24 November, Monday - Systems Biology

10:00-11:15 **Keynote**: Daniel Polani (University of Hertfordshire, UK), *Information: Currency of Life?*

Notwithstanding enormous advances in biological and Artificial Intelligence research, harnessing the power of living beings to achieve high levels of adaptivity and self-organization has long remained an elusive goal. This prompts the question where the sources lie which contribute to the enormous success of living organisms under so many different routes. In order to understand this, it behooves one to take a step back: instead of trying to copying the apparent form or dynamics of biological systems as closely as possible, it makes sense to ask what is common to all organisms, looking beyond the variety of seemingly incompatible solutions expressed by different organisms.

To this purpose, we will visit various achievements of organisms, with a particularly close look at how they act upon environmental signals in the world. It turns out that, with all variety encountered, the common denominator of all these scenarios is that organisms acquire, process and utilize information in a highly efficient way. In fact, among all possible resources of an organism, information (in a precisely quantifiable sense) is a resource of vital importance, and more than that: while many resource types may be specific to particular organisms, information is universal - a candidate for a currency of life.

11:15-11:30 Break

11:30-12:00 *Coherent Computation in Biological Networks* , Joseph T. Lizier(1,2), Mikhail Prokopenko(1) and Albert Y. Zomaya(2)

1. CSIRO Information and Communications Technology Centre, Australia
2. School of Information Technologies, The University of Sydney, Australia

Abstract: Random Boolean Networks (RBNs) are discrete dynamical systems which have been used to model Gene Regulatory Networks. We investigate the well-known phase transition between ordered and chaotic behavior in RBNs from the perspective of the distributed computation conducted by their nodes. We use a recently published framework to characterize the distributed computation in terms of its underlying information dynamics: information storage, information transfer and information modification. We find maximizations in information storage and coherent information transfer on either side of the critical point, allowing us to explain the phase transition in RBNs in terms of the intrinsic distributed computations they are undertaking.

12:00-12:30 *Centrality and Compoistion of Motifs in Metabolic Networks* , Mahendra Piraveenan(1,2), Kishan Wimalawarne(3), Mikhail Prokopenko(1), Albert Y. Zomaya(2)

1. CSIRO Information and Communications Technology Centre, Australia
2. School of Information Technologies, The University of Sydney, Australia
3. Department of Computer Science and Engineering, University of Moratuwa, Sri Lanka

Abstract: Analysing subgraph patterns and recurring motifs in networks is a useful way to understand their local topology and function. Motifs have been considered useful in analysing design patterns of networks as well. Three-node patterns (triads) in metabolic networks have been studied to some extent (e.g., frequency) producing classification of organisms based on triads, but their network placement was not analysed. We obtain the frequencies of all four-node subgraphs in a wide range of metabolic networks, construct significance profiles of subgraphs and employ correlation analysis to compare and contrast these profiles, highlighting four-node motifs. Like triads, four-node subgraphs in metabolic networks also show distinctive motifs. The correlation analysis shows that the significance profiles of Eukaryotic networks are highly correlated across organisms, whereas those of the Prokaryotic networks are correlated less so. We then compute specific centrality measures of nodes involved in each subgraph, namely betweenness centrality and closeness centrality. These motifs are not placed randomly, but are more likely to be found in areas of high shortest path density (high centrality). Finally, we analyse larger subgraphs (e.g., five-node subgraphs) in order to shed light on their frequencies and composition. Network motifs within larger subgraphs are shown to be mainly the combinations of three-node and four-node motifs. The analysis provides a tool to pinpoint the transition between evolution stages of Prokaryotic and Eukaryotic metabolic networks.

12:30-13:00 *Measuring Self-organisation: Sample Applications of Computer Vision* , Pascal Vallotton

CSIRO Mathematical and Information Sciences

Abstract: Self organisation is the basic theme of life - one that had been recognized as a central question early on and given particular names (vitalism, odic forces) - then dismissed as a curiosity that could presumably be reduced to more fundamental and better charted territories of science. The comeback of self organisation as a respected scientific topic is a sign of humble times - we do not really understand how an embryo develops - how the sand, the sea and the wind form ever changing patterns – or how ant colonies operate so efficiently. One approach for comprehending complexity is to measure it in as much detail as possible, then to attempt to build a model that progressively captures the observed dynamics faithfully. For example, we will be presenting a technique that measure biological polymer flow, assembly and disassembly in the lamellipodium of motile cells. We will also present preliminary work aiming to identify automatically individual cells in neurospheres to characterize and understand their development in space and time.

13:00-14:30 Lunch break

14:30-15:45 **Keynote**: Nihat Ay (Max Planck Institute for Mathematics in Natural Sciences, Leipzig Germany), *Network robustness in terms of information theory*

Abstract: In this talk I present an approach to robustness that uses information theory to quantify invariance of function against perturbations. Robust networks are demonstrated through computer simulations. Finally, I discuss an application of this theory to the analysis of the genetic code.

15:45-16:15 *Modelling Stigmergic Gene Transfer* , Daniel Polani(1), Mikhail Prokopenko(2) and Matthew Chadwick(2)

1. Department of Computer Science, University of Hertfordshire, United Kingdom
2. CSIRO Information and Communication Technology Centre, Australia

Abstract: We consider an information-theoretic model studying the conditions when a separation between the dynamics of a "proto-cell" and its proto-symbolic representation becomes beneficial in terms of preserving the proto-cell's information in a noisy environment. In particular, we are interested in understanding the behaviour at the "error threshold" level which, in our case, turns out to be a whole "error interval". We separate the phenomena into a "waste" and a "loss" component; the "waste" measures "packaging" information which envelops the proto-cell's information, but itself does not contain any information of interest, the "loss" measures how much of the proto-symbolically encoded information is actually lost. We observe that transitions in the waste/loss functions correspond to the boundaries of the "error interval". Secondly, we study whether and how different protocells can share such information via a joint code, even if they have slightly different individual dynamics. Implications for the emergence of biological genetic code are discussed.

16:15-16:45 *Self-organisation and Selection in the Context of Stem Cell Decision Making* , Julianne Halley and David Winkler

CSIRO Molecular and Health Technologies

17:00-17:30 GSO Program Committee meeting

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25 November, Tuesday - Adaptive Hardware and Robotics

10:00-11:15 **Keynote**: Ralf Der (Max Planck Institute for Mathematics in Natural Sciences, Leipzig Germany), *Guided Self-organization of Autonomous Robot Behavior*

Abstract: The talk starts with a brief review of self-organization   in physical systems and asks the question how the self-organization processes can be guided in these systems. Answers are translated to autonomous, embodied robots with many degrees of freedom. It will be argued that a gradient flow on information theoretic measures, predictive information in particular, is a viable scenario for self-organization. We derive on-line learning rules for the maximization of the predictive information and apply them to a number of example systems like artificial snakes, dogs, humanoids and some strange artifacts. These examples show that our learning rules drive these robots to a playful self-exploration of their bodily affordances. Eventually, possible routes for the guidance of these self-organization processes are outlined. Videos and more information on http://robot.informatik.uni-leipzig.de/research/videos/.

11:15-11:30 Break

11:30-12:00 *Adaptive Control of Distributed Energy Management: A Comparative Study* , Astrid Zeman, Mikhail Prokopenko, Ying Guo and Rongxin Li

CSIRO Information and Communication Technologies Centre

Abstract: Demand-side management is a technology for managing electricity demand at the point of use. Enabling devices to plan, manage and reduce their electricity consumption can relieve the network during peak demand periods. We look at a reinforcement learning approach to set a quota of electricity consumption for a network of devices. This strategy is compared with homeotaxis - a method which achieves coordination through minimising the persistent time-loop error. These policies are analysed with increasing levels of noise to represent loss of communication or interruption of device operability. Whilst the policy trained using reinforcement learning proves to be most successful in reducing cost, the homeotaxis method is more successful in reducing stress on devices and increasing stability.

12:00-12:30 *Agent-Based Algorithms for Optical Fibre Sensing Networks*, N. Hoschke et al.

CSIRO Materials Science and Engineering, Australia

Abstract: Structural health monitoring in aerospace vehicles is an application to which a multi-agent system is well suited. The advantages of these scalable and highly robust systems are demonstrated in the research done by CSIRO in collaboration with NASA's Dryden Flight Research Center and Langley Research Center. A hardware concept demonstrator has been developed which shows how fixed and robotic sensing agents can self-organise and respond to impact damage. This paper will report on the development of agent-based algorithms that enable the integration of a fibre-optic sensing network for thermal sensing with an impact-detection system.

The goal is to efficiently combine the impact detection system based on piezoelectric sensors with a thermal monitoring system based on fibre-optic Bragg grating sensors. A small number of piezoelectric sensors connected to each sensing agent enables the impact to be detected and its location determined. Once an impact, and therefore potential damage to the thermal protection layer, has been detected, the thermal properties of the thermal protection system in the vicinity of the impact must be measured. This is done by directing a source of thermal energy (which may be the sun) at the outer surface, and measuring the resulting spatial temperature distribution at the inner surface. An anomalous temperature distribution in the region of the impact may indicate that the thermal protection system has been compromised.

The advantage of using optical fibres for thermal monitoring is that thousands of sensors can be used on a single fibre, thus providing high spatial resolution of temperatures. However, this concept is not consistent with the robust properties of a multi-agent system, as a break in the fibre may render many of the sensors useless. To overcome this drawback, a network of optical fibre segments which may be switched by the sensing agents is proposed. This approach will require the agent algorithms to connect the fibre segments to form a continuous path from the probing laser to a point of interest in the structure, such as near an impact location. It is desirable that this system be capable of both checking the integrity of optic links and also forming paths that avoid broken links.

The gradient-based algorithms that have been used to guide robotic agents in our earlier work may be modified to connect the optical fibres in the proposed network. This paper will discuss the development of simulation representations and the agent algorithms, and the difficulties caused by different geometries.

12:30-13:00 Deploying Large-scale Autonomous Systems, M. Bruenig et al.

CSIRO Information and Communication Technologies Centre, Australia

Abstract: The Autonomous Systems Laboratory, in the CSIRO ICT Centre, is Australia's leading laboratory in the areas of field robotics, sensor network technology, and adaptive systems. With nearly 50 researchers and 20 students and visitors it is recognised for scientific contributions, and their application to domains such as mining, energy and the environment. The talk will provide an overview of achievements of the Laboratory, including landmark results in robotic excavation, award-winning vision-based underwater vehicles, and adaptive control of electrical systems.

13:00-14:30 Lunch break

14:30-15:45 **Keynote**: Ivan Tanev (Doshisha University, Kyoto, Japan), *Coevolution of Morphology of Active Sensing and Locomotion*

Wheelless, limbless snake-like robots (Snakebots) feature potential robustness characteristics beyond the capabilities of most wheeled and legged vehicles, e.g., ability to traverse challenging terrain that would pose problems for traditional wheeled or legged robots, and insignificant performance degradation when partial damage is inflicted. Some useful features of Snakebots include smaller size of the cross-sectional areas, stability, ability to operate in difficult terrain, good traction, high redundancy, and complete sealing of the internal mechanisms. However, compared to the wheeled and legged vehicles, snake-like robots feature (i) smaller payload, (ii) more difficult control of locomotion gaits and (iii) inferior speed characteristics. Focusing on the latter two drawbacks, in this talk I intend to address the following challenge: how to automatically develop the control sequences of actuators of realistically simulated Snakebots, which, incorporating the sensors' information is able to achieve fast speed of locomotion in confined, challenging environments.

I will elaborate on the approach of automated co-evolution of (i) the optimal values of attributes (orientation, range and timing of activation of sensors) of active sensing and (ii) the control of locomotion gaits that result in a fast speed of locomotion in a confined environment. I will illustrate the emergence of several wall-following navigation strategies of the fast sidewinding Snakebots. Especially, I will focus on the contactless wall-following navigation, accomplished by means of differential steering, facilitated by the evolutionary defined control sequences incorporating the readings of evolutionary optimized sensors.

15:45-16:15 *In situ Genetic Programming* , Philip Valencia

CSIRO Information and Communication Technologies Centre, Australia

Abstract: This research conjectures that agents within a complex real world environment can perform genetic evolution of logic to yield desirable and adaptive collective system behaviours. Devising logic for human-designed complex systems is typically performed off-line and biased by human intuition and simulation accuracy. Arguably it is easier for the designer to specify a 'solution fitness' and allow an in situ evolution of logic. While the evolution of collective
behaviour, or system self organisation, may not have an acceptable time frame, it may be possible to seed the logic to achieve an immediate acceptable performance while allowing exploration of logic in periods when performance is not essential.

16:15-16:45 Market-based Coordination for Field Robots, Robert Zlot

CSIRO Information and Communication Technologies Centre, Australia

Abstract: Robotics technology has matured to a point where it is becoming increasingly viable to deploy robots in the field for complex industrial and scientific tasks in unstructured environments. The use of autonomous robots promises improvements in efficiency, safety, reliability, and a reduction in production costs. Autonomous vehicles have been successfully demonstrated and utilized in mines, farms, processing plants, factories, for urban driving, and for scientific exploration. For many applications, teams of robots offer further benefits in terms of robustness, adaptability, and parallelization. However, the use of multiple robots also introduces other challenges with respect to system complexity and scalability.

In this presentation, I will discuss the "market-based" approach, in which the team of robots is modeled as a set of intelligent agents that coordinate through an artificial financial market. Market-based coordination is modeled after trading systems developed by human societies over thousands of years to deal with problems of scarcity and efficiency, analogous to conditions present in multirobot systems. The concept was first introduced for software agents in the 1970's, and has more recently been applied to robotic systems. In the past decade, this approach has been gaining popularity and has been applied to heterogeneous teams of land, sea, and air vehicles.

A key property of a market-based system is that each robot is capable of locally determining the cost or utility of each task or resource in the system, and that a mechanism is able to transform local prices into a global metric to produce an efficient outcome. The most common manifestation of the market-based approach is the implementation of task allocation through auctions. Individual robots estimate the costs of performing various tasks, and those with the lowest costs are deemed to be best-suited to execute them, and therefore win the associated auction. The role of auctioneer and bidder can be taken on dynamically, leading to a fully distributed system. However, the market-based approach can also allow for the opportunistic inclusion of centralized planning among subteams when resources are available. Therefore, the market can be thought of as a hybrid control scheme.

In this talk, I will introduce some of the central concepts in market-based coordination and auction-based task allocation, and discuss the practicality of the approach for current field robotics applications.

19:00 Dinner

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26 November, Wednesday - Complex Systems and Networks

10:00-11:15 **Keynote**: Nihat Ay (Max Planck Institute for Mathematics in Natural Sciences, Leipzig Germany), *An information-geometric approach to complexity*

Abstract: `The whole is more than the sum of its parts.' This famous quote from Aristotle refers to a property of complex systems that is commonly assumed to be fundamental. However, only a few attempts have been made towards its formalization. This talk reviews work on an information-geometric approach to this end and relates it to various well-known other notions of complexity. Applied to the temporal domain of stochastic processes, it provides a link to transfer entropy and directed information which intend

to capture the causal structure of a system. This link also highlights the important role of causality within complex systems research.

11:15-11:30 Break

11:30-12:00 *Optimising Sensor Layouts for Direct Measurement of Discrete Variables* , X. Rosalind Wang(1), George Matthews(1,2), Don Price(3), Mikhail Prokopenko(1)

1. CSIRO Information and Communication Technologies Centre, Australia
2. Australian Centre for Field Robotics, The University of Sydney, Australia
3. CSIRO Materials Science and Engineering, Australia

Abstract: Optimal sensor layout is attained by placing a limited number of sensors in an area such that the cost of the placement is minimised while the value of the obtained information is maximised. In this paper, we first introduce a criterion that maximises the value, or expected benefit, of using a sensor subset for a given sensor model relative to the environment. Defining the value allows us to represent the sensor layout problem as an entropy optimisation problem. We contrast this criterion with other well-known criteria. Finally, we compare the various criteria for optimal sensor layout using data from an existing wireless sensor network. This is achieved by firstly learning a spatial model of the environment using a Bayesian Network, then predicting the expected sensor data in the rest of the space, and lastly verifying the results with the ground truth.

12:00-12:30 *Local Assortativeness in Scale-free Networks* , Mahendra Piraveenan(1,2), Mikhail Prokopenko(1) and Albert Y. Zomaya(2)

1. CSIRO Information and Communications Technology Centre, Australia
2. School of Information Technologies, The University of Sydney, Australia

Abstract: The level of assortative mixing of nodes in real-world networks gives important insights about the networks design and functionality, and has been analyzed in detail. However, this network-level measure conveys insufficient information about the local-level structure and motifs present in networks. We introduce a measure of local assortativeness that quantifies the level of assortative mixing for individual nodes in the context of the overall network. We show that such a measure, together with the resultant local assortativeness distributions for the network, is useful in analyzing network's robustness against targeted attacks. We also study local assortativeness in real-world networks, identifying different phases of network growth, showing that biological and social networks display markedly different local assortativeness distributions to technological networks, and discussing the implications to network design.

12:30-13:00 *The influence of Real-world Environments on P2P Services: Constraints or Opportunities?* , Elth Ogston and Stephen A. Jarvis

Warwick University, UK

Abstract: A number of services form building blocks for accomplishing coordinated global functionality in peer-to-peer systems. Low-level services implement basic components such as node sampling, multicasting, failure detection, time synchronization, and system size estimation. Such services provide nodes with basic information about the system in which they are participating. Node sampling, for instance, informs nodes of the existence of other active nodes. These low-level components can be used to create higher-level services that build, maintain and adapt basic overlay structures.

The behavior of many peer-to-peer services have been well characterized theoretically, but is less well understood in real-world environments. In ideal theoretical peer-to-peer systems nodes are entirely equal and are able communicate with any of their peers. In actual systems nodes can have have widely varying resource capacities and a variety of factors, such as bandwidth and latency considerations, but also firewalls and network address translators, can restrict communications. High-level services rely on lower level services. This means that factors that have a small influence on the behavior of a protocol implementing a fundamental service can have a large impact on the overall performance of a complex peer-to-peer system.

In this work we examine how a real-world environment can alter the properties of a node-sampling protocol and explore the consequences of these alterations when using the sampling protocol to create a tree structure. A node sampling service is a degenerate form of directory, which instead of giving the address of a requested node, simply returns the address of a randomly selected node. If samples follow a uniform random distribution sampling can be used to create random networks that are known to have a low diameter, to make statistical estimates such as of the size of the system, and to allocate tasks in a way that is likely to balance load between nodes. In a non-ideal environment communication restrictions can result in samples that are weighted towards nearby nodes, while differences in node resources can weight samples towards more active nodes. There are two possible responses to these situations: either design protocols that account for and correct these effects or incorporate the expected sample distribution into the design of higher level services. We consider the problem of creating a tree using a random multicast protocol built on top of a sampling service. We study how changes in sample distribution changes the shape of this tree, and investigate when these changes should be avoided and when they can be beneficial.

13:00-14:30 Lunch break

14:30-15:45 **Keynote**: Larry Yaeger (Indiana University), *Passive and Driven trends in the Evolution of Complexity*

Abstract: The nature and source of evolutionary trends in complexity is difficult to assess from the fossil record, and the driven vs. passive nature of such trends has been debated for decades. There are also questions about how effectively artificial life software can evolve increasing levels of complexity. We extend our previous work demonstrating an evolutionary increase in an information theoretic measure of neural complexity in an artificial life system (Polyworld), and introduce a new technique for distinguishing driven from passive trends in complexity. Our experiments show that evolution can and does select for complexity increases in a driven fashion, in some circumstances, but under other conditions it can also select for complexity stability. It is suggested that the evolution of complexity is entirely driven—just not in a single direction—at the scale of species. This leaves open the question of evolutionary trends at larger scales.

15:45-16:15 *Self-organizing Networks where Fitness is Determined by Synchronization Properties* , Marcus Brede

CSIRO Marine and Atmospheric Research

Abstract: In this talk we investigate a simple procedure for self-organizing networks towards enhanced synchronizabilities. More precisely, we consider a system comprised of Kuramoto oscillators with different native frequency that are coupled via a network. This problem describes a prototypical situation, which is found in many complex systems in nature and technology: rhythms in the brain, pacemaker cells in the heart, power- sensor and communication systems are only some examples.

Assuming that the fitness of the system is related to the degree of synchronization, we explore simple evolution rules imposing various constraints (binary undirected links, binary directed links, weighted directed links). We also study whether a system with limited local information can reach the global optimum.

16:15-16:45 *Coordination and performances in communities of competing agents* , Fabio Boschetti and Markus Brede

CSIRO Marine and Atmospheric Research

Within a game-theoretical framework, we analyse four scenarios arising from the interaction of agents competing for limited resources: resource depletion resulting from local, greedy strategies ("tragedy of the commons"), resource waste due to agents imposing increasing constraints on competitors' behaviour ("tragedy of the anticommons"), crowd following ("majority wins") and competition for niches ("minority wins"). We show that these scenarios are extremes of a continuous resource exploitation problem and that complex and counter-intuitive behaviours are found at the transitions between "pure" scenarios. We discuss the likely community behaviours under centralised vs distributed decision making, the effect of private cost functions on global behaviour, the role of local information in the choice of private optimal strategy in a mixed-strategy setting and the inherent trade-off between optimally and resilience arising in several such settings. The results have relevance to applications ranging from the design of artificial multi-agent systems to the management of natural renewable resources.

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27 November, Thursday - Computational Neuroscience

10:00-11:15 **Keynote**: Michael Breakspear (The University of New South Wales), *Non-Gaussian Statistics of Spontaneous Cortical Activity*

Abstract: It is widely assumed that the brain is a complex system par-excellence and should hence exhibit all the hallmarks of a self organising system, such as nonlinearity, coherency and non-diffusivity. Surprisingly, at least at the very large-scale of neocortical dynamics, there is actually little empirical evidence to support this, and hence most computational and methodological frameworks have proceeded quite adequately from a purely linear/diffusive perspective. In this talk, I will review some recent evidence that shows that whilst these simple assumptions hold true at some temporal scales, there is strong evidence for bistability and super-diffusivity in key brain rhythms. Bistability is manifest as non-classic bursting between high and low coherent modes in the alpha rhythm, whereas the beta rhythm exhibits irregular extremal amplitude events due to super-diffusivity. Whilst there is a good conceptual framework for understanding bistability in cortical dynamics, the implications of the extremal events challenges existing computational tools.

11:15-11:30 Break

11:30-12:00 *Modelling Dynamically Driven Rewiring of Structural Brain Connectivity* , Mikail Rubinov(1), Olaf Sporns(2), Cees van Leeuwen(3), Michael Breakspear(1)

1. School of Psychiatry, University of New South Wales, Sydney, Australia
2. Department of Psychological and Brain Sciences, Indiana University, Bloomington, USA
3. Laboratory for Perceptual Dynamics, RIKEN Brain Science Institute, Saitama, Japan

Abstract: The nature and origin of complex structural and functional brain connectivity represents an intriguing research endeavour. There clearly exists an interdependent structural-functional relationship - neuronal activity is supported by the underlying structural connectivity, while gradually reshaping the structure through processes such as activity-dependent synaptic plasticity. Here, we employ nonlinear dynamical and graph theoretical analyses to explore the organizing principles of this interdependent relationship, hence testing the hypothesis that much of the observed complexity in the mature brain could arise through an interplay between structure and dynamics, without the need for an explicit wiring code.

We consider a model in which complex structural connectivity generates large-scale spontaneous neuronal activity, and is iteratively reshaped towards the resulting functional connectivity patterns, in an unsupervised fashion (hence mimicking activity-dependent plasticity). We find that random structural connectivity is able to generate ordered functional patterns; by gradually rewiring towards these patterns, structural networks acquire a robust, cortical-like, "modular small-world" topology. In spite of the ordered functional connectivity, structural networks remain globally interconnected - and therefore small-world - due to the presence of highly participating, inter-modular hub nodes. The noisy dynamics of these hubs enable them to persist, despite their participation in ongoing rewiring. Our findings outline a theoretical mechanism for self-organization driven by emergent dynamics; similar processes could take place in the developing brain.

12:00-12:30 *Distributed Dynamical Computation in Neural Circuits* , Pulin Gong

School of Physics, University of Sydney

Abstract: Spatiotemporally organized, propagating activity patterns of intriguing complexity are pervasive in spontaneous and evoked electrical activity of the brain. We present a theoretical model of a circuit of spiking neurons that generates dynamical activity patterns of similar complexity. We demonstrate how these patterns are capable of processing information. As self-sustained objects, moving coherent patterns signal information by propagating across the neural circuit in time. Computation occurs when these emergent patterns interact with each other. The ongoing behavior of these patterns naturally embodies both distributed, parallel computation and cascaded operations, enabling the system to work in an inherently flexible and efficient way. These results lead us to propose that propagating coherent activity patterns are the underlying primitives with which neural circuits carry out distributed dynamical computation.

12:30-13:00 *Towards Self-organised Optimisation in Reservoir Computing* , Joschka Boedecker(1), N. Michael Mayer(1), Oliver Obst(2), Minoru Asada(1)

1. Asada Lab, Osaka University, Japan
2. CSIRO Information and Communication Technologies Centre, Australia

The way information is encoded affects various information processing properties in neural networks. Sparse representations in the brain have been shown to maximize long term memory capacity. In a neural network, low activity makes the state of the hidden layer less dependent on the input, leading to a slower decay of information. We investigate ways to limit the activity of neurons in echo state networks, a particular kind of recurrent neural networks with a "reservoir" of randomly connected units in the hidden layer. With our method, it is possible to achieve sparse activity for typical inputs even with several hidden units. Ultimately, we aim for a method that maximizes short term memory capacity in recurrent neural networks based on local computation in a self-organized way.

13:00-14:30 Lunch break

14:30-15:45 **Keynote**: Mikhail Burtsev (Russian Academy of Sciences), *Learning-guided evolution*

Abstract: Learning can be considered as a "crane" for building up complexity in evolution. Learning-driven evolution under the assumption of hierarchical biological organization was studied in the model that incorporates a classical Hinton & Nowlan simulation and "Royal Staircase" fitness function of van Nimwegen & Crutchfield. The simulations demonstrated that, learning radically accelerates the evolution of complex adaptations. The one important implication of the study is that the effect of learning on the rate of evolutionary accumulation of innovations increases with the complexity of the challenges faced by the organism. The other key finding is that the genes associated with the functional systems which involve intensive learning during lifetime should evolve faster compared to the genes of less plastic systems of organism. The evidence for this prediction appears recently in the genomic studies which show higher level of substitutions in the brain specific sequences of DNA in human compared to chimpanzee and other species.

15:45-16:15 *Self-Organization of Semantic Networks in Natural Language Processing and Computational Social Science* , Kostas Alexandridis

CSIRO Sustainable Ecosystems, Australia

Abstract: A semantic network represents a structure for knowledge representation (KR) as a pattern of interconnected nodes and arcs (Sowa, 1991). Nodes and arcs in such a network encode a wide variety of semantic relationships, including linguistic approximations of knowledge and different types and scales of connectivity over complex hierarchical structures of subsumptional entities. Semantic expressions also introduce knowledge approximations (isomorphisms) to logic-based, rational propositional inference or formalisms (Schubert, 1991). According to Quillian (1967), semantic networks based on linguistic assertions represent an abstraction theory of the structure of the human long-term memory, able to embody knowledge as a computational model. The spreading-activation theory of semantic processing (Anderson, 1983; Collins and Loftus, 1975) allows the study of effects of priming in semantic memory via semantic network associations of interconnected relationships, stored and recalled in memory altogether (retention-activation properties). Semantic networks of memory processing are recently considered to be part of a new approach to learning theory, namely the connectivism learning theory (Siemens, 2005) that focuses on the understanding of how informal learning patterns and associations (as complex adaptive systems) help people utilize and connect learning and knowledge rather than information itself. Semantic networks are proven to be scale-free networks and strongly related to weak social ties in social networks of interactions. In this paper, the construction of semantic networks from natural language knowledge representation and the use of Hopfield-type Artificial Neural Networks will be explored. Hopfield ANNs present a type of recurrent NNs with simple neurons and no hidden layers (Hopfield, 1982). They utilize dynamic computation of auto-associative semantic rules in connecting synaptic nodes in the network. They represent content-addressable memory systems with binary threshold units. The iterative nature of semantic memory processing and retrieval in Hopfield Semantic Nets allows for finding a lower "energy" level for the network that self-organizes activation network patterns over knowledge hierarchies. The paper will showcase how semantic processing in semantic memory priming and retention, modelled using Hopfield-type ANNs allows for efficient and correct knowledge approximation and ontological representation of dynamics in human cognitive processing. It will also demonstrate how human memory self-organization of semantic patterns improves informal learning and decision-making.

16:15-17:00 Panel discussion