations and the non-linear stability of inertial oscillator networks that model power grids in the presence of losses on the lines. We find that the presence of energy losses on lines gives rise to a number of novel dynamical phenomena, including shifting the natural limit cycles of the system around and a pronounced imprint of the network structure in the vulnerability of individual nodes to fluctuations. I also discuss how Machine Learning techniques can be used to study the asymptotic behavior, and in particular changes in the basin stability, of networked systems under parameter changes.

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Network desynchronization by non-Gaussian fluctuations

Author(s): Jason Hindes

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Abstract: Many networks must maintain synchrony despite the fact that they operate in noisy environments. Important examples are electric-power networks, where a rapidly increasing amount of power is supplied by renewable sources, which are known to exhibit fluctuations with broad tails. Such non-Gaussian fluctuations can result in rare desynchronization. Here we build a general theory for oscillator network desynchronization by non-Gaussian noise, which can be parameterized, for example, by power-increment data. We compute the rate of desynchronization and show that higher-moments of noise enter at specific powers of coupling: either speeding up or slowing down the rate exponentially depending on how noise statistics match the statistics of a network's weakest stable mode. Finally, we introduce a technique that can be used to drastically reduce the number of equations needed to predict desynchronization in oscillator networks. For instance, when instability is associated with a single overloaded edge, the reduction is to one effective oscillator system.

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Synchronization of coupled oscillators and its thermodynamic cost

Author(s): Hyunsuk Hong

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Abstract: In this talk, we revisit a typical model of large population of coupled oscillators showing the collective synchronization. In particular, we consider the case that the oscillators play under the thermal noise, and explore how the thermal force affects the synchronization behavior of the coupled oscillators. We investigate the thermodynamic cost for the synchronizing oscillators, by measuring the quantity like heat in the system. We analytically derive the heat for the system, and investigate its critical behavior near the synchronization transition.

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Oscillations and transients in railway vehicle dynamics

Author(s): Hans True

Affiliation(s): Dept. of Applied Mathematics and Computer Science, Technical University of Denmark

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Abstract: The Railway Vehicle Dynamical problems are multibody problems with from 7 to 80+ degrees of freedom. The mathematical models are nonlinear and non-smooth with tabulated constraints. Only autonomous problems are considered. The dynamics depend on the speed V as a control parameter and the vehicles can run steady, oscillate symmetric or asymmetric periodically, multi periodically, quasiperiodically or chaotic, possibly with multiple attractors. Several kinds of bifucations exist. The theoretical dynamical models are investigated numerically and problems connected herewith will be briefly presented. Some interesting modes and bifurcations will be shown.

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Coupled Oscillators and Chaos in Gene Regulation

Author(s): Mogens H. Jensen

Affiliation(s): Niels Bohr Institute, University of Copenhagen, Denmark

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Abstract: Oscillating patterns with periods of 2-5 hours have been observed for transcription factors in single cells. The oscillations appear as a response to DNA damage and other induced stresses. We have identified the central feed-back loops leading to oscillations and formulated genetic networks in terms of mathematical equations. By applying an external periodic protein signal, it is possible to lock the internal oscillation of a transcription factor to the external signal [1]. We have observed that the two signals lock when the ration between the two frequencies is close to basic rational numbers iforming Arnold tongues[1]. When the tongues start to overlap we may observe mode hopping and chaotic dynamics in the concentration of proteins [1,2]. We investigate how this influences gene productions through stochastic simulations. In the chaotic regime, genes with high affinity decreases their production with increased external amplitude, while genes with low affinity increases their production [2].

- M.L. Heltberg, R. Kellogg, S. Krishna, S. Tay and M.H. Jensen, "Noise-induced NF-kB Mode Hopping Enables Temporal Gene Multiplexing", Cell Systems 3, p. 532–539 (2017)
- M.L. Heltberg, S. Krishna and M.H. Jensen, "On chaotic dynamics in transcription factors and the associated effects in differential gene regulation", Nature Communication, DOI:10.1038/s41467-018-07932-1 (2019)

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Detecting network size from the dynamics perceived from a few units only

Author(s): Marc Timme

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Abstract: The size of a network dynamical system, its number of dynamical variables, arguably constitutes its most fundamental property. Typically, however, N is unknown, because only a small subset of $n < N$ variables is perceptible. Here we introduce a detection matrix that suitably arranges repeatedly observed time series to detect network size via matching rank constraints [1]. The proposed method relies on basic linear algebra and as such is model-free, applicable across system types and interaction topologies, and nonstationary dynamics near fixed points. We further offer extensions to periodic and chaotic collective motion. Even if only a small minority of units is perceptible and for systems simultaneously exhibiting nonlinearities, heterogeneities, and noise, exact detection is feasible.

[1] Detecting Hidden Units and Network Size from Perceptible Dynamics, H. Haehne, J. Casadiego, J. Peinke, and M. Timme, Phys. Rev. Lett. 122:158301 (2019)
https://doi.org/10.1103/PhysRevLett.122.158301

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Source detection in a fluid network

Author(s): Jean-Guy Caputo

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Abstract: Small disturbances on a fluid network can be described by the graph wave equation, where the usual Laplacian is replaced by the graph Laplacian. We consider that a time-dependent source emits at one node of the network and address the inverse problem of it's identification. We prove that time records taken at a strategic set of two nodes yield uniqueness of the two unknown elements: the source position and the emitted signal. Using graph theory, we discuss the number and location of the observation nodes. Numerical experiments on a 5 node graph confirm the feasibility of the approach.

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Time-Step independent statistics in simulated Langevin systems

Author(s): Niels Grønbech-Jensen

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Abstract: Numerical simulations of classical equations of motion always involve discretization of time, and as the time step is increased the discrete-time behavior not only becomes increasingly different from the anticipated continuous-time dynamics, it also develops internal inconsistencies between, e.g., configurational and kinetic measures. We present a new, simple simulation technique for Langevin systems in thermal equilibrium. We briefly review our stochastic Størmer-Verlet algorithm that preserves proper configurational sampling (diffusion and Boltzmann distribution) in discrete time. The resulting method, which is as simple as conventional Verlet schemes, has been numerically tested on both low-dimensional nonlinear systems as well as more complex molecular ensembles with many degrees of freedom. We further present a recent solution to the "velocity-problem", and we show a simple approach for achieving precise measures for both configurational and kinetic sampling. We show exact analytic results for linear systems, and demonstrate the applicability of the method for both nonlinear and complex systems, which can be accurately simulated at any time step within the stability limit. The method [1] is in the standard form of a Verlet-type algorithm, and is therefore easy to test and apply in existing codes, including Molecular Dynamics.

- Grønbech Jensen and Grønbech-Jensen, "Accurate configurational and kinetic statistics in discrete-time Langevin systems", Molecular Physics (2019),
https://doi.org/10.1080/00268976.2019.1570369

∞

Entangling the complex dynamics of the climate from a time series: The case of tipping points

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Abstract: It is taken for granted that the limited predictability in the initial value problem, the weather prediction, and the predictability of the statistics are two distinct problems. Predictability of the first kind in a chaotic dynamical system is limited due to critical dependence on initial conditions. Predictability of the second kind is possible in an ergodic system, where either the dynamics is known and the phase space attractor can be characterized by simulation or the system can be observed for such long times that the statistics can be obtained from temporal averaging, assuming that the attractor does not change in time.

For the climate system the distinction between predictability of the first and the second kind is fuzzy. On the one hand, weather prediction is not related to the inverse of the Lyapunov exponent of the system, determined by the much shorter times in the turbulent boundary layer. These time scales are effectively averaged on the time scales of the flow in the free atmosphere. On the other hand, turning to climate change predictions, the time scales on which the system is considered quasi-stationary, such that the statistics can be predicted as a function of an external parameter, say atmospheric CO2, is still short in comparison to slow oceanic dynamics. On these time scales the state of these slow variables still depends on the initial conditions. This fuzzy distinction between predictability of the first and of the second kind is related to the lack of scale separation between fast and slow components of the climate system.

The non-linear nature of the problem furthermore opens the possibility of multiple attractors, or multiple quasi-steady states. As the paleoclimatic record shows, the climate has been jumping between different quasi-stationary climates. The question is: Can such tipping points be predicted? This is a new kind of predictability (the third kind). The Dansgaard-Oeschger climate events observed in ice core records are analyzed in order to answer some of these questions. The result of the analysis points to a fundamental limitation in predictability of the third kind.

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Cyclic replacements in Collapse-Driven Population Dynamics

Author(s): Kim Sneppen

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Abstract: The rate of unlimited exponential growth is traditionally used to quantify fitness of species or success of organizations in biological and economic context respectively. However, even modest growth quickly saturates any environment. I will discuss a model where redistribution driven by sudden and severe collapses of entire populations free up resources for the growth of others. The emergent property of this type of dynamics are cyclic "diversity waves" each triggered by collapse of a dominating population. In biology collapse may be disease driven, for example associated to predation of phages on their host bacteria. This suggest a density dependent variation of the above model in which phage infections give rise to abrupt and severe collapses of the largest bacterial sub.populations. In this case we predict that each bacterial population follows cyclic dynamics of exponential growth interrupted by sudden declines. Counter-intuitively this predict that microbial communities exposed to more violent perturbations should have higher diversity. In economy, the mechanism of bubbles and bursts may similarly be associated to the impact of a rare or a slow negative feedback, counteracting the positive feedback in growth of a socially successful concept. This leads us to introduce a slightly more detailed model of burst and bubbles of fashions.

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Bacteria vs. phages: the art of war among the unseen majority

Author(s): Namiko Mitarai

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Abstract: Bacteriophages are viruses that infect bacteria. A virulent phage infection to a host bacterial cell results in lysis of the cell, where possibly hundreds of phage particles are released after a latency time. When the phage is temperate, infection can also lead to lysogeny with a certain probability, where the phage genome replicates with the host doubling without killing the host. Further more, some satellite/pirate phage does not code for some proteins needed for phage particle production, but instead takes over another phage that co-infect the host. The phage pressure is believed to be an important factor to shape microbial community and a driving force of their evolution, and yet we are far from having a full picture of their warfare. In this talk, I discuss various aspects of phage-bacteria interaction that contribute to coexistence of diverse bacteria and phage.

- J.O. Haerter, N. Mitarai, K. Sneppen, Phage and bacteria support mutual diversity in a narrowing staircase of coexistence. The ISME journal 8(11):2317 (2014).
- N. Mitarai, S. Brown, K. Sneppen, Population dynamics of phage and bacteria in spatially structured habitats using phage λ and Escherichia coli. Journal of bacteriology 198(12):1783-93 (2016).
- R. S. Eriksen, S. L. Svenningsen, K. Sneppen, N. Mitarai, A growing microcolony can survive and support persistent propagation of virulent phages. PNAS 115(2):337-42 (2018).
- R. S. Eriksen, N. Mitarai, K. Sneppen, Sustainability of spatially distributed bacteria-phage systems. bioRxi:1:495671.
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Hysteretic oscillations in a well-mixed population of budding yeast

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Abstract: I will discuss the "yeast metabolic cycle", wherein budding yeast growing in a well-mixed chemostat produce incredibly regular oscillations between quiescence and proliferation which can sustain for weeks. I'll describe a simple mathematical model of a relaxation oscillator that we think captures many aspects of this oscillation. The model helps us deduce that the the key metabolite triggering the switch from quiescence to proliferation is probably Acetyl-CoA, and I will discuss some variants of this model and preliminary data that provides more details of the underlying molecular mechanism. If there is time, I'll also discuss the results of experiments and modelling of the same system grown on a 2d plate, which results in yeast cells in two different metabolic states self-organizing into a complex intermingled spatial pattern, with one state dependent on the other for metabolic raw material.

- S. Krishna and S. Laxman, A minimal "push-pull" bistability model explains oscillations between quiescent and proliferative cell states, Mol. Biol. Cell, 29, 2243–2258 (2018).
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Stucture of adaptive flow networks under load fluctuations

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Abstract: Flow networks are crucial to the functioning of natural systems and technological infrastructures. In many scenarios, such as rivers or blood vessels, acyclic networks (i.e., trees) are the most efficient (optimal) solutions to a flow with given time-independent in- and out-flows at sources and sinks. Rather than global optimization, we here apply a local adaptation rule for the dynamics of the conductances: the change of a conductance is function only of the local pressure gradient. This reproduces the tree stuctures obtained under constant in- and out-flows. Imposing fluctuations of growing amplitude, however, renders the tree unstable and gives cyclic connections a positive conductivity in a transcritical bifurcation. The type of non-linearity in the adaptation rule controls the location of cyclic structures. For a super-linear dependence on pressure gradient, cycles first appear close to the tips ("capillaries"). We discuss these theoretical results in the light of real data of mammalian vasculature.

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- E. A. Martens and K. Klemm. Cyclic structure induced by load fluctuations in adaptive transportation networks. ECMI book subseries of Mathematics in Industry (to appear) http://arxiv.org/abs/1810.10049

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Classification and Dynamics of Continuous Time Markov Chains with Applications in Reaction Networks

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Abstract: Stochastic biochemical models can be formulated in terms of a continuous time Markov chain (CTMC). This talk contributes to classification of states, (ii) sharp checkable criteria via three parameters out of graphical structure of CTMC for various dynamical properties–recurrence, transience, positive/null recurrence, (non)explosivity, (non)implosivity, (non)existence of first passage times, as well as uniform exponential ergodicity of (quasi)stationary distributions and, (iii) asymptotics of tails of stationary distributions/ quasi-stationary distributions, of a CTMC with polynomial transition rates on a one-dimensional subset of a d-dimensional non-negative integer lattice. Results are applied to stochastic reaction networks (SRNs): a recently proposed positive recurrence conjecture for weakly reversible SRNs are justified to be well-posed, and proved for SRNs with one-dimensional stoichiometric subspace.

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POSTERS

Stochastic Model Identification of a Duffing Oscillator Benchmark System

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Abstract: The richness of the available model structures and estimation approaches makes the system identification of nonlinear systems a significant challenge. The main objective of this paper to study if the prior knowledge (or the lack of it) of the system can be utilised efficiently in the identification of the nonlinear systems. Stochastic differential equations based grey-box models offer a good trade-off between the physics-based (white-box) models and data-driven statistical (black-box) models. In this paper, we identify a continuous-time stochastic grey-box model for the widely studied Duffing oscillator based on the iterative residual analysis. The benchmark data from the so-called Brussels "SilverBox" system, which is an electrical circuit mimicking the Duffing oscillator dynamics is used for this purpose. Finally, the identified model performance (the simulation errors) is compared with the existing results available in the literature.

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Localized solutions of nonlinear network wave equations

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Abstract: We study localized solutions for the nonlinear graph wave equation on finite arbitrary networks. Assuming a large amplitude localized initial condition on one node of the graph, we approximate its evolution by the Duffing equation. The rest of the network satisfies a linear system forced by the excited node. This approximation is validated by reducing the nonlinear graph wave equation to the discrete nonlinear Schrodinger equation and by Fourier analysis. Finally, we examine numerically the condition for localization in the parameter plane, coupling versus amplitude and show that the localization amplitude depends on the maximal normal eigenfrequency.

- J-G. Caputo, I. Khames, A. Knippel and A. B. Aceves. Localized solutions of nonlinear network wave equations. J. Phys. A: Math. Theor. 52, 035101 (2019). http://doi.org/10.1088/1751-8121/aaf1e6

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On the complexity of failure: A functional approach on vibration analysis for mechanical systems

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Abstract: Complexity is a trademark of failure of mechanical systems. Complex failures are characterised by a heterogeneous degradation of individual components and an altered load distribution over the components. This makes them: too complex to understand, as the altered load distributions stretch the modelling possibilities from a physics perspective at a system-wide scale, and; too complex to observe, as the available failure observations are limited quantity- and quality-wise for the construction of robust, generalizable models that assess failure proliferation. In sum, an increased understanding of the changes on load distribution is needed for the development of more effective methods to assess and even avoid failure; and, perhaps of greater importance, for the design of more reliable yet efficient mechanical systems. The assessment of complex failures is proposed through studying the behavior of failing systems. This implies direct observation of the failure behavior, and the theorizing about factors (and their interactions) that influence it.

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Bistability, hysteresis and limit cycles in networks of coupled Theta neurons

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Abstract: In computational neuroscience, the quadratic integrate-and-fire model (QIF) is a neuron model that exhibits repeated spiking depending on an input stimulus current. An equivalent formulation of this model is given by the Theta neuron or Ermentrout-Kopell model. We consider networks of Theta neurons with modular structure, i.e., the network is structured into subpopulations which mimic densely connected neural populations or neural masses. In this situation, the effective coupling within the subpopulation is then stronger than between adjacent subpopulations. Using the Ott-Antonsen method, the collective dynamics of each sub-population with (infinitely) many neurons can be exactly described by only two state variables. Here, we investigate the bifurcation structure of such a system with two such sub-populations. In the resulting four dimensional ODE system we find both symmetric and asymmetric equilibria. Asymmetric limit cycles are born via Hopf bifurcations, and may be destroyed via Hopf bifurcation, saddle node of limit cycles or homoclinic bifurcations. The resulting bifurcation curves are organized around codimension-2 bifurcations (Garilov-Guckenheimer, Bogdanov-Takens).

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- So, P., Luke, T. B., and Barreto, E. Networks of theta neurons with time-varying excitability: Macroscopic chaos, multistability, and final-state uncertainty. Physica D: Nonlinear Phenomena, (1), 1–11 (2013). https://doi.org/10.1016/j.physd.2013.04.009
- Bick, C., Goodfellow, M., Laing, C. R., and Martens, E. A. (2019). Understanding the dynamics of biological and neural oscillator networks through mean-field reductions: a review. arXiv: 1902(05307v2).

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Phase reconstruction with iterated Hilbert transforms

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Abstract: We have developed a method that allows for extraction of high-frequency components in the phase reconstructions process based on iterative reuse of the obtained phases of the analytic signal. The phase of the analytic signal gives insights to synchronization patterns and coupling properties. However, it is a main drawback of the Hilbert transform that it effectively mixes modulations of phase and amplitude such that an experimentalist will be confronted with false phase modulations in the subsequent analysis. The new approach reuses the obtained phase as the new integration variable and by this effectively demodulates amplitude and phase. The accuracy of the procedure is limited mainly by the amplitude modulation present in the signal. A preprint of our current work, including an outline of the analytic description of the method can be found here: https://export.arxiv.org/abs/1901.08774.

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Dynamic and transient stability of power grid networks

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Abstract: With the prospect of a future power grid constituted of many distributed sources, the grid is shifting into a new decentralized form, where the dynamics are not fully understood. These new units of power (such as windmills and solar cells) are often autonomous in nature, which makes it relevant to investigate how the grid behaves without active control. In my work, I adopt a model which have drawn a lot of attention in relation to the electric power system, namely the Kuramoto model which models all consumer and generator units as synchronous motors. On the basis of this model, I measure how topological features impact the dynamic and transient stability of the network. I find that distributing the power demand over many (small) generators favor dynamic stability, and a indication that grids without any articulation nodes raises transient stability

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