MARIE CURIE ACTIONS

SEVENTH FRAMEWORK PROGRAMME

NETT INTERNATIONAL CONFERENCE

ON SYSTEM LEVEL APPROACHES TO NEURAL ENGINEERING

BARCELONA 2015

NETT NEURAL ENGINEERING TRANSFORMATIVE TECHNOLOGIES

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About ICSLANE 2015

The International Conference on System Level Approaches to Neural Engineering (ICSLANE) is organised by the Fellows of the NETT consortium (Neural Engineering Transformative Technologies). This three-days long event, September 21st – 23rd 2015, is the 8th training event organised by the NETT consortium and takes place in PRBB, Barcelona, Spain.

The aim of this interdisciplinary conference is to bring together theoretical and experimental neuroscientists, roboticists and microfluidics experts to present and discuss the state of the art in the field of neural engineering. It is designed to provide fertile grounds for establishing collaborations between classical neuroscientists and leaders in the up-and-coming robotics and microfluidics fields to develop novel neural engineering techniques and promote the understanding of the brain.

About NETT

The NETT consortium is a Marie Curie Initial Training Network involving neuroscience research laboratories from the UK, France, Italy, the Netherlands, Spain and Portugal, and industrial partners. The network is coordinated by Professor Stephen Coombes from the University of Nottingham, UK.

Organising Committee Coordinators and Local Organisers

Alessandro Barardi and Maciej Jedynak

Organising Committee

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Renaud Schuck
Weronika Wojtak

Monday, 21 September			
8:00 - 9:00	Registration & Coffee		
9:00 - 9:15	Welcome – Alessandro Barardi and Maciej Jedynak		
9:15 - 10:15	Eugene Izhikevich	Brain Corporation, San Diego	Spikes
10:15 - 10:45	Coffee break		
Session 1: Brain-on-Chip			
10:45 - 11:20	Yoonkey Nam	Korea Advanced Institute of Science and Technology, Daejeon	Building biological neural network on a chip
11:20 - 12:00	Albert Folch	University of Washington	Microfluidic Chips for Highly Parallel Neuroscience Research
12:00 - 13:30	Lunch		
13:30 - 13:50	Florian Jetter	Natural and Medical Sciences Institute at the University of Tübingen	Electrical stimulation of retinal neurons using a CMOS microelectrode array of 1024 capacitive stimulation sites
13:50 - 14:10	Benjamin Lassus	IBPS, CNRS, Paris	Reconstructing rodent and human oriented neuronal networks to model Neurodegenerative syndromes
14:10 - 14:45	Thibault Honegger	CNRS, Grenoble	Three-dimensional structural and functional neural networks for connectome on a chip
14:45 - 15:00	Coffee break		
Session 2: Optical Neurotechnology Methodology			
15:00 - 15:35	Fritjof Helmchen	University of Zurich	Imaging Neocortical Dynamics During Behavior
15:35 - 16:10	Adam Packer	University College London	All-optical interrogation of neural circuits
16:10 - 16:30	Matthieu Louis	Centre for Genomic Regulation, Barcelona	Sensorimotor control underlying larval chemotaxis
16:10 - 16:30	Coffee break		
16:50 - 17:25	Eftychios Pnevmatikakis	Simons Foundation, New York	Demixing and deconvolution of calcium imaging data
17:25 - 18:00	Amanda Foust	Imperial College London	Holographic Light Sculpting for Fast, Parallel, and Spatially Precise Neural Microcircuit Investigation
18:00 - 18:20	Anat Marom	Israel Institute of Technology, Haifa	Hydrogel-based Microfluidic Chip for Site-specific Chemical Treatment and Optical Imaging of 3D Neuronal “Optonets”

Tuesday, 22 September			
Session 3: Neural Learning and Control			
9:15 - 9:50	Alex Pouget	University of Geneva	Probabilistic synapses
9:50 - 10:25	Reza Shadmehr	Johns Hopkins University, Baltimore	Encoding of movements by Purkinje cells of the cerebellum
10:25 - 10:50	Coffee Break		
10:50 - 11:25	Dario Farina	Bernstein Center for Computational Neuroscience, Goettingen	Bionic Reconstruction of Upper Limb Function

11:25 - 12:00	Gregor Schöner	Ruhr University Bochum	Toward an integrated neural processing account for object-oriented movement: principles from human movement science, theory, and robotic demonstration
12:00 - 13:30	Lunch		
13:30 - 14:05	Sami Haddadin	Institute of Automatic Control, Leibniz Universität Hannover	Robot reflexes and soft-skills for interaction
14:05 - 14:40	Patrick van der Smagt	Technical University of Munich	Learning movement without neural coding
Session 4: Neural Dynamics			
14:40 - 15:15	Benjamin Lindner	Humboldt University Berlin	How correlated fluctuations shape the spike statistics in the sensory periphery and in recurrent networks
15:15 - 15:45	Coffee Break		
15:45 - 16:20	David Liley	Swinburne University of Technology, Hawthorn	Neural field modeling of brain activity: physiological insights, practical applications and mathematical challenges
16:20 - 16:40	Alex Roxin	Centre de Recerca Matemàtica, Barcelona	The encoding of episodic memory via spike-timing-dependent plasticity: a computational model
16:40 - 17:00	Andre Longtin	University of Ottawa	Invariance mechanisms for separating distance from velocity and for focussing
17:00 - 17:20	Claudio Mirasso	IFISC, UIB, Palma de Mallorca	Reconciling causal influence and negative time lag in neuronal circuits
17:20	Poster Session & Coffee Break		
20:00	Social Dinner		

Wednesday, 23 September			
Session 5: Neural Coding			
9:30 - 10:05	Stefano Panzeri	Italian Institute of Technology, Rovereto	On the role of spike timing in sensory information coding and perceptual decisions
10:05 - 10:40	Romain Brette	Institut de la Vision, Paris	The ecological approach to neural computation
10:40 - 11:05	Coffee break		
11:05 - 11:40	Andre Bastos	The Picower Institute for Learning and Memory, MIT, Cambridge, MA	Spectral asymmetries in feedforward and feedback connectivity: a basic motif in cortical processing?
11:40 - 12:00	Thomas B. DeMarse	University of Florida	On the Nature and Transmission of Information Among Cell-Assemblies In Engineered Neuronal Topologies
12:00 - 13:30	Lunch		
13:30 - 14:05	Jan W. H. Schnupp	University of Oxford	Bottom-up and top-down approaches to understanding neural coding in the auditory pathway
14:05 - 14:40	Kenneth Harris	University College London	The neural marketplace
14:40 - 15:40	Nikos Logothetis	Max Planck Institute for Biological Cybernetics Tübingen	NET-fMRI of Large-Scale Brain Networks: Mapping Dynamic Connectivity in Epochs of Synaptic and System Consolidation

SPIKES

Eugene Izhikevich, Brain Corporation, San Diego

Most communication in the brain is via spikes. While we understand the spike-generation mechanism of individual neurons, we fail to appreciate the spike-timing code and its role in neural computations.

BUILDING BIOLOGICAL NEURAL NETWORK ON A CHIP

Yoonkey Nam, Korea Advanced Institute of Science and Technology, Daejeon

Dissociated neuronal cultures combined with planar-type microelectrode arrays (MEAs) have been used as one of the Brain-on-a-Chip models to study the fundamental mechanism of neural information processing. In order to obtain functional models on a chip, it is imperative to engineer neuronal culture system that could provide experimenters with the control of network form or connectivity. This talk presents an in vitro network chip design technique that produces well-ordered neuronal networks on a microelectrode array. Our approach is to pattern cell-repulsive agarose hydrogel using MIMIC (Micromolding in capillaries) technique which is one of the soft-lithographic techniques that are easily adaptable to existing microelectrode arrays. Based on this approach, we were able to build multi-node neuronal networks composed of embryonic day 18 (E18) rat hippocampal neurons. MEA recordings showed that propagating spontaneous electrical activities were generated after 2 weeks in the network, and electrical stimulation of one cluster evoked synaptically transmitted action potentials to the other cluster. The proposed neuronal network is expected to be a useful in vitro model system for basic neuroscience and cell chip applications.

MICROFLUIDIC CHIPS FOR HIGHLY PARALLEL NEUROSCIENCE RESEARCH

Albert Folch, University of Washington

Delivering drugs and growth factors to tissues and cells in a quantitative manner is an ongoing challenge. During embryonic development, axons are guided over large distances by a host of cues that first orients and then navigates it through a rich and dynamic extra-cellular environment. The challenges associated with investigating the complex and intricate processes of axon-guidance in vivo without interference from organism-wide responses motivates the development of high-throughput platforms that can present precisely controlled gradients of diffusible biochemical cues to isolated individual cells and track their response in real time. I will present the results of a large-scale study conducted with netrin-1 to induce axon guidance in primary mammalian neurons using an integrated platform that combines a large (1024-element) array of microfluidic gradient generators capable of creating gradients on open surfaces.

ELECTRICAL STIMULATION OF RETINAL NEURONS USING A CMOS MICROELECTRODE ARRAY OF 1024 CAPACITIVE STIMULATION SITES

Florian Jetter, Natural and Medical Sciences Institute at the University of Tübingen

Towards improved applications of electrical stimulation it is essential to better understand the cellular and remote effects of this method. Therefore a CMOS-based microelectrode array comprising 1024 capacitive stimulation sites within 1 mm² or 4 mm² was developed.1 The biocompatible insulation using $TiZrO_2$ enables the application of arbitrary stimulation waveforms over extended durations at arbitrary user-defined positions on the array. The stimulated neuronal activity is detected at 25 kHz using a second array of 4225 sensor sites interleaved between the stimulation sites. The amplitude of the applied stimulation current is calculated from the voltage drop across a resistor, which is in series to the Ag/AgCl ground electrode. The stimulation performance of the electrode array is demonstrated using sinusoidal stimulus waveforms applied to healthy and blind mouse retina. In epiretinal configuration stimuli of different frequencies (10 – 90 Hz), of different amplitude and of different size (0.0025 - 1 mm²) are investigated. The induced electrical activity in retinal ganglion cells is detected either during stimulus presentation or after filtering the recorded extracellular voltage using notch filters. Stimulation using low frequencies (i.e. 10 Hz) in healthy retina is induced by the activation of circuitry presynaptic to the retinal ganglion cells. A similar result is found for the stimulation of blind retina. Current research is aimed towards a selective activation of retinal interneurons towards the discrimination of light onset versus offset in blind retina.

RECONSTRUCTING RODENT AND HUMAN ORIENTED NEURONAL NETWORKS TO MODEL NEURODEGENERATIVE SYNDROMES

Benjamin Lassus, IBPS, CNRS, Paris

The brain is a complex structure comprising many different neuron populations making specific and long ranged polarised connections, or synapses. As such, neurons are ordered in exquisitely complex yet organised directional neuronal pathways. In an effort to optimise reconstruction of oriented neuronal network, we have previously shown that fluidically isolated cell culture chambers separated by asymmetrical microstructures and micro-channels ('axon diode'), allow efficient unidirectional orientation of axons. Here, using these concepts we reconstructs multi-components neuronal network in which specific neuronal subtypes are derived from rodent and human iPS cells. Using functional assays, optogenetic stimulation and calcium imaging, allowing to monitor the establishment of synaptic connection, glutamatergic transmission, and synchronous rhythmic activities, we characterised the development of the reconstructed neuronal networks and demonstrated their full functionality. These Rodent and Human 'Brain-on-Chip' platforms which mimic neuro-anatomical pathways are currently used to model progressive neurodegenerative syndromes and several application examples will be presented.

THREE-DIMENSIONAL STRUCTURAL AND FUNCTIONAL NEURAL NETWORKS FOR CONNECTOME ON A CHIP

Thibault Honegger, CNRS, Grenoble

The central nervous system (CNS) is a dense, layered, 3D interconnected network of populations of neurons, and thus recapitulating that complexity for in vitro CNS models requires methods that can create defined neuronal networks in 3D. Several three-dimensional patterning approaches have been developed but are unable to recapitulate the topological complexity of in vivo networks. In this talk, I will present a method using microfluidics and AC electrokinetic forces to organise several populations of neurons within a chip and to guide, accelerate, slow down and push up neurites in un-modified collagen scaffolds. This method allows creating in vitro neural networks of arbitrary complexity by using such forces to create 3D intersections of primary neuronal populations that are plated in a 2D plane. I will present for the first time in vitro basic brain motifs that have been previously observed in vivo and show that their functional network is highly decorrelated from their structure. This platform can serve as building blocks to reproduce in vitro the complexity of a human connectome and provide minimalistic environment to study the structure-function relationship of the brain circuitry.

IMAGING NEOCORTICAL DYNAMICS DURING BEHAVIOR

Fritjof Helmchen, Universtiy of Zurich

Through the combination of in vivo optical imaging and chronic expression of genetically encoded calcium indicators it has recently become feasible to directly 'watch' neuronal population dynamics in the neocortex of awake, head-restrained mice during specific behaviours. Here, I will exemplify the use of in vivo two-photon calcium imaging as well as other optical methods to elucidate neocortical dynamics in behaving mice trained in a texture discrimination task. We are especially interested in analysing the activation patterns of identified cortico-cortically projecting neurons - linking local circuit dynamics to the mesoscale - and in revealing the changes in network dynamics that occur during task learning. To this end, we have built a novel multi-area microscope that is capable of measuring local population activity in two distant areas simultaneously. I will highlight the various imaging tools now available for analysing neocortical dynamics and also discuss ongoing developments and future prospects.

ALL-OPTICAL INTERROGATION OF NEURAL CIRCUITS

Adam Packer, University College London

We describe an all-optical strategy for simultaneously manipulating and recording the activity of multiple neurons with cellular resolution in vivo. We performed simultaneous two-photon optogenetic activation and calcium imaging by co-expression of a red-shifted opsin and a genetically encoded calcium indicator. A spatial light modulator allows tens of user-selected neurons to be targeted for spatiotemporally precise concurrent optogenetic activation, while simultaneous fast calcium imaging provides high-resolution network-wide readout of the manipulation with negligible optical cross-talk. Proof-of-principle experiments in mouse barrel cortex demonstrate interrogation of the same neuronal population during different behavioural states and targeting of neuronal ensembles based on their functional signature. This approach extends the optogenetic toolkit beyond the specificity obtained with genetic or viral approaches, enabling high-throughput, flexible and long-term optical interrogation of functionally defined neural circuits with single-cell and single-spike resolution in the mouse brain in vivo.

SENSORIMOTOR CONTROL UNDERLYING LARVAL CHEMOTAXIS

Matthieu Louis, Centre for Genomic Regulation, Barcelona

Behavioural strategies employed for chemotaxis have been studied across phyla, but the neural computations underlying odor-guided orientation responses remain poorly understood. Combining electrophysiology, optogenetics, quantitative behavioural experiments and computational modelling, we study how dynamical olfactory signals experienced during unconstrained behaviour in odor gradients are processed by first-order sensory neurons of the Drosophila larva, and how this information is converted into orienting behaviour. The activity of a single larval olfactory sensory neuron (OSN) is sufficient to direct larval chemotaxis. By characterising the activity of a targeted OSN in response to naturalistic changes in stimulus intensity, we report the surprising degree of information processing taking place in first-order olfactory neurons. Using an ordinary-differential-equation formalism, we find that the nonlinear response characteristics of an OSN can be described by a general class of regulatory motifs that includes the incoherent feedback loop and the integral feedback. This quantitative model explains two basic operations carried out by the OSN on the stimulus: temporal differentiation on short timescales and temporal integration on longer timescales, which in concert enable the OSN to detect features related to changes in the stimulus acceleration. Using optogenetics in virtual reality experiments, we studied the sensorimotor integration underlying the navigation of odor gradients. We examined how increases in the activity of an OSN can suppress turning, whereas abrupt decreases in activity can initiate turning. We explain how the conversion of OSN activity into a choice between alternative behavioural states – running or turning – can be accounted for by a simple stochastic model. Altogether, our work clarifies the link between neural computations at the sensory periphery and action selection during navigational behaviours in a sensory landscape.

DEMIXING AND DECONVOLUTION OF CALCIUM IMAGING DATA

Eftychios Pnevmatikakis, Simons Foundation, New York

We present a modular approach for analysing calcium imaging recordings of large neuronal ensembles. Our goal is to simultaneously identify the locations of the neurons, demix spatially overlapping components, and denoise and deconvolve the spiking activity from the slow dynamics of the calcium indicator. Our approach relies on a constrained nonnegative matrix factorization that expresses the spatiotemporal fluorescence activity as the product of a spatial matrix that encodes the spatial footprint of each neuron in the optical field and a temporal matrix that characterises the calcium concentration of each neuron over time. This framework is combined with a novel constrained deconvolution approach that extracts estimates of neural activity from fluorescence traces, to create a spatiotemporal processing algorithm that requires minimal parameter tuning. We demonstrate the general applicability of our method by applying it to in vitro and in vivo multi-neuronal imaging data, whole-brain light-sheet imaging data, and dendritic imaging data.

HOLOGRAPHIC LIGHT SCULPTING FOR FAST, PARALLEL, AND SPATIALLY PRECISE NEURAL MICROCIRCUIT INVESTIGATION

Amanda Foust, Imperial College London

A rapidly evolving toolbox of synthetic and genetic methods endows Neuroscientists with the capability to control and measure the flow of electrical communication among neurons with light. In order to fully leverage these advancements, Neuroscience now needs methods to pattern light into brain tissue with spatial and temporal complexity mimicking that of naturally occurring brain activity. Computer-generated holography enables simultaneous, multiple-shape, multiple-location, and axially confined light sculpting. Importantly, holographically generated shapes can simultaneously silence or generate transmembrane currents, as well as fluorescence, throughout cells or structures of interest. I will review the theory and implementation of computer-generated holograms for neural circuit investigation, discussing advantages, limitations, and applications for rapid optogenetic activation and high signal-to-noise ratio functional (e.g. voltage, calcium) fluorescence imaging.

HYDROGEL-BASED MICROFLUIDIC CHIP FOR SITE-SPECIFIC CHEMICAL TREATMENT AND OPTICAL IMAGING OF 3D NEURONAL 'OPTONETS'

Anat Marom, Israel Institute of Technology, Haifa

Planar neural networks and interfaces serve as a versatile in vitro model of CNS physiology, but adaptations of related methods to three dimensions (3D) have met with limited success. Although early attempts at extending MEA technology to 3D were demonstrated, it is generally accepted that opto-physiology methods are optimally suited for the required non-contact, volumetric interfacing. Here, we demonstrate volumetric functional imaging during site-specific pharmacological manipulation in an optically accessible bio-engineered 3D neural network 'optonet'. Optonets consist of rat primary cortical cells densely embedded in a transparent hydrogel scaffold and forming optically-accessible networks with brain-like density and composition. Optonet cellular activity is visualised by 3D calcium imaging either by equipping a standard fluorescence microscope with a piezoelectric actuator capable of moving the objective lens to multiple focal planes or using a novel hybrid multiphoton-temporal focusing microscope with large-scale volumetric imaging capabilities. To make this in vitro model system into a powerful screening platform for toxicity testing and drug discovery applications, we designed a novel microfluidic neuronal device for site-specific chemical treatment of the 3D optonet. To test the efficacy of the device, several drugs were locally introduced through one of the top channels resulting in spatially-localized and reversible alteration in the activity patterns of the 3D neuronal network. Altogether, hybrid microfluidic-hydrogel platforms that combine bio-realistic growth conditions and optical access hold potential for high-throughput toxicity testing, drug discovery and point-of-care applications.

PROBABILISTIC SYNAPSES

Alexandre Pouget, University of Geneva

Organisms face a hard problem: based on noisy sensory input, they must set a large number of synaptic weights. However, they do not receive enough information in their lifetime to learn the correct, or optimal weights (i.e., the weights that ensure the circuit, system, and ultimately organism functions as effectively as possible). Instead, the best they could possibly do is compute a probability distribution over the optimal weights. Based on this observation, we hypothesise that synapses represent probability distribution over weights; in contrast to the widely held belief that they represent point estimates. From this hypothesis, we derive learning rules for supervised, reinforcement and unsupervised learning. This introduces a new feature: the more uncertain the brain is about the optimal weight of a synapse, the more plastic it is. This makes intuitive sense: if the uncertainty about a weight is large, new data should strongly influence its value, while if the uncertainty is small, little learning is needed. We also introduce a second hypothesis, which is that the more uncertainty there is about a synapse, the more variable it is. This new perspective on synaptic weights makes several experimental predictions, two of which that we have already verified and several others that have yet to be tested.

ENCODING OF MOVEMENTS BY PURKINJE CELLS OF THE CEREBELLUM

Reza Shadmehr, Johns Hopkins University, Baltimore

Execution of accurate eye movements depends critically on the cerebellum, suggesting that Purkinje cells (P-cells) may predict motion of the eye. Yet, this encoding has remained a long-standing puzzle: P-cells show little consistent modulation with respect to saccade amplitude or direction, and critically, their discharge lasts longer than duration of a saccade. Here, we analysed P-cell discharge in the oculomotor vermis of behaving monkeys and found neurons that increased or decreased their activity during saccades. We estimated the combined effect of these two populations via their projections on the caudal fastigial nucleus (cFN) and uncovered a simple-spike population response that precisely predicted the real-time motion of the eye. When we organied the P-cells according to each cell's complex-spike directional tuning, the simple-spike population response predicted both the real-time speed and direction of saccade multiplicatively via a gain-field. Therefore, the cerebellum predicts the real-time motion of the eye during saccades not via simple-spikes of individual P-cells, but via combined inputs of P-cells onto individual nucleus neurons. A gain-field encoding emerges if the P-cells that project onto a nucleus neuron are not selected at random, but share a common complex-spike property.

BIONIC RECONSTRUCTION OF UPPER LIMB FUNCTION

Dario Farina, Bernstein Center for Computational Neuroscience, Göttingen

Bionic reconstruction consists in the replacement of lost limbs with mechatronic devices and this includes surgical procedures, such as targeted muscle reinnervation (TMR), to improve the functional outcome. In upper limb substitution, a man-machine interface that establishes a link between the user's nervous system and the robotic limb (prosthesis) is needed. This interfacing is commonly done with the remnant muscles above the amputation, either through their physiological innervation or using the surgical approach of TMR. Muscle interfacing or myoelectric control consists in the recording of electromyographic (EMG) signals for extracting control signals to command prostheses. In commercial systems, the intensity of muscle activity is extracted from the EMG and used for single degree of freedom activation (direct control). Over the past decades, the academic research has progressed to more sophisticated approaches but, surprisingly, none of these academic achievements has been implemented in commercial systems so far. The academic state-of-the-art relies on pattern recognition as a method to control multiple motor tasks using a relatively small number of electrodes. However, this approach has important limitations. We proposed a change of focus on myocontrol research in the direction of approaches for simultaneous and proportional control of multiple degrees of freedom, which are based on regression methods. Moreover, the exclusive use of EMG as a source for feed-forward control of prostheses may not be sufficient. Therefore, methods that integrate the EMG information with that from other sensors, within semiautonomous systems, are described. The talk will cover these topics with a discussion on the major challenges in filling the gap between commercial/clinical and academic methods for myocontrol. Finally, the new approach of bionic reconstruction of upper limb function in brachial plexus injured patients, following elective amputation, will be introduced.

TOWARD AN INTEGRATED NEURAL PROCESSING ACCOUNT FOR OBJECT-ORIENTED MOVEMENT: PRINCIPLES FROM HUMAN MOVEMENT SCIENCE, THEORY, AND ROBOTIC DEMONSTRATION

Gregor Schöner, Ruhr University Bochum

Humans are the most dexterous species. How we reach, grasp, and manipulate objects shapes how we think, all the way into human language (such as when you 'grasp' what I just said). In fact, the embodiment stance in cognitive science traces the foundation of human cognition back to our motor competences. Conversely, how humans generate movement that is directed at perceived objects is challenging exactly because such movement entails scene and object perception, spatial and motor cognition, including sequence generation, as much as pure motor control. Integration among all these processes is key to the smoothness and flexibility of human motor skills. I will sketch a theoretical framework for integration in movement generation based on neural dynamics, the evolution in time of activation in strongly recurrent neural networks. In particular, I will review how Dynamical Field Theory (DFT), a variant of neural dynamics, lends itself to understanding scene representation, attentional selection of objects, and movement preparation. The sequential organisation of movement emerges from the dynamic instabilities that are at the core of DFT. Movement timing and coordination can be understood on the basis of oscillations and active transients in DFT. How low-dimensional timing signals are transformed into commands to the many muscles of the degree of freedom problem, central to motor control. In my talk, I will present the theoretical framework with its empirical foundations, but will also demonstrate its function in simple robotic demonstrations of integrated movement generation.

ROBOT REFLEXES AND SOFT-SKILLS FOR INTERACTION

Sami Haddadin, Institute of Automatic Control, Leibniz Universität Hannover

Enabling robots for direct physical interaction and cooperation with humans as well as their dynamic environment has been one of robotics research primary goals over decades. In this context, equipping robots with suitably fast and sophisticated sensory-motor control loops is of fundamental interest. In particular, building also on the systemic understanding of human motor control, robots shall have extremely fast tactile reflexes, as well as intelligent soft-skills for interaction and manipulation. At the same time, the primary objective of a robot's action around humans is to ensure that even in case of malfunction or user errors no human shall be harmed because of the robot's action or inaction. For this, possibly learnt instantaneous, safe, and intelligent context based reflex reaction schemes, paired with according subsequent actions to unforeseen events in partially unknown environments become crucial. Among other things, I will particularly focus on recent results in unified impedance/force control for force-sensitive manipulation and generalised collision/contact handling based on proprioceptive and tactile sensing for soft-robots.

LEARNING MOVEMENT WITHOUT NEURAL CODING

Patrick van der Smagt, Technical University of Munich

A traditional way of representing movement of human or robotic limbs is by writing down dynamical models, estimating their parameters, and combining those with the available neural or mathematical controllers. Opposing this systemic approach, we venture to represent movement using generative probabilistic models. Focussing on deep autoencoders and recurrent neural networks, we can use these to accurately model human or robot movement, based on measured movement data alone. Moreover, these movements can be reconstructed from different types of sensors, which when combined increase accuracy and reduce error.

HOW CORRELATED FLUCTUATIONS SHAPE THE SPIKE STATISTICS IN THE SENSORY PERIPHERY AND IN RECURRENT NETWORKS

Benjamin Lindner, Bernstein Center for Computational Neuroscience and Humboldt University Berlin

Neurons are subject to various sources of noise that result in a pronounced stochasticity of their spike trains. These fluctuations often show pronounced temporal correlations both in the neural periphery (e.g. by slow intrinsic ion channel noise or external sensory signals) and in the recurrent networks of the brain (e.g. by stochastic network oscillations or non-Poissonian spike statistics of the presynaptic neurons). Many theoretical investigations neglect these correlations and approximate fluctuations by white Gaussian noise. In my talk I review some recent analytical results for integrate-and-fire models driven by coloured noise with arbitrary temporal correlations. The formulas for the interspike-interval density and correlation coefficient of a simple perfect integrate-and-fire neuron model are used to quantitatively explain the spike statistics of two types of neurons: auditory receptor cells in locust and electro-afferent cells in paddlefish. The theory also explains features of the spike statistics of neurons in recurrent networks driven by non-Poissonian spike trains. Moreover, it predicts a transition from short- to long-correlated network fluctuations as the overall coupling strength between neurons is increased. A smoothed version of such a transition can be observed in numerical simulations of biophysically more realistic network models.

NEURAL FIELD MODELLING OF BRAIN ACTIVITY: PHYSIOLOGICAL INSIGHTS, PRACTICAL APPLICATIONS AND MATHEMATICAL CHALLENGES

David Liley, Swinburne University of Technology, Hawthorn

This talk will begin with a brief overview of neuronal population, or mean field, modelling approaches that have been developed to describe meso- and macroscopic level brain activity. We will then outline one particular mean field approach to modelling brain activity that has been particularly successful in articulating the genesis of rhythmic electroencephalographic activity in the mammalian brain. In addition to being able to provide a physiologically consistent explanation for the genesis of the alpha rhythm, as well as expressing an array of complex dynamical phenomena that may be of relevance to understanding cognition, the model is also capable of accounting for many of the macroscopic electroencephalographic effects associated with anaesthetic action, a feature often missing in similar formulations. We will then outline how the physiological insights afforded by this mean field modelling approach can be translated into improved methods for the clinical monitoring. The talk will then conclude with an overview of the challenges this and other theories will need to negotiate in order to progress as neurobiologically effective explanatory frameworks.

THE ENCODING OF EPISODIC MEMORY VIA SPIKE-TIMING-DEPENDENT PLASTICITY: A COMPUTATIONAL MODEL

Alex Roxin, Centre de Recerca Matemàtica, Barcelona

It is well known that the hippocampus plays a major role in the formation and retrieval of episodic memories. In rodents, hippocampal cells called place-cells exhibit activity which is selective to the spatial location of the animal in a given environment. As the animal traverses the environment, a particular pattern of place-cell activity will be generated, corresponding to the specific trajectory taken. In this way, cells with spatially adjacent place fields will also fire in temporal proximity, potentially leading to changes in their recurrent synaptic weights via spike-timing-dependent plasticity (STDP) mechanisms. Here we model this process with a computational model in which we consider both pairwise and triplet STDP rules in a recurrent network of hippocampal place cells. We study how the exploration of the animal over time can lead to the formation of low-dimensional attracting manifolds in the neuronal network, each one of which encodes the memory of a specific environment. For example, the traversal of a 1D ring-like environment leads, via STDP, to a so-called ring attractor. Once formed, the presence of the attractor can explain the dynamics of so-called hippocampal replay, via spontaneous re-activation of spatially localised bump states. In fact, the temporal compression of replay can be related to the details of the underlying STDP rule. Interestingly, once the memories of several distinct environments have been encoded, the correlation of replay activity with any given memory can be modulated by the level of external input.

INVARIANCE MECHANISMS FOR SEPARATING DISTANCE FROM VELOCITY AND FOR FOCUSSING

Andre Longtin, University of Ottawa

Early sensory neurons must convey information about all aspects of a scene. Disentangling position from velocity and acceleration of an object is important for its identification and tracking, which ultimately drives an animal's motion towards or away from it. We show that power-law adaptation can be used to separate distance from velocity in early sensors. This kind of adaptation produces a rate code for distance of looming objects that is invariant to velocity and acceleration. Their postsynaptic neurons in turn produce firing patterns that are non-renewal, including bursting. We show that bursting onset, linked to a saddle-node bifurcation, underlies a focussing mechanism that is invariant to object attributes.

RECONCILING CAUSAL INFLUENCE AND NEGATIVE TIME LAG IN NEURONAL CIRCUITS

Claudio Mirasso, IFISC, Universitat de les Illes Balears, Palma de Mallorca

Understanding how information is processed in the brain is one of the key issues in neuroscience. Among the many possible scenarios, it happens that synchronisation among different brain areas might play a significant role. Among the tools available to assess the coordinated activity of two or more areas, the correlation function is the most widely employed. However, correlation does not detect the directionality of the connection. Granger causality (GC) has shed light into the directional influence and the time arrow of the information flow. A positive GC from an area A to an area B indicates that the activity of area A causes the activity of area B. Intuitively, one tends to assume that a positive GC is accompanied by a positive time delay (relative phase) between the activities of areas A and B, signalling that activity in A precedes that of B. But, would it be possible to compute a positive GC and a negative time delay? This is precisely the scenario we study in this work, motivated by experiments reported in monkeys while performing a visual discrimination task. We find a minimal model that accounts for the observed behaviours and opens new perspective into the role that inhibition can play in neuronal circuits.

THE ROLE OF SPIKE TIMING IN SENSORY INFORMATION CODING AND PERCEPTUAL DECISIONS

Stefano Panzeri, Italian Institute of Technology, Rovereto

Generating a percept and selecting an action based on that percept, does the brain use the simple code of spike counts on a tens of millisecond scale, or a more complex code based on the relative temporal displacement of action potentials on a millisecond-scale (a 'pure temporal code'), or a combination of both? To investigate this question, we recorded responses from neurons in primary (S1) and secondary (S2) somatosensory cortex as five rats performed a tactile discrimination. On each trial the rat was presented one of three textures and used its whiskers to palpate the stimulus; it was required to withdraw and turn to the reward spout specified by texture identity. We computed two types of information carried by spike count by a pure temporal code, and by the combination of both during each whisker's contact with the texture: the information carried about texture in trials where the rat made a correct choice, and the information carried about the animal's behavioural choice. For both types of information, the S1 and S2 neurons' pure temporal code carried more information than spike count, and their combination carried much more texture information than each code alone. This suggests that the neural code used by somatosensory cortical neurons to encode information and its readout mechanism used to produce behaviour rely on a multiple-time-scale combination of millisecond firing patterns and of spike counts. This leads to the hypothesis that single-trial texture information in millisecond precise relative time of spikes had a direct impact on the accuracy of the rat's percept that goes beyond what provided by spike counts. We confirmed this hypothesis by finding that the rat's choice was more likely to be correct when the relative temporal displacement of spikes in that trial carried faithful texture information, and choice was less likely to be correct when this purely temporal code carried misleading texture information. The association between behavioural performance and rate was significant too, but much less strong than that of spike timing. These results indicate that the temporal pattern of firing of cortical neurons, not just their time-averaged activity, contributes to somatosensory perception.

THE ECOLOGICAL APPROACH TO NEURAL COMPUTATION

Romain Brette, Institut de la Vision, Paris

How does the brain make sense of sensory inputs in terms of things in the world, given that those inputs are all it ever has access to? This old puzzle has motivated a number of theories in philosophy, psychology and neuroscience in general. The visual psychologist James Gibson articulated an 'ecological approach' to perception, according to which the basis of perception is the 'invariant structure' of sensory flows, which can be interpreted as models of sensory inputs. I will elaborate on this idea and propose a possible neural basis for this psychological theory, where synchrony reflects relations between sensory inputs, defining a model, and coincidence detection corresponds to the identification of a model. I will present recent physiological data on sound localisation in mammals that support this view.

SPECTRAL ASYMMETRIES IN FEEDFORWARD AND FEEDBACK CONNECTIVITY: A BASIC MOTIF IN CORTICAL PROCESSING?

André Bastos, The Picower Institute for Learning and Memory, MIT, Cambridge, MA

A growing body of evidence suggests that distinct frequencies are used to communicate information in feedforward and feedback directions. Faster frequencies in the gamma-band (40-100 Hz) have been implicated in feedforward communication while slower frequencies in the alpha- (8-12 Hz) and beta-bands (14-30 Hz) have been implicated in feedback communication. Multiple sources of evidence now converge on the idea that oscillations at multiple frequency bands support a highly structured and dynamic cortical and subcortical hierarchy by functionally segregating feedforward and feedback communication via distinct frequencies. This phenomenon may be ubiquitous in cortical networks, and may therefore reflect something canonical about the cortex and the computations it performs. In this talk I will present this evidence and discuss what the functional/computational significance of these spectral asymmetries may be, with a particular emphasis on current models of predictive coding.

ON THE NATURE AND TRANSMISSION OF INFORMATION AMONG CELL-ASSEMBLIES IN ENGINEERED NEURONAL TOPOLOGIES

Thomas B. DeMarse, Department of Biomedical Engineering, University of Florida

Transient propagation of information across neuronal assembles is thought to underlay many cognitive processes. However, the nature of the neural code embedded within these transmissions or interaction between a networks structural topology and functional computation that occurs within those assemblies is only partially understood. Much of our understanding of how information is transmitted among neuronal assemblies has been derived from computational models. These models make simplifying assumptions about the biophysical properties of neurons that may influence the nature of computation or the neural code that is expressed. The strategy of our group is to use current MEMs technologies to create or "recreate" networks of neurons with specific network topologies to study transmission of information. We first report results from a simple two-chamber in vitro system representing two small cortical populations interconnected through micro-scale tunnels in a feed-forward network topology. These living cortical networks spontaneously form network wide bursts of activity (oscillations). We study the communication between small functional sub-networks that dynamically form during each burst event, transmit information in the form of spike trains within and between each network, before fading away at the end of each oscillation. We manipulate the number of communication pathways between each neural population and measure the effects this reduction has on the nature and fidelity of information in the form of spike trains as they are transmitted between networks using multielectrode (MEA) electrophysiology. We then report results from our second technology in which microprinting of neuronal adhesion molecules is used to create three distinct network topologies that differ in the degree of convergence of information and compare the effects these topologies have upon the structure of functional connectivity and fidelity of information among neurons at information flowed across these networks.

BOTTOM-UP AND TOP-DOWN APPROACHES TO UNDERSTANDING NEURAL CODING IN THE AUDITORY PATHWAY

Jan W. H. Schnupp, University of Oxford

The auditory system is a peculiar beast. Sound waves go into the ears, and at the other end of the system, auditory perceptions come out, rich with perceptual qualities such as sound source location, loudness, pitch, and timbre, which have no direct equivalent in the physics of the sound. This transformation is the product of a pathway of staggering complexity with dozens of subcortical processing stations and numerous cortical areas, and how these anatomical structures map onto functional processing remains quite unclear. In this talk I shall describe some of the rather disparate approaches that have been used to try to shed light on the way in which sounds are encoded by the activity of neurons along the auditory pathway. Focussing mostly on midbrain and cortical levels, I will review work that attempts to capture the computations carried out by the auditory pathway in terms of feed-forward, linear or non-linear receptive field models, give examples of applications of information theory which are much more agnostic about the underlying signal transformation, and will present approaches that combine behavioural and electrophysiological work in order to try to assess the role of the neural activity in shaping subjective perception rather than signalling physical stimulus properties. By contrasting these approaches I hope to highlight both the advantages and limitations of each of these approaches in the context of applications to adaptive frequency processing, spatial hearing, pitch and timbre processing and speech encoding.

THE NEURAL MARKETPLACE

Kenneth Harris, University College London

The brain is made of billions of neurons, which automatically assemble into working networks. This occurs with no central point of control. Outside of neuroscience, the only known system where a comparable number of individual information-processing units self-organise into productive networks, is the global economy, where independent profit-seeking behaviour by individuals or firms - based on locally available information - causes a system of supply chains to self-organise, even though no one individual plans or even understands the entire system. Here we outline a mathematical theory for how similar self-organisation could occur in the brain. This theory is based the 'retroaxonal hypothesis' which holds that strengthening of a neuron's output synapses causes a signal to pass slowly backward along its axon, resulting in consolidation of its input synapses. This hypothesis is supported circumstantially by multiple experimental results, which suggest that such a retroaxonal signal may be carried with neurotrophins, and consolidate recently tagged synapses via activation of CREB. In the economic analogy, each neuron is like an entrepreneur, producing a spike train 'product'. If other neurons 'buy' the product by forming synapses onto our cell's axon, it gets 'paid' retroaxonally, and continues to make the same product. Otherwise, our cell continues to change its inputs until it finds a message that other neurons want to hear. Mathematically, we model a recurrent network of excitatory and inhibitory firing-rate neurons, whose performance is gauged by a cost function of the outputs of a few 'output cells', which in the economic analogy correspond to end-consumers. We define the 'worth' of any neuron to be the deterioration in network performance if it were to die. We show that neurons may estimate their worth by passing slow retroaxonal signals, from output cells to other, 'producer' cells, as well as between producers. Changes to a cell's worth function as an individually-tailored reinforcement signal, allowing the network to learn much faster than would be possible with a single global reward signal. We demonstrate the theory using simulations.

NET-FMRI OF LARGE-SCALE BRAIN NETWORKS: MAPPING DYNAMIC CONNECTIVITY IN EPOCHS OF SYNAPTIC AND SYSTEM CONSOLIDATION

Nikos Logothetis, Max Planck Institute for Biological Cybernetics Tübingen

Neural-Event-Triggered fMRI (NET-fMRI) can potentially map whole-brain activity, associated with individual local events - or their interactions - in various brain structures. In my talk, I'll describe a number of characteristic states of widespread cortical and subcortical networks that are associated with the occurrence of thalamic, hippocampal and pontine events, which may be related to synaptic and systems consolidation of different memories.

Brain-on-Chip

Nitzan Herzog, University of Nottingham
Viability and Activity of In Vitro Neuronal Networks under Perfusion

Eugene Malishev, Saint Petersburg Academic University
Axon growth investigation in asymmetric microfluidic channels

Benjamin Paul, University of Nottingham
Direct laser writing of microstructures for patterning in vitro neural cell cultures

Alexey Pimashkin. N.I.Lobachevsky State University of Nizhny Novgorod
Design of synaptic connectivity and cell patterns in dissociated neuronal cultures using microfluidics and micro-electrode arrays

Sara Teller, Departament d'ECM, Universitat de Barcelona
Clustered Neuronal Cultures: Probing neuronal circuits in a Dish

Optical Neurotechnology Methodology

Luca Annecchino, Imperial College London
An automated approach for two-photon targeted recordings in vivo

Cher Bachar, Imperial College London
Image analysis tools for studying axonal and presynaptic bouton dynamics in the living brain

Monica Frega, Radboud University Nijmegen
Characterization of the electrophysiological activity of EHMT1-deficient neuronal networks during development

Stefania Garasto, Imperial College London
Theoretical groundwork for visual stimulus reconstruction from two photon calcium imaging in mouse V1

Diana Lucaci, Imperial College London
The study of age-related changes in brain circuits

Peter Quicke, Imperial College London
Fluorescence imaging of peripheral nerves using genetically encoded voltage indicators

Stephanie Reynolds, Imperial College London
Lower bounds on the temporal precision of spike detection from calcium imaging data

Houda Sahaf, University of Nottingham
Chemical functionalisation for surface plasmon resonance imaging of neural networks activity

Renaud Schuck, Imperial College London
Rapid three dimensional two photon neural population scanning

Neural Learning and Control

Ivan Herreros Alonso, Universitat Pompeu Fabra / DTIC / SPECS
Anticipatory control based in counterfactual sensory error predictions

Gianpaolo Gulletta, University of Minho
Human-like bimanual synchronous movements in anthropomorphic robots

Jordi-Ysard Puigbò Llobet, SPECS - Universitat Pompeu Fabra
A self regulated and adaptive humanoid robot

Hans-Christian Ruiz, Radboud University Nijmegen
Adaptive path integral importance sampling

Andreea Sburlea, BitBrain Technologies, Zaragoza
Robust EEG based BCIs for the detection of gait intention

Dominik Thalmeier, Radboud University Nijmegen
Learning universal computations with spikes

Nicole Voges, CRG - Systems Biology, Barcelona
First steps in encoding the link between sensory neural firing and behaviour in Drosohila larvae

Neural Dynamics

Xerxes D. Arsiwalla, Universitat Pompeu Fabra, Barcelona
Network dynamics of the human brain connectome with BrainX3

Alessandro Barardi, UPC, UPF, Barcelona
Phase-coherence transitions and communication in the gamma range between delay-coupled neuronal populations

Joao Barbosa, Intitut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS), Barcelona
A biophysical neural network model for visual working memory that accounts for memory binding errors

Rodrigo Alejandro Cofre Torres, UNIGE
Spatio-temporal linear response of spiking neural network models

Joshua Davis, University of Nottingham
Travelling wave and bump dynamics in a spiking neuronal network

Pavel Esir, N.I.Lobachevsky State University of Nizhny Novgorod
Superbursts and complex activity patterns in mathematical models of cultured neural networks

Arseniy Gladkov, N.I.Lobachevsky State University of Nizhny Novgorod
Network synaptic plasticity in dissociated neuronal culture with directed connectivity

Yu-Ting Huang, Institute of Physics, Academia Sinica, Taipei
Synaptic mechanism of reverberation activities of a synchronized bursting event in neuronal cultures

Maciej Jedynak, UPF/UPC, Barcelona
Stimulus induced resonance in a neural mass model driven with a temporally correlated noise

Bahadir Kasap, Radboud University Nijmegen
Synchronized population activity in a spiking neural network model of the midbrain superior colliculus

Filip Melinščak, BitBrain Technologies, Zaragoza
EEG-based decoding of attentional states during movement

Ernest Montbrio, Universitat Pompeu Fabra, Barcelona
Macroscopic description for networks of spiking neurons

Diogo Santos Pata, SPECS, UPF, Barcelona
The effects of hyperpolarization-reset on entorhinal grid cells scale and intrinsic frequencies along the dorsal-ventral axis

Jose Luis Perez Velazquez, University of Toronto
Control of pathological behaviours using feedback intracerebral stimulation: Using the brain's own dynamics to control its activity

Sid Visser, Centre for Biomedical Modelling and Analysis, University of Exeter
GPU accelerated evaluation of delays neural fields

Emma Wilson, University of Sheffield
Cerebellar calibration of topographic maps in the superior colliculus using the adaptive filter model

Weronika Wojtak, University of Minho
Learning joint representations for order and timing of perceptual-motor sequences: a robotics implementation of a dynamic neural field model

Neural Coding

Iñigo R. Arandia, Fundacio Sant Joan de Deu, Barcelona
Fluctuations of population activity modulate neuronal tuning and impact encoded information

Oded Barzely, Tel Aviv University
Implementation of sparse coding for pitch estimation

Nebojša Božanić, ISC, CNR, Sesto Fiorentino
SPIKE-Synchronization: A parameter-free and time-resolved coincidence detector with an intuitive multivariate extension

Alban Levy, University of Nottingham
Envelope coding in the Cochlear Nucleus: a Data Mining Approach

Qian Liu, University of Manchester
Benchmarking spike-based visual recognition

Gorana Mijatović, Faculty of Technical Sciences, Novi Sad
Oscillatory dynamics of field potentials in the frontal cortex during decision making

Mario Mulansky, ISC, CNR, Sesto Fiorentino
Time-resolved and parameter-free measures of spike train synchrony: Properties and applications

Ramon Nogueira, Fundacio Sant Joan de Deu, Barcelona
Neuronal activity in OFC is predictive for rats' upcoming choice

Alexander Simonov, N.I.Lobachevsky State University of Nizhny Novgorod
Reinforcing inputs of single neuron in a simple model of spiking neural network

The abstracts of the posters can be found at the following link:
http://www.neural-engineering.eu/BarcelonaConference2015/PosterAbstract.pdf

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Other useful information

Talks will be held at the Conference Hall - Auditorium of PRBB. It is situated on the first floor of the central courtyard and has independent access from the rest of the building (through stairs located at the ground floor, main entrance of PRBB). A large terrace in front of the conference hall overlooks the sea.
To get access to the auditorium, participants do not need to register at the reception of the main building. The conference hall has independent access.

Coffee breaks will be offered in the half-covered terrace in front of the main entrance of the conference hall.

Lunches will be served at the Canteen inside the PRBB. The restaurant is located inside the main building of PRBB at the ground floor. ***To access the restaurant, you'll need to show your voucher and badge at the reception.***

The poster session will be held on Tuesday on the ground floor of the PRBB.

Throughout the conference wireless connection will be available and the password will be provided by the organisers. The PRBB also participates in the Eduroam project, which aims to allow network access for visitors from academic institutions associated with Eduroam. Access to the service is always delivered with the same credentials as in the home institution.

The conference dinner will be held at the restaurant of the Hotel Pere IV, Carrer de Pallars, 128-130, near the PRBB.

More information is available on the conference webpage:
http://www.neural-engineering.eu/BarcelonaConference2015/

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