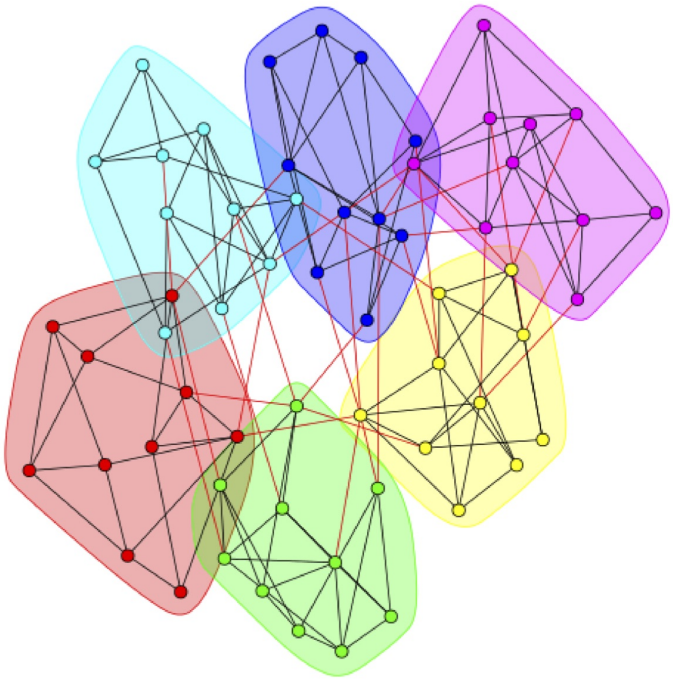

Workshop - Integrative Research:

Challenges of complex systems for technological applications

March 9 – 13, 2015, Escola Politécnica da USP, Cidade Universitária, São Paulo, SP, Brasil

ESCOLA POLITÉCNICA DA USP

UNIVERSITY OF ABERDEEN

FAPESP

BRITISH COUNCIL

Organizing Committee

Prof. Dr. José Roberto Castilho Piqueira (coordinator)
Escola Politécnica da USP - Brasil
Dr. Murilo S. Baptista (coordinator)
Universidade de Aberdeen - UK
Prof. Dr. Antonio C. Roque da Silva Filho
Universidade de São Paulo em Ribeirão Preto - Brasil
Prof. Dr. Antônio Politi
Universidade de Aberdeen - UK
Prof. Dr. Celso Grebogi
Universidade de Aberdeen - UK
Prof. Dr. Elbert E. N. Macau
Instituto Nacional de Pesquisas Espaciais - Brasil

Workshop description

The modern world is increasingly dependent upon very large, very complex interacting systems. These systems are increasingly intertwined and interdependent. This creates a complex system with complex behaviours. The main challenges in the research of complex system today are: Characterisation; Modelling; Universal behaviours of models; Control, observability, and predictability. This workshop will gather an interdisciplinary team of 6 senior researchers with expertise in one or more challenging topics, presenting keynote lectures that will target one or more of the challenges, aiming at training a critical mass of young researchers on the state-of-the-art aspects coming from the Theories of Complex Networks, Synchronisation, Information, Compressive Sensing, Control, and Evolutionary Games, and the use of this knowledge to characterise, identify, model, predict, and control realistic models of complex systems such as the brain, ecological networks, communication networks, and the power-grid. Young researchers will contribute by presenting complementary material to the keynote lectures and engaging into pro-active discussions that will not only produce new ideas to tackle each one of the 4 challenges but also to create pathways for the development of research that can deal simultaneously with more than one of the challenges. This will enable the creation of a Brazilian-UK research network that can in the short and long-term understand how to carry out integrative research in complex systems. In a near future, the participants of this workshop will be able to do integrative research on the challenges of complex systems.

EVENT LOCATION: Escola Politécnica da USP
'Prédio do Biênio e Cirquinho'
Av. Prof. Luciano Gualberto, travessa 2, nº128
CEP 05508-070 São Paulo, SP
Cidade Universitária, São Paulo, SP

General Information

PROGRAM

Agenda for the workshop

Research session 1 and 2: participants will be split in 3 groups of roughly 13 people. Relevant research works will be the initial basis for the discussions with the leading senior researcher at the room. Discussions should aim at establishing the new directions to the proposed themes.

Research session 3 and 4: participants will be split in 3 groups of roughly 13 people. Relevant research works will be the initial basis for the discussions with the leading senior researcher at the room. Discussions should aim at creating new ideas to carry out integrative inter-intra disciplinary research in complex systems to tackle more than one of the challenges of the workshop.

Networking session: participants will be split in groups of roughly 6 people. Networking will be driven by discussions related to one of the 4 challenges proposed in this workshop (characterisation, modelling, universal behaviours, control). In each group, people will introduce themselves, give a brief description of their main research interest, and how their research could be used to solve the challenges being proposed in the workshop.

Sunday - Arrival (08/03/2015)

17:00 - 19:00

Registration, and reception of participants by coordinators and mentors.

19:00 - 21:00

Dinner

Day 1 workshop (Monday, 09/03/2015)

09:15 - 09:45

Opening ceremony

09:45 - 10:30

Keynote lecture by Prof C. Grebogi, “Compressive Sensing Based Prediction of Complex Dynamics and Complex Networks”

10:30 - 11:15

Keynote lecture by Prof J. R. Piqueira, “Measuring complexity”

11:15 - 11:35

Coffee break

11:35 - 12:35

Contributed talks

11:35 - 11:50

Francisco Aparecido Rodrigues, “Centrality and dynamical processes on complex networks”

11:50 - 12:05

Nicolás Rubido, “The modern power-grids from a complex system perspective”

12:05 - 12:20

Diego Paolo Ferruzzo Correa, “Bifurcation and stability in time-delayed fully connected oscillator networks with symmetry”

12:20 - 12:35

Ioana Pisica, “Wide Area Monitoring of Power Systems - Challenges and performance evaluation”

12:35 - 14:00

Lunch Break

14:00 - 15:00

Contributed talks

14:00 - 14:15

Tomislav Stankovski, “Universality of coupling functions: from biology to secure communications”

14:15 - 14:30

Marcos G. Quiles, “Community Detection via Particle Dynamics”

14:30 - 14:45

Marcio Porto Basgalupp, “A Hyper-Heuristic Evolutionary Algorithm for Automatically Designing Decision-Tree Algorithms”

14:45 - 15:00

André Alves Ferreira, “Chaotic oscillator circuits together PLLs for information encoding and decoding”

15:00 - 15:15

Kyle Wedwood, “Coarse grained analysis of patterned activity in a minimal neural network”

15:15 - 15:30

Sandro Perrone, “Computational model of a planar mea for cortical neuronal culture”

15:30 - 15:45

Robert Merrison-Hort, “Using computational modeling to understand the neuronal circuitry of the tadpole spinal cord”

15:45 - 16:00

Helmut Schmidt, “The role of networks in idiopathic generalised epilepsy”

16:00 - 16:30

Coffee break

16:30 - 17:30

Research Session 1

Room 1: Led by Prof C. Grebogi and Dr M. S. Baptista. Topic: “Evolutionary Game Theory in Multilayered Networks”

Room 2: Led by Prof A. Politi and Dr A. C. Roque. Topic: “Collective Behaviour in Neural Networks”

Room 3: Led by Prof J. R. Piqueira and Dr E. Macau. Topic: “Synchronisation in Communication Networks”

17:30 -

To hotel, followed by dinner

Day 2 workshop (Tuesday, 10/03/2015)

09:00 - 09:30

Overview by Camila Morsch (Senior Manager of Newton Fund in Brazil) of the research base and funding opportunities: a brief introduction to the research base in the UK and the Newton Fund - how research is funded, size, strengths, international collaborative activity, links with industry.

09:30 - 10:15

Keynote lecture by Dr M. S. Baptista, "The physics of information transmission in complex systems and applications"

10:15 - 11:00

Keynote lecture by Dr E. E. Macau, "Adaptive node-to-node pinning control of complex networks".

11:00 - 11:30

Coffee break

11:30 - 12:15

Contributed talks

11:30 - 11:45

Marcio Eisencraft, "A Practical Discrete-time Chaos-based Communication System"

11:45 - 12:00

Alasdair Clarke, "Failure of intuition when presented with a choice between investing in a single goal or splitting resources between two goals"

12:00 - 12:15

Mikko Kivelä, "multilayer Networks, multiplex networks and triadic structures in them"

12:15 - 13:45

Lunch Break

13:45 - 15:45

Research Session 2

Room 1: Led by Dr E. Macau and Prof J. C. Piqueira. Topic: "Stability of synchronisation in delay-coupled complex networks"

Room 2: Led by Dr M. S. Baptista and Prof Celso Grebogi. Topic: "Chaos-based communication"

Room 3: Led by Prof A. Politi and Dr A. C. Roque. Topic: "Collective Behaviour in Cortical Networks"

15:45 - 16:15

Coffee break

16:15 - 17:30

Networking session

17:30 -

To hotel and dinner

Day 3 workshop (Wednesday, 11/03/2015)

09:00 - 09:30

Overview by FAPESP Representative of the research base and funding opportunities: a brief introduction to the research base in São Paulo and Brazil - how research is funded, size, strengths, international collaborative activity, links with industry.

09:30 - 10:15

Keynote lecture by Dr A. C. Roque, "Realistic model of the hippocampus dentate gyrus: role of cell morphology".

10:15 - 11:00

Keynote lecture by Prof A. Politi, "Characterizing complex dynamics".

11:00 - 11:30
Coffee break
11:30 - 12:30
Contributed talks
11:30 - 11:45
Ulysses Sengupta, "Parallel computation and big data for complex smart cities"
11:45 - 12:00
Deljana Iossifova, "Cities as a complex adaptive evolving system"
12:00 - 12:15
Reuben O'Dea, "Network structure and activation - Simulation and analyses"
12:15 - 12:30
Christos Antonopoulos, "Do brain networks evolve by maximizing their information flow capacity?"
12:30 - 14:00
Lunch Break
14:00 - 17:00
Networking in the Brazilian cultural background
18:00 - 22:00
Conference dinner
Day 4 workshop (Thursday, 12/03/2015)
09:30 - 11:00
Contributed talks
09:30 - 09:45
Thiago Brito, "Agent-Based Simulation applied to Container Terminal Operations Management"
09:45 - 10:00
Antônio Mário de Torres Ramos, "Applications of Conditional Mutual Information: Causality Network Between Different Climate Systems"
10:00 - 10:15
Theodore Papamarkou, "EWS-FLI1 employs an E2F switch to drive target gene expression"
10:15 - 10:30
Leonardo Paulo Maia, "Optimal channel efficiency in a sensory network"
10:30 - 10:45
Yoshikatsu Hayashi, Nature of mutual anticipation from behaviour to brain"
10:45 - 11:00
Linda Sommerlade, "Estimating networks from neural signals"
11:00 - 11:30
Coffee break
11:30 - 11:45
Contributed talks
11:45 - 12:00
Diego Colón, "Polynomial Chaos and Its Applications in Linear and Nonlinear Dynamical Systems"
12:00 - 12:15
James Ing, "Modelling, parameter fitting and characterisation of oilwell drilling applications"
12:15 - 14:30
Lunch Break

14:00 - 15:30

Contributed talks

14:30 - 14:45

Andreia Nalu Soares Hisi, "The phase transition of a SIRS Infectious disease model on structured populations"

14:45 - 15:00

Davoud Taghawinejad, "ABCE a python agent-based modelling platform"

15:00 - 15:15

Renato Candido, "Do chaos-based communication systems really transmit chaotic signals?"

15:15 - 15:30

Kelly Cristiane Iarosz, "Interactions among neuronal cells and glioma with a chemotherapic treatment"

15:30 - 16:00

Coffee break

16:00 - 17:30

Research Session 3

Room 1: Led by Dr M. S. Baptista and Dr E. E. Macau. Topic: "Inter disciplinary research in informational-based inference and modelling identification of complex systems"

Room 2: Led by Dr A. C. Roque and Prof C. Grebogi. Topic: "Intra disciplinary research in data-based modelling and prediction of complex systems for applications in ecological systems and animal behaviour"

Room 3: Led by Prof A. Politi and Dr J. C. Piqueira. Topic: "Inter disciplinary research in Physics and Engineering."

17:30

to hotel, followed by dinner

Day 5 workshop (Friday, 13/03/2015)

09:00 - 11:00

Research Session 4

Room 1: Led by Dr M. S. Baptista and Dr E. E. Macau. Topic: "The modern power-grid, an example of a case study for the intra study of synchronisation, information transmission, and the control of interdependent multilayer networks"

Room 2: Led by Dr A. C. Roque and Prof A. Politi: "The brain, an example of a case study for the intra study of data-based modelling and prediction of behaviour in complex systems"

Room 3: Led by Prof C. Grebogi and Dr J. C. Piqueira. Topic: "Inter-disciplinary research: The engineering and the physical aspects of complex systems"

11:00 - 11:30

Plenary discussion session (everybody present) about the inter and intra disciplinary research ideas being proposed in Research sessions 3 and 4.

11:30 - 12:30

Lunch Break

12:30 - 13:30

Plenary discussion session about how the knowledge shared or produced in this workshop can actively contribute to the economic development and social welfare of Brazil and lead to positive impact on the lives of people on low income and within a reasonable timeframe (3-15 years)?

13:30 - 13:45

Closing remarks and end of workshop

ABSTRACTS

Failure Of Intuition When Presented With A Choice Between Investing In A Single Goal Or Splitting Resources Between Two Goals

Alasdair D. F. Clarke, A. R. Hunt
School of Psychology, University of Aberdeen, UK

We face many competing demands on our attention in our daily life and regularly have to divide our time and attention between different tasks. Morgan and Maloney (2012) recently demonstrated a fundamental failure in human observers to direct saccades to the location that maximises their accuracy. In their study, participants must chose whether to split their visual attention between two equally likely potential target locations, or prioritise one location at the expense of the other. When the target locations are close to one another, the best strategy is to fixate in-between them. As the distance increases beyond the point where participants can discriminate the target accurately, they should switch strategy and focus on one potential location at the expense of the other. We present a series of experiments that replicate this finding in a larger sample, and demonstrate that the results are not particular to the human saccadic system, and exist in tasks involving throwing and memory.

Chaotic oscillator circuits together PLLs for information encoding and decoding

André Alves Ferreira
Universidade Estadual Paulista - UNESP

Connected oscillators systems and circuits with chaotic behavior are present in innumerable natural processes; therefore, the study and comprehension of these systems became an essential part of the contemporaries' technology and sciences. In one hand the telecommunications systems wide use the electronic oscillator synchronism, being the system efficiency related with the synchronism stability. In the other hand, the communication security needs to increase more and more every day.

The phase transition of a SIRS infectious disease model on structured populations

Andreia Nalu Soares Hisi
Instituto Nacional de Pesquisas Espaciais – INPE

Here we simulate disease spreading by means of a mechanistic stochastic model. We systematically explore different network size, probability of traveling among subpopulations and mobility network topology, reconstructing the phase space of pathogen persistence and the dynamics out of the equilibrium. We consider a susceptible-infected- recovered-susceptible model (with a certain rate, recovered individuals lose immunity to the disease and return susceptible) on a metapopulation system where individuals are distributed in subpopulations connected with a network of mobility flows.

Applications of Conditional Mutual Information: Causality Network Between Different Climate Systems.

Antônio Mário de Torres Ramos
Instituto Nacional de Pesquisas Espaciais - INPE

We intend to construct a network of meteorological influence between different regions of the Amazon and its surrounding climate systems. The network should display directional links based on a framework that comprise statistical and information theory approaches. For instance, the directional links between different regions can be set using the multivariate transfer entropy applied with conditional mutual information.

CHARACTERIZING COMPLEX DYNAMICS

Antonio Politi
Institute for Complex Systems and Mathematical Biology
King's College, University of Aberdeen
Aberdeen AB24 3UE, UK

I start with a brief introduction of the basic concepts of deterministic chaos. This includes a definition of the Lyapunov exponents (and of their fluctuations) of fractal dimensions, and of their relationship. Next, I analyse the concept of extensivity, which applies to standard spatially extended systems, as well as to networks of various types (in the presence of either sparse or massive coupling). More specifically, I introduce the notion of entropy potential and revisit the Kolmogorov-Sinai entropy in a space-time context. Then the convective Lyapunov exponents are introduced as a tool to explore the propagation of perturbations in complex systems. Finally, some basic elements of collective dynamics are discussed.

COMPRESSIVE SENSING BASED PREDICTION OF COMPLEX DYNAMICS AND COMPLEX NETWORKS

Celso Grebogi
Institute for Complex Systems and Mathematical Biology
King's College, University of Aberdeen
Aberdeen AB24 3UE, UK

In the fields of complex dynamics and complex networks, the reverse engineering, systems identification, or inverse problem is generally regarded as hard and extremely challenging mathematically as complex dynamical systems and networks consists of a large number of interacting units. However, our ideas based on compressive sensing, in combination with innovative approaches, generates a new paradigm that offers the possibility to address the fundamental inverse problem in complex dynamics and networks. In particular, in this talk, I will argue that evolutionary games model a common type of interactions in a variety of complex, networked, natural systems and social systems. Given such a system, uncovering the interacting structure of the underlying network is key to understanding its collective dynamics. Based on compressive sensing, we develop an efficient approach to reconstructing complex networks under game-based interactions from small amounts of data. The method is validated by using a variety of model networks and by conducting an actual experiment to reconstruct a social network. While most existing methods in this area assume oscillator networks that generate continuous-time data, our work successfully demonstrates that the extremely challenging problem of reverse engineering of complex networks can also be addressed even when the underlying dynamical processes are governed by realistic, evolutionary-game type of interactions in discrete time.

[1] Network reconstruction based on evolutionary-game data via compressive sensing, W.-X. Wang, Y.-C. Lai, C. Grebogi, and J. Ye, Phys. Rev. X 1, 021021 (2011)

[2] Predicting catastrophe in nonlinear dynamical systems by compressive sensing, W.-X. Wang, R. Yang, Y.-C. Lai, V. Kovanis, and C. Grebogi, Phys. Rev. Lett. 106, 154101 (2011)

[3] Forecasting the future: Is it possible for adiabatically time-varying nonlinear dynamical systems? R. Yang, Y.-C. Lai, and C. Grebogi, Chaos 22, 033119 (2012)

[4] Optimizing controllability of complex networks by minimum structural perturbations, W.-X. Wang, X. Ni, Y.-C. Lai, and C. Grebogi, Phys. Rev. E 85, 026115 (2012)

DO BRAIN NETWORKS EVOLVE BY MAXIMIZING THEIR INFORMATION FLOW CAPACITY?

Ch. G. Antonopoulos[1], *S. Srivastava*[1], *S. S. Pinto*[2], *M. S. Baptista*[1]
[1]*Department of Physics (ICSMB), University of Aberdeen, United Kingdom*
[2]*Departamento de Física, Universidade Estadual de Ponta Grossa, Brazil*

In this talk I will present a working hypothesis supported by numerical simulations that brains evolve based on the principle of the maximization of their internal information flow capacity. We have found that synchronous behavior and capacity of information flow of the evolved networks reproduce well the same behaviors observed in the brain dynamical networks of Caenorhabditis elegans and humans, networks of Hindmarsh-Rose (HR) neurons with a graph given by these brains. I will then discuss on the verification of our hypothesis by showing that HR neural networks evolved with coupling strengths that maximize information flow capacity are those with the closest graph distance to the brain networks of Caenorhabditis elegans and humans. Finally, I will demonstrate that global neural synchronization levels decrease during brain evolution, reflecting on an underlying global no Hebbian-like evolution process, which is driven by no Hebbian-like learning behaviors for some of the clusters during evolution, and Hebbian-like learning rules for clusters where neurons increase their synchronization.

ABCE a python agent-based modelling platform

Davoud Taghawinejad
Universidade de São Paulo - USP

ABCE is a Python Agent-Based Complete Economy Platform, written by Davoud Taghawi-Nejad. With ABCE, you can write economic, agent-based simulations in python. ABCE handles, trading production an consumption automatically. The agents, written by the modeler do only have to make the decisions and instruct the platform to trade, produce and consume. ABCE makes sure the economy is closed, that means no goods appear, disappear or are otherwise unaccounted for. It is therefore particularly useful for macro models.

CHANGING CITIES: INFRASTRUCTURE AS PROCESS

Deljana Iossifova
University of Manchester, UK

This paper explores closely linked processes of urban restructuring, initially in China: rural-to-urban migration, urban redevelopment (including demolition and resettlement) and the ‘worlding’ of cities. It combines qualitative and quantitative methods of data collection and analysis in the transcalar study of sociospatial change. It traces changing sanitation infrastructure in the context of sociospatial transformation in a splintered urban neighborhood between old and new in Shanghai. Building on observation and interviews, it outlines the varying sanitation-related practices among different social groups and how they are embedded within other patterns of everyday life. It asks if and how a complexity science framework can be used to capture and understand the patterns and processes of sociospatial transformation. Can this process-based approach provide the basis for new theorizations of ‘infrastructure’ as a context-specific as well as comparable process of urbanization and sociospatial changes over time?

Polynomial Chaos and Its Applications in Linear and Nonlinear Dynamical Systems

Diego Colón
Universidade de São Paulo - USP

We present the method of polynomial chaos (MPC) to solve general (linear and nonlinear) systems of differential equations (DE) with parameters that are random variables or stochastic processes, and present some examples and applications of the method for practical problems. The MPC consists in transforming a system of stochastic DE (that could be ordinary or partial) into a larger set of deterministic equations by supposing that the random variables in the system (parameters) can be expanded in a orthogonal polynomial basis (like Hermite and Legendre polynomials) according to the probability measure. The system's solution can also be expanded in a Fourer-like series (in the polynomial basis) and the resulting deterministic DE are equations for the Fourier coefficients. The polynomial expansion must be truncated and the deterministic equations are solved by traditional numerical methods. This method presents in general faster convergence, if compared to the Monte Carlo methods. In particular, the method can be used to evaluate robustness of nonlinear closed loop control systems, in which the traditional linear methods (based in Functional Analysis) cannot be applied.

Bifurcation and stability in time-delayed fully connected oscillator networks with symmetry

Diego Paolo Ferruzzo Correa
Universidade de São Paulo - USP

Bifurcations in delayed differential equations (DDEs) and their stability are well studied problems mainly due to its importance in many engineering problems. In a N-node fully-connected time-delayed oscillator network, for critical values of the parameters, bifurcations emerge naturally changing the nature of the solutions. Due to the network symmetry it is possible to decompose the infinite-dimensinal space into two irreducible representations; these representations are use to find symmetry-preserving and symmetry-breaking Hopf bifurcations. The Center Manifold theorem extended to delayed differential equation is used to compute stability of simple symmetry-preserving Hopf bifurcations. Although we explore second-order PLL oscillators, results are extendable to higher order nodes.

Centrality and dynamical processes on complex networks

Francisco Aparecido Rodrigues
Universidade de São Paulo - USP

One of the most interesting challenges in network science is to understand the relation between the structure of the system and its emergent dynamical properties. Particularly, network centrality plays a fundamental role on the evolution of dynamical processes, such as epidemic spreading and synchronization. For instance, since the most central nodes can diffuse their influence to the whole network faster than the rest of nodes, it is expected that such agents are the most influential spreaders. In addition, recent works have verified that an explosive synchronization can be observed in scale-free networks when Kuramoto oscillators have natural frequencies correlated with the local centrality. In this presentation we will discuss some results concerning the identification of the most influential spreaders in networks and the influence of centrality on the emergence of synchronization. We will show that a new centrality measure called accessibility can identify the most influential spreaders in networks. In addition, we will demonstrate that the emergence of synchronization is considerably influenced by a positive correlation between intrinsic dynamics and local topology of each oscillator. The role of centrality in several applications will also be discussed.

THE ROLE OF NETWORKS IN IDIOPATHIC GENERALISED EPILEPSY

Helmut Schmidt[1], *G. Petkov*[1], *M. Richardson*[2], *J. Terry*[1]
[1]*University of Exeter, Exeter, UK*
[2]*King's College London, London, UK*

Epilepsy is a complex dynamic disease, which affects approximately one per cent of the world's population. It is characterised by recurrent seizures, with seizure rates varying between a few seizures per year to multiple seizures per day, depending on the syndrome. Recent studies using different imaging techniques have demonstrated that both functional and structural networks are implicated in persons with idiopathic generalised epilepsy. However, without a modelling approach it is not clear how networks can facilitate seizure activity, and whether they play a critical role in the emergence of seizures. Seizures may be understood as the synchronisation of large areas of cortex beyond levels required for information processing, thus giving rise to large amplitude oscillations as seen in EEG and other imaging modalities. We use a model of phase-coupled oscillators on modular networks to describe large-scale brain activity. We show that within modular networks two distinct mechanisms may drive the emergence of synchrony at the global level. We term the first of these mechanisms 'network-driven synchrony', which is facilitated by the presence of cycles (recurrent connections) within the network. The second mechanism we term 'node-driven', which is characterised by the ability of an individual node (or nodes) to drive synchrony across the rest of the network. By applying this framework to functional networks derived from routine clinical EEG recordings from people with idiopathic generalised epilepsy and from age matched healthy controls, we demonstrate that brain networks of persons with epilepsy have a greater tendency to synchronise than do brain networks of healthy controls. This finding demonstrates a critical role for network structure in the tendency to have seizures.

WIDE AREA MONITORING OF POWER SYSTEMS – CHALLENGES AND PERFORMANCE EVALUATION

M. Golshani, Ioana Pisica, G. A. Taylor
Department of Electronic and Computer Engineering, Smart Power Networks, Brunel University London, UK

The concept of collecting real-time measurements extensively throughout electricity transmission networks provides the possibility to operate and manage such systems more efficiently and securely. In this respect, a Wide Area Monitoring System (WAMS) can enable improvement in the supervision, operation, control and protection of transmission systems. Conventional data acquisition systems are not effectively designed for such real-time smart grid applications, due to the typically low measurement rates of the order of seconds and lack of accurate time synchronization. WAMS will be vital in the operation of future Smart Grids, where the need to instantly detect problems and react swiftly to a wide range of technical issues will become far more crucial in order to deliver secure and reliable electrical power. In this regard, a system has been developed by Psymetrix in order to perform continuous analysis of the dynamics of the Great Britain (GB) transmission system. This system is running the PhasorPoint application to monitor the inter-area modes and detect any oscillations between England and Scotland. Critical to the operation of such systems is a robust and secure communication infrastructure; with the performance of communications links between Phasor Measurement Units (PMUs) and Phasor Data Concentrators (PDCs) or local control systems having a direct impact on the ability to meet specific monitoring and control requirements. By employing simulations through a model developed in OPNET Modeler, the characteristics of communication delays and bottlenecks that can occur in WAMS can be determined.

MODELLING, PARAMETER FITTING AND CHARACTERISATION OF OILWELL DRILLING APPLICATIONS

James Ing
Centre for Applied Dynamics Research, School of Engineering, University of Aberdeen, UK

During oilwell drilling, various vibrations of the drillstring can occur which are detrimental to the drilling process. These include stick-slip, a severe form of torsional vibration, axial vibration, also known as bit bounce, and lateral vibration and whirling. All of these involve some form of non-smoothness due to the formation and drill-bit interaction during the cutting process, and intermittent contact with the wellbore due to bit bounce or torsional buckling of the drill-string. Various attempts have been made by engineers to model these processes; various phenomenalogical models exist, as well as integrated multi degree of freedom models. The drawbacks of both of these types of approach will be outlined. In essence, models fail to be predictive due to high parameter sensitivity in non-smooth systems, and a lack of downhole data and reliable parameter estimation. Some preliminary results attempting to address this will be presented.

Interactions among neuronal cells and glioma with a chemotherapic treatment

Kelly Cristiane Iarosz
Universidade de São Paulo - USP

In recent years, it became clear that a better understanding of the interactions among the main elements involved in the cancer network is necessary for the treatment of cancer and the suppression of cancer growth. In this work we propose coupled differential equations for a tumour model. We have analysed the effect of a control on the glioma, we have verified the possibility of the tumour growth to be controlled, and identified values of the parameters for which the inhibition of the glioma growth is obtained with a minimal loss of healthy cells.

COARSE GRAINED ANALYSIS OF PATTERNED ACTIVITY IN A MINIMAL NEURAL NETWORK

Kyle C. A. Wedgwood, D. Avitabile
School of Mathematical Sciences, University of Nottingham

Certain neural systems perform computation through patterned activity: persistent localised activity, in the form of bumps has been linked to working memory, whilst the propagation of activity in the form of waves has been associated with binocular rivalry tasks. The assumption of infinitely fast synapses allows for the replacement of firing patterns with firing rates, resulting in a neural field model that is amenable to perturbative analysis. This description of the network averages out fluctuations in both space and time ignoring these small-scale effects. Our aim is to perform analysis on a network that retains these effects, but whose large-scale behaviour can be predicted in an analogous way to neural field models. We present analysis of a network of non-locally pulse-coupled three-state neurons whose transitions are probabilistic, so that the network can be realised as a Markov chain. By first ignoring the stochastic effects and considering a network of infinitely many neurons, we demonstrate the existence of bump and wave states in terms of the synaptic current profile. We then go on to show how coarse-grained analysis can be used to construct bifurcation diagrams for the network when these limits are relaxed and demonstrate how these can be used to reduce the complexity of the dynamics. Recasting the Markov chain as a dynamical system defined over sets of neurons sharing the same state, we show how to perform stability calculations so that we make concrete predictions about observed states in the network. By analysing the network through this lens, we achieve a significant reduction in the complexity of the network. Through coarse-grained analysis, we can connect the fine and coarse scales of our model, and demonstrate that these states persist as we move away from the limit of infinitely many neurons, so that that finite-size effects are not sufficient to disrupt these phenomena. Finally, we now reinstate the random fluctuations in the model, and we perform existence and stability calculations using the equation-free method.

We find that coherent network states are robust to the inclusion of these noise sources, but also find bifurcations between distinct states as the strength of the stochastic processes on the network dynamics is varied. These results show that our multi-scale approach can be used to perform analysis at a coarse scale, whilst respecting fine scale fluctuations. This can potentially provide an avenue for analysing models of biological networks that respect their underlying biophysical complexity. Future work will investigate network structures that are informed by experiments on real neural networks.

Optimal channel efficiency in a sensory network

Leonardo Paulo Maia
Universidade de São Paulo - USP

We report computational studies that strongly suggest that a stimulus-free feature rules the behavior of an important psychophysical measure of the sensibility of a sensory system to a stimulus, the so-called dynamic range. We show that the entropy of the distribution of avalanche lifetimes always accompanies the dynamic range in the benchmark model for sensory systems. By simulating the Kinouchi-Copelli model on two broad families of model networks, we generically observed that both quantities always increase or decrease together as functions of the average branching ratio and that the information efficiency typically exhibits critical optimization jointly with the dynamic range. We rely on data collapses as robust signatures of criticality to claim that critical optimization may happen even when the distribution of avalanche lifetimes is not a power law, as suggested by a recent experiment. Finally, we note that the entropy of the size distribution of avalanches does not always follow the dynamic range and the information efficiency when they are critically optimized, despite being more widely used than the latter to describe the computational capabilities of a neural network.

ESTIMATING NETWORKS FROM NEURAL SIGNALS

Linda Sommerlade[1,2], *C. Wischik*[3], *B. Schelter*[1,2,3]
[1]*Institute for Complex Systems and Mathematical Biology, University of Aberdeen, UK*
[2]*Institute for Pure and Applied Mathematics, University of Aberdeen, UK*
[3]*TauRx Therapeutics Ltd, UK*

Inferring interactions between processes promises deeper insights into mechanisms underlying network phenomena, e.g. in the neurosciences where the level of connectivity in neural networks is of particular interest. We use renormalized partial directed coherence as a measure for Granger causality to reconstruct networks from data. Two main challenges that are common in applications are observational noise and non-stationarity. We discuss state space modelling as an approach to deal with both. An application to electroencephalogram (EEG) data will complement the investigations.

A Practical Discrete-time Chaos-based Communication System

Marcio Eisencraft
Universidade de São Paulo – USP

In this work, I review a discrete-time chaos-based communication system adapted to obtain reasonable performance in non-ideal channels. Its behavior in scenarios involving bandwidth limitation and noise is accessed bearing in mind the viability of the proposed scheme. Present issues and future researches are discussed.

A Hyper-Heuristic Evolutionary Algorithm for Automatically Designing Decision-Tree Algorithms

Marcio Porto Basgalupp
Universidade Federal de São Paulo - UNIFESP

Decision tree induction is one of the most employed methods to extract knowledge from data, since the representation of knowledge is very intuitive and easily understandable by humans. The most successful strategy for inducing decision trees, the greedy top-down approach, has been continuously improved by researchers over the years. This work, following recent breakthroughs in the automatic design of machine learning algorithms, proposes a hyper-heuristic evolutionary algorithm for automatically generating decision-tree induction algorithms, named HEAD-DT. We perform extensive experiments in 20 public data sets to assess the performance of HEAD-DT, and we compare it to the traditional decision-tree algorithms C4.5 and CART. Results show that HEAD-DT can generate algorithms that significantly outperform C4.5 and CART regarding predictive accuracy and F-Measure.

Community Detection via Particle Dynamics

Marcos G. Quiles
Universidade Federal de São Paulo – UNIFESP

Communities are present in most complex networks in nature and detecting them is still a big challenge for researchers. Here, we introduce a new method for detecting communities by using a particle dynamical model. In our model, each vertex in the network is represent by a particle inserted into a virtual Euclidean space, named spatial representation. By using the network structure in association with the spatial representation, we define the model's dynamics by means of two interactions types: the first is related to the network structure and it is responsible for approaching particles representing neighbor vertices. The proposed model guarantees that particles associated to adjacent vertices become closer into the particle space. At the same time, unrelated hubs repel each other allowing the formation of group of particles, which represents the communities. Simulation results demonstrate that our model can, accurately, detect community in benchmark and real networks, outperforming state-of-art community detection methods. Additionally, as shown in simulations, our model can be applied to perform community detection in time-varying networks due to its natural dynamics.

MULTILAYER NETWORKS, MULTIPLEX NETWORKS AND TRIADIC STRUCTURES IN THEM

Mikko Kivelä
Oxford Centre for Industrial and Applied Mathematics,Mathematical Institute, University of Oxford, Oxford OX1 3LB, UK

In this talk I will first briefly introduce the general frameworks of "multilayer networks" that we recently developed to represent networks where the nodes and edges are organized on "layers" [1,2]. Multilayer networks can be used to represented a wide variety of networks such as interconnected networks, node-colored networks, and multiplex networks [1]. In the rest of the talk I will concentrate on using a multilayer network framework to study triadic structures in multiplex networks. The clustering coefficient, i.e., the ratio of closed triplets to connected triplets, is a well-known triadic structural measure in network science and it has been previously generalized for weighted networks and directed networks. Until recently, the only method to study clustering in multiplex networks was either to calculate the clustering coefficient in each layer separately or to aggregate the edges in all layers together with a procedure that yields a weighted network and calculate a weighted clustering coefficient. The clustering coefficient can be naturally generalized for multiplex networks by generalizing the concept of a walk for multiplex networks [3]. This approach lead us to identify several different types of multiplex triangles which we called "elementary cycles", and allowed us to decompose a weighted clustering coefficient into contributions of these elementary cycles. We

then applied the resulting multiplex clustering coefficient to multiplex social networks and transportation networks and showed that even though both of these types of networks have similar clustering in the aggregated network level they have different types of multiplex triangular structures. This talk is based on work done in collaboration with the authors of Refs. [1-3].

[1] Multilayer networks, M. Kivelä, A. Arenas, M, Barthelemy, J. P. Gleeson, Y. Moreno, M. A. Porter, Journal of Complex Networks, 2(3): 203-271 (2014)

[2] Mathematical Formulation of Multilayer Networks, M. De Domenico, A. Solé-Ribalta, E. Cozzo, M. Kivelä, Y. Moreno, M. A. Porter, S. Gómez, A. Arenas, Phys. Rev. X 3, 041022 (2013)

[3] Structure of Triadic Relations in Multiplex Networks, E. Cozzo, M. Kivelä, M. De Domenico, A. Solé, A. Arenas, S. Gómez, M. A. Porter, Y. Moreno, arXiv:1307.6780

THE PHYSICS OF INFORMATION TRANSMISSION IN COMPLEX NETWORKS AND APPLICATIONS

Murilo S. Baptista
Institute for Complex Systems and Mathematical Biology
King's College, University of Aberdeen
Aberdeen AB24 3UE, UK

The amount of information exchanged per unit of time between two nodes in a dynamical network or between two data sets is a powerful concept for analysing complex systems. This quantity, known as the mutual information rate (MIR), is a fundamental quantity in science. Its maximal value gives the information capacity between any two sources of information (no need for stationarity, statistical stability, memoryless). Therefore, alternative approaches for its calculation or for the calculation of bounds of it are of vital relevance. In this talk, I will show a simple alternative way to calculate the MIR in dynamical networks or between two time-series, and to calculate its upper and lower bounds without having to calculate probabilities, but rather in terms of well known and well defined quantities (e.g. Lyapunov exponents, expansion rates, and dimensions) in dynamical systems. As I will show, the equations from which these quantities can be calculated offer a simple way to explain the relationship among information, synchronisation, network topology, time recurrences, and the correlation decay in complex systems. I will then discuss how to link the topological properties of phase space partitions constructed from observations to determine the causality between two time-series, i.e. the direction and the intensity of the flow of the information between them. To illustrate the applicability of these previously described theoretical approaches, I will briefly describe our current group's research (http://homepages.abdn.ac.uk/murilo.baptista/pages/) to infer the connecting topology of complex networks, to model the symbolic language of the DNA, to evolve neural networks that have similar topologies than the ones found in the Brain, to communicate wirelessly and securely, and to understand and quantify how much information is actually transmitted in the different neural codes.

THE MODERN POWER-GRIDS FROM A COMPLEX SYSTEM PERSPECTIVE

Nicolás Rubido[1,2]*, C. Grebogi*[2]*, and M. S. Baptista*[2]
[1]*Universidad de la República, Instituto de Física Facultad de Ciencias, Uruguay*
[2]*University of Aberdeen, King's College, Institute for Complex Systems and Mathematical Biology, U.K*

The complex system perspective allows us to tackle the problems of understanding how the energy is transmitted and distributed in power-grids (i.e., the network of power-lines connecting generators, such as power-plants, with consumers, such as factories) as well as in determining how robust this transmission and distribution is when modifications in the grid (e.g., due to intended attacks or natural grid expansions) or power (e.g., failures in power-plants or transmission lines) happen. The main outcome we find from following this perspective is the derivation of explicit relationships between the structure of the grid, namely, the underlying network of power-lines, the optimal transmission and distribution of energy, namely, the supply meeting the demand, and the dynamical behaviour of the

systems composing the power-grid. In this talk, I am going to stress the importance of having such relationships and make an overview of our main results.

Do chaos-based communication systems really transmit chaotic signals?

Renato Candido
Universidade de São Paulo - USP

Many communication systems based on the synchronism of chaotic systems have been proposed as an alternative spread spectrum modulation that improves the level of privacy in data transmission. However, depending on the map and on the encoding function, the transmitted signal may cease to be chaotic. Therefore, the sensitive dependence on initial conditions, which is one of the most interesting properties for employing chaos in telecommunications, may disappear. In this work, we numerically analyze the chaotic nature of signals modulated using a system that employs the Ikeda map. Additionally, we propose changes in the communication system in order to guarantee that the modulated signals are in fact chaotic.

NETWORK STRUCTURE AND ACTIVATION – SIMULATION AND ANALYSES

Reuben D. O'Dea
Centre for Mathematical Medicine and Biology, University of Nottingham, UK

The effective modelling, prediction and control of complex networks is key to a wide range of fields, from systems biology to industy. I will briefly summarise the results of some recent projects concentrating on the analysis and simulation of network activation, with a specific focus on how network stucture can affect the dynamics of processes which occur upon them. In particular, I will present a new continuum analysis of activation propagation in a discrete lattice, a study of optimal flow through a congestible network, and a geometric network model of grey-matter connectivity in the human cortex.

USING COMPUTATIONAL MODELLING TO UNDERSTAND THE NEURONAL CIRCUITRY OF THE TADPOLE SPINAL CORD

Robert Merrison-Hort, R. Borisyuk
School of Computing and Mathematics, Plymouth University, Plymouth, UK

The spinal cord of young Xenopus tadpoles contains a complex network of a few thousand neurons. From a very early age this network is capable of producing several behaviours, such as swimming and struggling, which allow animals to escape predators. Our work involves building computational models of the growth of the spinal cord and its dynamic behaviour, in order to try to understand which features of development are important in order to be able to produce given behaviours. In my talk I will present an overview of our work, and demonstrate how a remarkably simple model for axonal growth can produce functional networks that produce useful behaviours in a similar way to the spinal cords of real tadpoles.

COMPUTATIONAL MODEL OF A PLANAR MEA FOR CORTICAL NEURONAL CULTURE

Sandro Perrone[1], *A. B.A. Capurro*[1], *P. Balino*[1], *T. Pierce*[2], *M. Giugliano*[3], *R. Luthi-Carter*[1]
[1]*Cell Psicology and Pharmacology Department, University of Leicester, UK*
[2]*Neuroengineering Department, University of Antwerp, Belgium*
[3]*Enginering Department, University of Leicester, UK*

The understanding of the neural network dynamics and its alterations in neurodegenerative diseases is urgently needed to screen for possible therapeutic targets [1]. Here we present a biological neural network model for a rat planar primary culture based on MEA recordings. The model consists of excitatory and inhibitory neurons connected following spatial patterns deduced from functional connectivity measures (as pairwise cross-correlograms and Granger Causality) that we applied to our MEA recordings during spontaneous activity. The connectivity patterns as a function of the distance between neurons can be a useful biomarker to study neurodegenerative diseases and propose targets for potential treatments. We demonstrate that the model network can reproduce the recordings in many levels, from the membrane potential of individual cells to the dynamics of population bursts and the effect of potential treatments for Huntington's disease. 1) Gambazzi L, Gokce O, Seredenina T, Katsyuba E, Runne H, Markram H, Giugliano M, Luthi-Carter. The Journal Of Pharmacology and experimental therapeutics (2010). Diminished activity-dependent BDNF expression underlies cortical neuron microcircuit hypoconnectivity resulting from exposure to mutant huntingtin fragments.

EWS-FLI1 EMPLOYES AN E2F SWITCH TO DRIVE TARGET GENE EXPRESSION

R. Schwentner[1], *T. Papamarkou*[2], *M. O. Kauer*[1], *V. Stathopoulos*[2], *F. Yang*[3], *S. Bilke*[3], *P. S. Meltzer*[3], *M. Girolami*[2], *H. Kovar*[1,4]
[1]*Children's Cancer Research Institute, St. Anna Kinderkrebsforschung, Vienna, Austria*
[2]*Department of Statistics, University of Warwick, Coventry, CV4 7AL, UK*
[3]*Genetics Branch, Center for Cancer Research, National Cancer Institute, Bethesda, USA*
[4]*Dept. of Pediatrics, Medical University, Vienna, Austria*

In ETS-driven cancers of the bone and prostate, activating E2F3 cooperates with ETS on target promoters. The mechanism of target co-regulation has been unknown. Using mathematical modeling, four candidate mechanistic models are compared in order to understand the observed EWS-FLI1/E2F3 cooperation. Bayesian model selection reveals the formation of a synergistic complex between EWSFLI1 and E2F3 as the most likely mechanism explaining the observed kinetics of E2F target induction. It is thus proposed that cell cycle activation in Ewing sarcoma is due to the de-repression of E2F targets as a consequence of transcriptional induction and physical recruitment of E2F3 by EWS-FLI1 replacing E2F4 on their target promoters.

Agent-Based Simulation applied to Container Terminal Operations Management

Thiago Brito
Universidade de São Paulo - USP

In order to meet the increasing container handling demand, container terminals (CT) will have no option but to improve performance: that would potentially better rely on the improvement of the management of logistics processes. There has been recently much research on CT logistics processes management improvement. Most researches are based on a number of Operation Research (OR)-methods and differ widely in specific objectives, complexity and aggregation. However, they are typically based on a centralized system for planning, scheduling and controlling the CT logistics processes. Contrarily, CTs (as most logistic systems) are classified as multipart organizations, composed by multiple subsystems that interact and which overall performance depends upon a mix of factors affecting the individual subsystems. Also, there has been in recent years a growing interest in decentralized OR approaches,

especially regarding agent-based technologies. The agent-approach is considered to hold high promises for developing complex logistics systems, due to concept of agent .This work proposes then the implementation of an agent-based simulation (ABS) approach to integrate the yard management logistics processes, that comprises a set of CT planning problems. The proposition is to build an ABS model that will represent the system operation, and build strategies that may increase the CT performance.

UNIVERSALITY OF COUPLING FUNCTIONS: FROM BIOLOGY TO SECURE COMMUNICATIONS

Tomislav Stankovski, Peter VE McClintock, Aneta Stefanovska
Department of Physics, Lancaster University, Lancaster LA1 4YB, United Kingdom

Complex interacting dynamical systems abound in nature and science attempts to understand them as much as possible. Often, the interest is not only to understand the structure of systems, but also the functions and mechanisms that define and connect them. First, we developed a method for time-evolving dynamical Bayesian inference of coupled systems in presence of noise [1]. The method was designed to infer multivariate phase dynamics of interacting oscillatory dynamics. We applied it to better understand the human cardio-respiratory interactions under time-varying conditions. The cardio-respiratory coupling functions were reconstructed and shown in detail how the heart oscillations accelerate or decelerate due to the coupling influence from the lungs. Moreover, we found that the cardio-respiratory coupling functions are time-varying processes for themselves. Then we used this knowledge of time-varying coupling functions and applied it to build new improved secure encryption protocol [2, 3]. We encode the information signals as modulating scales of plurality of coupling functions between two dynamical systems at the transmitter. Two signals, one from each system, are transmitted and the dynamical systems are reconstructed at the receiver through complete synchronization. Knowing the exact form of coupling functions in use (eventually forming the encryption key) we were able to decrypt the information signals by use of the time-evolving dynamical Bayesian inference. In this way, we showed that the coupling function protocol has unbounded encryption possibilities, allows multiplexing inherently and is extremely noise resistant. We presented the encryption protocol on amplitude state model consisting of coupled chaotic Lorenz and Rossler systems forming a coupled pair in the transmitter (and in the receiver) subject to channel noise. We have connected two seemingly very different areas – biology and communications – because we exploited the universality of the theoretical construct of coupling functions. Needless to say, the methodology and the theory constructs have wide implications for interacting dynamical systems in general.

References:

[1] Stankovski, T., Duggento, A., McClintock, P. V., and Stefanovska, A. (2012). Inference of time-evolving coupled dynamical systems in the presence of noise. Physical review letters, 109(2), 024101.

[2] Stankovski, T., McClintock, P. V., and Stefanovska, A. (2014). Coupling functions enable secure communications. Physical Review X, 4(1), 011026.

[3] Subject to U.K. patent application No. GB1314114.8, Lancaster University, filed 7 2013.

INTEGRATED CITY: TOOLS FOR PARTICIPATION AND GOVERNANCE IN THE AGE OF BIG DATA

Ulysses Sengupta, Robert Hyde, Deljana Iossifova, Eric Cheung
Manchester School of Architecture, MMU
Chatham Building, Cavendish Street Manchester M15 6BR, United Kingdom

This paper examines the development of future planning methodologies (ongoing research) in the age of ‘big data’ with emphasis on how new digital platforms can lead to greater citizen participation and motivate structural alterations to urban governance. The aim of the research is to find new ICT based tools to enable urban transformation towards equitable and resilient cities using a co-productive top-down and bottom-up approach. The primary aim of the new digital platforms is to examine possibilities for discourse and decision-making rather than simply dissemination. The framework based on complex adaptive systems uses theories from the complexity sciences to incorporate changes over time, clear distinctions between positive and negative feedback loops, and ecological resilience theory incorporating the non-metaphoric study of cities as evolutionary systems. Prototypes of new participatory digital tools for immanent urban regeneration in Manchester, undertaken as part of a new masters (CPU: Complexity, Planning and Urbanism) at the Manchester School of Architecture in co-operation with the East Manchester Regeneration body, are examined with regard to their potential to affect spatial change. Possibilities for greater stakeholder participation in the co-design of future cities are set against the structural change required to organisational frameworks in planning related governance and e-governance. By combining ‘gamification’, original ICT development and CAS, the research

aims to move to experimentation with level 4 systems in planning. New digital App's, tools and portals are aimed at ICT enabled capacities for multi-stakeholder participation, longitudinal data capture and analysis, and development of future scenarios for discussion.

References:

[1] Alexander, C., 1978. A Pattern Language: Towns, Buildings, Construction, OUP USA.
[2] Banerjee-Guha, S., 2002. Shifting Cities: Urban Restructuring in Mumbai. Economic and Political Weekly, pp. 121-128.
[3] Batty, M., Marshall, S., 2012. The Origins of Complexity Theory in Cities and Planning, in: Complexity Theories of Cities Have Come of Age. Springer, pp. 21–45.
[4] De Roo, G., Hillier, J., Van Wezemael, J., 2012. Complexity and Planning: Systems, Assemblages and Simulations. Ashgate Publishing.
[5] Holling, C. S. (1996). "Engineering resilience versus ecological resilience." Foundations of Ecological Resilience: 51-66.
[6] Weinstock, M., 2010. The architecture of emergence: the evolution of form in nature and civilisation. Wiley.
[7] Roy, A., 2005. Urban Informality: Toward an Epistemology of Planning. Journal of the American Planning Association, pp.147-158.

NATURE OF MUTUAL ANTICIPATION FROM BEHAVIOUR TO BRAIN

Yoshikatsu Hayashi and S. J. Natuto
Brain Embodiment Lab, School of Systems Engineering, University of Reading, UK

How can we communicate with other members of society, synchronise our motion in realtime manner despite of the time-delay in the sensory-motor systems? Crucial to a sense of communication is first the ability to entrain perceptually with other members of society, i.e., to be able to follow, to lead, and anticipate others to synchronise their motion. However, the reorganisation of the brain activity under realtime coordinated motion has not been investigated in terms of simultaneous scanning/analysis of two brains. The aim of the presentation is to summarise the characteristic of synchronisation behaviour and to discuss the ongoing EEG experiments, focusing on the dynamical functions of the brain using functional connectivity network analysis.

LIST OF PARTICIPANTS

Alasdair D. F. Clarke
University of Aberdeen
a.clarke@abdn.ac.uk

Amanda Leite de Camargo
Universidade Federal do ABC
amandaleitepolastro@gmail.com

André Alves Ferreira
Universidade Estadual Paulista - UNESP
andre.ferreira@sjbv.unesp.br

Andreia Nalu Soares Hisi
Instituto Nacional de Pesquisas Espaciais - INPE
andreia.hisi@inpe.br

Antonio C. Roque da Silva Filho
Universidade de São Paulo em Ribeirão Preto - Brasil
antonior@ffclrp.usp.br

Antônio Mário de Torres Ramos
Instituto Nacional de Pesquisas Espaciais - INPE
tonipeixe@gmail.com

Antônio Politi
University of Aberdeen
a.politi@abdn.ac.uk

Celso Grebogi
University of Aberdeen
grebogi@abdn.ac.uk

Christos Antonopoulos
University of Aberdeen
chris.antonopoulos@abdn.ac.uk

Davoud Taghawinejad
Universidade de São Paulo - USP
davoud@taghawi-nejad.de

Deljana Iossifova
University of Manchester
deljana.iossifova@manchester.ac.uk

Diego Colón
Universidade de São Paulo - USP
diego@lac.usp.br

Diego Paolo Ferruzzo Correa
Universidade de São Paulo - USP
dferruzzo@usp.br

Edmilson Roque dos Santos
Universidade de São Paulo - USP
edmilson.roque.usp@gmail.com

Eduardo Ferreira Franco
Escola Politécnica - USP
eduardo.franco@gmail.com

Elbert E. N. Macau
Instituto Nacional de Pesquisas Espaciais - Brasil
elbert.macau@inpe.br

Francisco Aparecido Rodrigues
Universidade de São Paulo - USP
francisco@icmc.usp.br

Helmut Schmidt
University of Exeter
H.Schmidt@exeter.ac.uk

Ioana Pisica
Brunel University London
Ioana.Pisica@brunel.ac.uk

James Ing
University of Aberdeen
j.ing@abdn.ac.uk

Jose Antonio Mendez Bermudez
Benemerita Universidad Autonoma de Puebla
jmendezb@ifuap.buap.mx

Jose Augusto Morais de Andrade Junior
FEARP - USP
jamaj@usp.br

José Roberto Castilho Piqueira
Escola Politécnica da USP - Brasil
piqueira@lac.usp.br

Kelly Cristiane Iarosz
Universidade de São Paulo - USP
kiarosz@gmail.com

Kyle Wedgwood
University of Nottingham
Kyle.Wedgwood@nottingham.ac.uk

Leonardo Paulo Maia
Universidade de São Paulo - USP
lpmaia@ifsc.usp.br

Linda Sommerlade
University of Aberdeen
l.sommerlade@abdn.ac.uk

Marcio Eisencraft
Universidade de São Paulo - USP
marcio@lcs.poli.usp.br

Marcio Porto Basgalupp
Universidade Federal de São Paulo - UNIFESP
basgalupp@gmail.com

Marcos G. Quiles
Universidade Federal de São Paulo - UNIFESP
quiles@gmail.com

Mikko Kivela
University of Oxford
bolozna@gmail.com

Murilo S. Baptista
University of Aberdeen
murilo.baptista@abdn.ac.uk

Nicolás Rubido
University of Aberdeen/Universidad de la Republica
nrubido@fisica.edu.uy

Rafael Alves da Costa
Universidade Federal do ABC
r.costa@ufabc.edu.br

Renato Candido
Universidade de São Paulo - USP
renatocan@lps.usp.br

Reuben O'Dea
University of Nottingham
reuben.o'dea@nottingham.ac.uk

Robert Merrison-Hort
University of Plymouth
robert.merrison@plymouth.ac.uk

Rodrigo Calvo
Universidade Estadual de Maringá
calvo.rodrigo@gmail.com

Sandro Perrone
University of Leicester
sandro.perrone@gmail.com

Theodore Papamarkou
University of Wawick
t.papamarkou@warwick.ac.uk

Thiago Brito
Universidade de São Paulo - USP
tbbrito@gmail.com

Tomislav Stankovski
Lancaster University
t.stankovs@lancaster.ac.uk

Ulysses Sengupta
University of Manchester
u.sengupta@mmu.ac.uk

Vinícius Antonio Battagello
Instituto Tecnológico de Aeronáutica
battagello@gmail.com

Wendell Pereira Barreto
Universidade de Campinas - UNICAMP
wendellb@ifi.unicamp.br

Yoshikatsu Hayashi
University of Reading
y.hayashi@reading.ac.uk