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List of Abstracts (in alphabetical order)

Application Command Protocol a new system to spread commands to a Neuromorphic Multicore Platform

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Neuromorphic hardware architectures represent an active and growing research field. Multicore neuromorphic platforms come with a custom library for efficient development of neural network simulations. While these architectures are mainly focused on real-time biological network simulation using detailed neuron models, their application to a wider range of computational tasks is increasing. The reason is their effective support for parallel computation characterised by an intensive communication among processing nodes and their inherent energy efficiency.

For instance, an N-body simulation requires the computation of interactions between a large number of bodies to determine the overall system evolution. This is the core of a number of computational physic and biology applications such as atomistic and molecular dynamics simulations. However, to unlock the full potential of these architectures for a wide range of applications, a library support for a more general computational model has to be developed. My work focuses on the implementation of a standard MPI interface for parallel programming of neuromorphic multicore architectures. The MPI library has been developed on top of the SpiNNaker multi-core neuromorphic platform, featuring a packet support for multicast communication. The proposed MPI implementation has been evaluated using an N-body simulation kernel, showing very good efficiency behaviour. Results suggest that the considered neuromorphic platform with our MPI library are very promising for tasks where communication is prevalent."

SPH simulation of unified radiative and kinetic AGN feedback and their effect on Galaxy Clusters

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Hydrodynamic simulations of simplified sub-grid models for gas accretion on to black holes and AGN feedback have so far been done on single galaxies and large-scale cosmological simulations. Such models typically depend on various free parameters, which are not well constrained. We present a new advanced model containing a more detailed description of AGN feedback. The model takes the dependence of these parameters on the black hole properties into account and describes a continuous transition between the feedback processes acting in the so-called radio-mode and quasar-mode. The energy from a supermassive black hole (SMBH) is coupled to the surrounding gas in radiative and kinetic form depending on the accretion rate. The kinetic feedback will mimic the relativistic AGN jet, by imparting a one- time velocity increment on gas particles lying inside a bi-conical volume around the SMBH. We perform hydrodynamical simulations of an isolated galaxy cluster (total gas mass 1.51e8 M_sun/h). The study is still in progress and I can therefore give a report on the current state of our research.

Robot Control with Spiking Neural Networks

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Recurrent neural networks designed according to the principle of reservoir computing harness their rich dynamics for high-dimensional representations of a continuous stream of input data. Those representations can subsequently be used for learning a mapping between a given input to a desired output stream. The concept of Liquid State Machines (LSMs) has been proposed in [1,2] for modeling the computation in cortical microcolumns using a randomly connected spiking neural network as reservoir. Neuromorphic architectures like SpiNNaker [3] provide massively parallel computation necessary for running complex spiking neural networks in real-time while being energy efficient - both highly important properties for robotic systems. Research done within the Neurorobotics Subproject of the European Human Brain Project aims at leveraging the computational properties of LSMs for robot control. Musculoskeletal robots promise compliant and save human-robot interaction but suffer from being hard to control due to inherent nonlinearities and a typically non-unique muscle Jacobian. Therefore, instead of traditional control strategies, LSM-based neural control is being tested in a supervised trajectory learning task. In a different project, an LSM is used for the control of an autonomous mobile robot. In a future phase of the project an event-based dynamic vision sensor will be added, allowing for lower power consumption and higher computational efficiency as well as faster response time to dynamic changes in the environment. This presentation intends to give an overview of different approaches for implementing Liquid State Machines on the neuron simulator NEST as well as on SpiNNaker and using them for neural control of robotic systems in hardware and simulation.

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Modeling brain responses to perceived speech with artificial neural networks

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One of the ways to understand how the human brain processes information is through modeling the observed neural activity evoked during an experimental task. In case of natural speech comprehension, this approach would mean training a model to predict the brain activity based on some features of natural speech. Some previous work has shown significance performance of linear models in this task, however, to our knowledge more advanced models, such as artificial neural networks, have not yet been applied in this context. In the present study, we collected the brain responses to a naturalistic audiovisual stimulus, such as a short feature film and modeled the observed responses using acoustic sound features in a number of modeling frameworks. The neural responses were obtained using electrocorticography (ECoG). The acoustic sound features were extracted from the soundtrack of the feature film. We used three different sets of features: timedomain features, spectrogram features and spectrotemporal modulation energy features. As a baseline model we used a kernel linear ridge regression which provided a linear mapping from the acoustic feature space to the observed neural responses. Apart from the linear model, we implemented several recurrent neural network (RNN) models varying in architecture of the hidden units, amount of the hidden units and number of hidden layers. The performance of the linear model and the RNN models was compared using oneway ANOVA and post-hoc Tuckey's honest significant difference (HSD) tests. We found that the brain responses to unconstrained natural speech could be modeled successfully by the RNN models regardless of the type of the input features. The performance of the linear ridge regression model depended strongly on the type of the input features. Using complex non-linear features, such as spectrotemporal modulation energy filters led to insignificant difference in performance between all models. Successful performance using the time domain features was only achieved with the RNN models. Further analyses showed that among the factors that contributed to the superior performance of the RNN models was the ability of the RNN models to integrate the input information over time, as well as the presence of the non-linear transformations in the hidden units. Finally, analysis of the hidden states learned by the RNN models showed that different input features at varying time points contributed to the model predictions throughout the temporal and frontal cortices. Overall, in the present study we observed that many of the constructed models provided significant predictions of the neural responses to perceived speech. We observed that the artificial neural networks (RNNs) yielded best performance and learned interpretable features representations. We believe that application of artificial neural networks to the functional brain data is a promising new direction in the field of computational cognitive neuroscience.

Segmentation of images imitating axon branching using Deep Learning networks

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One of the key challenges in medical imaging is to automate image processing after acquisition. In this field one of the key problems, known as segmentation, is to identify and locate the structures of interest within an image. Obtaining segmented medical images is very promising because it would allow other algorithms to perform many tasks like identifying malformations and diseases. However the segmentation issue still remains unaddressed even if there are many suggested possibilities. However, many of the proposed solutions are fragile: they are developed for one type of imaging problem and are only weakly transferable or unreliable when applied to another. Hence the aim of my project is to exploit the potential of deep learning neural networks, which turn out to be very efficient at performing such tasks. My project focuses on thin and long structures such as axons and vasculature. Another issue of medical image processing is the recurrent imperfections present in all images. It is widely known that all current methods of imaging introduce more or less noise and attenuations, sometimes responsible for partial disappearance of structures. Here we propose to address this problem along with segmentation. The inputs of the neural network would be grey-scale images of axons and vasculature as they are acquired with existing technics (meaning with noise, attenuation, gaps, etc.). The network will learn to denoise the original image and to perform segmentation. Eventually the output would be a labelled and cleaner version of the input. The results of such a process could then be used to run other algorithm. The need of reconstructing images leads us to use particular networks called Autoencoders coded on Python that will denoise and label the images at the same time. To obtain decent results, a deep learning network has to be trained with a huge amount of data (several tens of thousands). However in our case obtaining such a dataset would be very long, difficult and expensive due to the experimental aspect of the task. In order to decrease the number of real data needed for the training, we will first use surrogate images mimicking axons and vasculature. Then we will use real acquisitions for fine-tuning in order to obtain good results when testing the network with real data. That is why the first part of this project focuses on generating a good model for the artificial images, which will be also provided to other colleagues to train different other networks.

Neurogenesis on SpiNNaker

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Neurogenesis is a process of nerve tissue creation taking place during prenatal development or during adulthood in two discrete areas of the brain: the subgranular zone (SGZ) of the hippocampal dentate gyrus, and the subventricular zone (SVZ), which projects through the rostral migratory stream to the olfactory bulb. In the hippocampus, newborn cell survival has been shown to increase performance in trace eyeblink conditioning, while levels of proliferation positively affects reactions to novelty, with positive correlations regarding perceptual and memory functions also identified in the olfactory bulb. We are investigating the problem of designing structurally evolving spiking neural networks running on the SpiNNaker neuromorphic computation platform, as well as the computational advantages of enabling neural populations to self organize using stochastic processes. This platform is a massively parallel system relying on low-power ARM CPUs interconnected using a custom communication fabric in order to efficiently simulate spiking neural networks in biological real time. The research revolves around enhancing the existing PyNN neural simulator running on SpiNNaker to allow for structural plasticity in a biologically plausible way. More specifically, the processes to be investigated are neurogenesis and synaptogenesis as they occur post-development, in preexisting circuits. Initially, the process of synaptogenesis will be modeled in the context of topographic map formation, laying the groundworks for encoding and using spatial information in spiking neural networks (SNN) simulated on this distributed neuromorphic system. Afterwards, newborn neurons will be allowed to be created at runtime, the rate of which will be controlled using a homeostasis mechanism. These experiments have as a main desired outcome the exploration of additional learning mechanisms in artificial spiking neural networks, more specifically a mechanism to complement synaptic plasticity (STDP[5]). The mechanism that we are exploring is expected to provide a longer-term type of learning, encoded by the topology of the network (weeks to months), while STDP provides shortterm learning (minutes to hours). One application of structural plasticity on SpiNNaker will be in creating an agent that will learn to play video games using a reinforcement learning algorithm implemented in spiking neurons. In the context of this task, this novel learning mechanism is expected to provide transferable skills between different games, i.e. to allow the agent to learn a new game more rapidly based on previous knowledge of a different, yet similar game. Additionally, we postulate that synaptic rewiring can, from a computational point of view, provide a form of random search of the state space of the game, thus helping in exploration.

Optimizing neuronal stimulation using a gradient-based algorithm

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The action potential is the central information carrier in the brain. Hence it is crucial to understand what input signals leads to its initiation. This is constrained by the dynamical properties of the neuron. An additional major constraint on the nervous system is its energy consumption, which is indeed mostly spent on synaptic input signals. In this project we aim to characterize optimal input signals for a given neuron model. The search for an optimal stimulus can be seen as a constrained optimization problem: the goal is to change the state of the neuron such that it fires an action potential under the constraint that the costs of the incoming stimulus are minimal. Previous work (Chang and Paydarfer, 2014) proposed a gradient-based algorithm that iteratively finds such a stimulus given a predefined cost function. This work was based on a particular type of the Hodgkin-Huxley model of the giant axon of the squid and on a quadratic cost function on the stimulus. However, numerous classes of neurons exist with different dynamical properties. We therefore extend the algorithm and apply it to more general models (e.g., the Morris-Lecar model) to compare optimal stimuli of neurons with different dynamical properties. Furthermore, we formulate and test candidates for biologically more relevant cost functions and investigate how exogenous parameters such as temperature might influence the shape of the theoretically optimal stimulus. The goal of our project is to see how different cost functions change the optimal stimuli for eliciting an action potential and how the resulting stimuli compare to those observed experimentally. Additionally, we hope to contribute to applications in which stimulus waveforms applied to neurons play a crucial role, e.g., in the field of deep brain stimulation.

Machine learning tools for cognitive status prediction through language analysis

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Due to the increasing incidence and prevalence of dementia across the world, its thoughtful care is becoming socially paramount and improving its prevention is increasingly demanded by public health. Detecting the disease as early as possible in order to make more effective interventions is a key research goal. Using spontaneous conversations, we aim to identify verbal and non-verbal communication features that are helpful in predicting cognitive status with respect to Alzheimer's disease. We plan to train machine learning and natural language processing models to differentiate the speech of AD and non-AD patients using (at first) the Carolina Conversation Collection, a dataset to which I have recently got approval to access. Our hypothesis is AD diagnosis will show identifiable patterns during dialogue interactions, such as disrupted turn taking, differences in speech rate, lexicon, prosody, etc.. given they generally show poorer conversation abilities. One of the characteristics that difference our approach from others (to the best of our knowledge), is that we are not only looking at the patient's speech features, but we will also detect AD based on characteristics of spontaneous spoken language dialogue, adding information and improving prediction accuracy. Automatically recognise the first signs of disrupted communication using speech features can provide useful tools for the design of technologies for care-giving and cognitive health monitoring to help address these challenges. Thus, this approach offers the possibility of mental health monitoring methods which would be non-invasive and low-cost in terms of time and resources. In future work, we plan to use these tools to infer neuropsychological and psycholinguistics aspects of behaviour, and for more reliable prediction of cognitive decline.

Interpretable Deep Learning to elicit Learner Patterns

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The successful implementation of Interpretable Deep Neural Networks(DNNs) will not only elicit additional domain information, but also because of their biologically inspired structure, their interpretability could provide clues on how the human minds operate. A deeper and more detailed understanding of the cognitive processes that govern learning will increase both the efficiency, with which teachers deliver new information, and will enable students to process new information more rapidly and successfully by allowing them to be more self-aware of the way they learn. This project will develop a method to analyse and explore the internal operations of DNN in order to provide interpretable reasons for the model's behaviour. Our goal is to create extremely effective machine learning methods that make sense of humans by making sense to humans. AI in Education(AIEd) investigates all forms of knowledge acquisition in order to enhance both formal education and the personal lifelong desire to learn. This project investigates reverse-engineering learning patterns from student interactions with Massive Online Open Courses (MOOCs) through a methodology for Interpretable Deep Learning. The successful development of such methodology will lead to the extraction of generalizable inferences about the cognitive processes that govern learning. The results will increase both the efficiency, with which teachers deliver new information, and the learners capacity to process new information more rapidly by allowing them to be more self-aware of the way they learn.

Neuronal Tracking using Trust Region Policy Optimization

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A better understanding of the brain functionality requires a thorough understanding of which neurons are connected with each other. Current imaging technique are able to provide precise scans of the cortex but because of a lack of available algorithms that are able to digitally trace neuronal structures despite breaks in the axon, studying the connectome requires a lot of time and can not be done on a greater scale. Finding a method that will accurately trace neurons is the main obstacle remaining towards an accurate reconstruction process of the brain map. Despite the fact that progress has been made in image processing algorithms in the past years, manual tracing remains the safest procedure. Therefore, although an important part of the work can be automated, the work done by humans still needs to be reduced. Simple algorithms that just follow a line fail in realistic scenarios containing break errors, but an agent using a more complex algorithm, should theoretically continue across the discontinuity. This project aims to test a new deep reinforcement learning method called Trust Region Policy Optimisation (TRPO) that will trace neuronal axons in artificial 2D data sets. This algorithm is a policy optimization method that combines reinforcement learning with the use of neural networks as function approximators. It has recently provided high-quality results in robotics and game playing from images (at Berkeley), and we hypothesize that it will also yield strong results in tracking axon branches.

Using Ordinal Synchronization to evaluate coordination between dynamical systems

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In 2002, Bandt and Pompe proposed the use of ordinal patterns to evaluate the entropy and complexity of time series [1]. Their methodology consists on binning a given time series (each bin with length D), and ranking the values inside each bin, which leads to a series of vectors of length D. Next, the evaluation of entropy and complexity is based on the probability distribution of the obtained vectors, each one corresponding to an ordinal pattern. Here, we propose a generalization of this idea, with the aim of quantifying the coordination between two (or more) dynamical systems through the analysis of their corresponding time series. We call this new measure, the Ordinal Synchronization (OS). As Bandt and Pompe, we obtain a series of ordinal patterns of length D from the binning of the times series of two dynamical systems. Next, the inner product of each vector against its correspondent one from the other time series is computed. The result is averaged and normalized to get a value between −1 and 1 for each pair of time series. A value near −1 indicates opposite or anti-synchronization (as vectors in each time series tend to be, on average, antiparallel), a value near 0 indicates no synchronization (orthogonal vectors), and a value near 1, high synchronization (parallel vectors).

We analyzed several simulated and real time series, for different number of dynamical systems and coupling between them, and compared the results with classical synchronization measures, namely mutual information (MI), coherence (C) and phase locking value (PLV). Our results show how OS captures subtle differences not accounted by classical measures. Both amplitude and phase determine the rank of each value in every bin, so this new measure offers a trade-off between phase and amplitude synchronization. It shows several advantages when compared to other synchronization measures: computation time is extremely decreased; it doesn't make any assumption on the time series distributions; it is robust to noise; as a general measure for synchronization, it is applicable in many contexts; and, further more, it captures anti-phase synchronization, a very realistic process in natural and artificial systems, many times neglected by a diversity of synchronization measures.

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Transition Between Encoding and Consolidation in the Hippocampus. A Modeling Investigation

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Modeling is an effective way to try to understand how a system works as we try to come up with a model that describes the system and predicts its behavior. Here we investigate how the dynamics of the place cells in the hippocampus changes between encoding and consolidation/replay of spatial memory. For building a model we need to have assumptions that are based on physiological data for our model to be as realistic as possible. We base our model on the theory of cholinergic modulation of the CAN current (calcium activated non-specific cation current). Acetylcholine levels are known to be high during periods of active waking which correspond to memory encoding and low during periods of sleep or quiet waking which correspond to memory consolidation. It is also known that acetylcholine suppresses synaptic transmission and enhances cellular excitability via the activation of CAN current. Consequently, we observe in our model -on one hand- persistent firing of the place cells in the high acetylcholine state that leads to activation of the following place cell in the memory sequence in real time. On the other hand, we observe firing of the whole memory sequence of place cells in timely compressed manner in the low acetylcholine state due to enhancement of synaptic transmission.

A Neuromorphic Implementation for Legged Robot Walking

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The aim of this project is to develop a central pattern generator output for controlling the walking of a 4-legged robot (Allbot). The neuromorphic hardware Spinnaker is used to train a spiking neural network for generating the CPG patterns for each joint of the robot.

On biological accuracy in neural networks and the “moral status” side effects of developing conscious machines

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In the past decades researchers have attempted to create artificial neural networks (ANNs) that, in one way or another, attempt to exhibit consciousness. Even though consciousness per se is one of the few concepts in philosophy and science that is yet to be defined and that is often deemed elusive and even beyond comprehension, various artificial intelligence (AI) systems are created with an endeavour to manifest this complex and mysterious property of biological (especially human) systems.

Using various computer simulations (such as CRONOS(Simons), CyberChild and Go) as examples, and drawing on philosophical concepts and theoretical models this work will present why all current attempts at achieving conscious states are bound to failure. Specifically, the distinction between biologically implausible and biologically accurate ANNs will be drawn as the main obstacle on the way of ANNs manifesting consciousness. I will focus on why biological plausibility (in terms of cortical architecture and functioning characteristics) is the only logical possibility of creating true intelligence and consciousness. Finally, an emerging problem of the moral status of such ANNs will be introduced, with reference to the relevant theoretical works in philosophy and neuroscience, as well as the latest practical implementation attempt by the EU.

Real-time neuromorphic encoding of visual stimuli acquired with a camera through Labview interface

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The processing of the visual information in humans ends in the cortex but already starts at the level of the retina. The first neural encoding of visual stimuli occurs at the level of the ganglion cells whose axons converge into the optic nerve. However, the firing rates of the ganglion cells carry information about the external stimulus after that this has already been processed by the complex neural circuits within the retina, made of photoreceptors, horizontal, amacrine and bipolar cells. The aim of this work is to emulate the neural dynamics of human ganglion cells through a real time implementation of spiking neuron models. Visual data acquired by means of a webcam will be encoded in the spiking patterns of the simulated ganglion cells mimicking the way the same image would have been encoded in ganglions cells firing after reaching the retina. Our algorithm in particular aims at encoding colour features of the image with a neuromorphic approach, contributing to the quest for an innovative bioinspired artificial visual system. Briefly, image processing and reconstruction work as follows. A grid of arbitrary size is applied on the real time acquired image, determining the resolution of the artificial sense. Each one of the regions of interest feeds a virtual neuron. The neurons are implemented on a National Instrument myRIO embedded device, which is reconfigurable and reusable and can feature parallel programming and high execution frequencies. We modelled ganglions cell with an Izhikevich neuron model, implemented in LabVIEW. A proper choice of the model parameters was selected to replicate the adaptive properties of the retina in processing to contrast and colours. Exploiting the adaptive dynamics of the neurons, 9 colour features, that are 7 biologically relevant colours and black and white, are encoded into different firing rates. Real time decoding of these firing rates finally leads to a colour based reconstruction of the image. The obtained results show real time recognition of 5 out of the 9 classes previously encoded (red, green, blue, black and white), under certain controlled luminosity constraints. The 20 kHz updating frequency of the decoding of the image is biologically plausible. Moreover, the achievable spatial resolutions of the grid compete, or in some cases even exceed, the ones of the available artificial retinal implants. This work offers a classification method for visual features recognition. The advantage of bioinspired methods is the reduction of computational complexity, resulting in an overall optimization, keeping high efficiency. Taking advantage of the built-in Wi-Fi of the myRIO board, the developed system could be exploited in autonomously moving robots. Finally, this study may be useful for closed loop hybrid bionic systems to restore missing vision-sensory function or to augment it and it could also be integrated in neurophisiological studies.

Cognitive Robot Architectures - A Design Decisions Perspective

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Architectural design decisions are essential elements of system design and development. Likewise, they significantly affect engineering approaches in designing cognitive robots. Consequently, the experiences and knowledge gained from making and employing design decisions can evolve into a well-established knowledge base, such as design patterns. As an example, in regular software development, an architect can resort to a range of architectural patterns or styles to create a design for a particular scenario. However, such established design patterns and styles are not available in the area of cognitive robotics. Moreover, although design decisions and approaches to a problem determine a significant part of the solution, to the contrary they are not explicitly recorded and maintained. As a result, resulting artifacts fall short form showing what rationale, rules, and constraints lead to those design artifacts. Hence, understanding and documenting design decisions is crucial and may prevent repetitions of failures which could be otherwise avoided.

Therefore, this study aims to survey the state-of-the-art in cognitive robotics architecture and assess design decisions by mining the architectural knowledge base in cognitive robotics research. The perspective is set from the aspect of software engineering, mainly architectural design decisions with significant value to cognitive robot design and implementation. As a research agenda, a review of cognitive robot architecture is outlined to synthesize architectural design patterns in cognitive robotics.

Keywords:

cognitive robots, cognitive robot architecture, design decisions, design patterns, embodiment, neurorobotics

Single patients as outliers in neuroimaging? Introducing the Mahalanobis-distance as a novel tool for epileptic lesion detection using DTI data

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MCDs are important causes of drug-resistant epilepsy. Some subtypes, e.g. focal cortical dysplasias (FCDs) pose serious challenge to identify in MRI. We aimed to develop an automated post-processing tool for the identification of such lesions by the examination of WM microstructure, based on T1 and diffusion weighted MRI data. Methods and Materials: 18 patients with MCDs and 31 controls were involved. MCD subtypes included polymicrogyria (7) schizencephaly (2), subependymal heterotopia (2), and FCD (12). Diffusion weighted images (SE-EPI sequence, 32 DWI directions with b=800s/mm2, one b=0 image, 1.67x1.67mm resolution, 2mm thick axial slices, no gap) and high resolution 3D T1W (1mm isotropic resolution, sagittal slices) images were acquired at 3T. DWI preprocessing steps were performed in ExploreDTI, including motion and susceptibility distortion correction, registration to the T1W image for EPI-distortion correction, robust tensor fitting with outlier exclusion and calculation of tensor-eignevalues. We used SPM12 for anatomical segmentation and spatial normalization using the DARTEL approach. Each of the diffusion tensor eigenvalues was used as a dimension in the composition of multivariate Gaussian probability distributions; thereby each WM voxel was assigned 4 numbers in each subject. Voxel-wise, multi-dimensional Mahalanobis-distance was calculated as a measure of difference between a patient and the group of control subjects in simulated and real datasets. Simulations and fractional receiver operator characteristics analysis (FROC) were used in order to evaluate the methods diagnostic performance. The statistical significance of the distances was assessed using the cumulative distribution function of the F-squared distribution with appropriate degrees of freedom. Family-wise error rate and false discovery rate control with Benjamini-Hochberg step up algorithm was employed to correct for multiple comparisons. To validate the results of our approach, MCD ROIs were delineated using an automated toolbox (MAP07) and reviewed and corrected by experienced radiologists. Results We found significant ($p<0.001$) alterations of white matter microstructure adjacent to the lesions in 15 of 18 cases, with 12 of 18 patients showing changes in contralateral white matter, as well. Sign of the changes corresponded to literature i.e. FA tended to decrease and RD (or MD) tended to increase. As the mean age of our control group was 25, the method performed better with adults. In three patients (below the age of 10) additional to the expected regions adjacent to MCDs our approach identified regions in the internal capsule with smaller RD and variable FA values; these findings underline the importance of properly selected controls. Conclusion Our new, data-driven approach can serve as an aid in the identification of minute structural changes in MCDs; however, further research is needed to improve the specificity of the method.

Temperature dependent depolarization block in neurons

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Cooling is a way to reversibly silence neurons. Although the effect is thought to be related to a temperature induced shift of the so-called excitation block, the overall mechanism is not yet well understood. We numerically examine which temperature-dependent ion channel properties contribute to the addressed phenomenon and how the onset of the excitation block is altered by temperature in different channel configurations. We show that perturbations in temperature are capable of changing firing properties by adjusting channel gating rates as well as channel conductances. In particular, we demonstrate that cooling induces neuronal hypersensitivity by a reduction of peak channel conductance, leading to reduced input tolerance.

Benchmarking Neuromorphic Hardware

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We designed and implemented a modular benchmark framework for “black-box” testing of neuromorphic hardware systems and spiking neural network software simulators. The motivation for having a reasonable number of benchmarks is twofold: First, benchmarks evaluated on different platforms provide measures for direct comparison of relative efficiency (e.g. resource efficiency, runtime, ...), thus supporting the decision for or against a system based on personal requirements. Second, benchmarks may reveal opportunities for effective improvements of the system and can contribute to the development of future systems. Systems like the Heidelberg BrainScaleS-project [1], IBM TrueNorth [2] or the Manchester SpiNNaker chip [3] drive the evolution of neuromorphic hardware implementations, while comparable benchmarks and corresponding measures are still rare. The problem of “comparable” measures can be addressed in two ways: concerning application driven measures like classification accuracy it may be advantageous to implement these algorithms in a highly specialized manner to get the best result on every hardware (see e.g. [4]). This approach reveals what can be achieved on a specific or deficiencies, as these are worked around in backend, but will not necessarily uncover differences or deficiencies, as these are worked around in the specialization process. The alternative is a “black-box” approach, where benchmark networks are developed independent of the hardware on which they will be executed. We will give an overview of our work on benchmarking neuromorphic hardware and present some results from different hardware backends.

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Reliability in Wireless Communication of Medical Implants

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Chronic care is an eminent application of implantable body sensor networks (IBSN). Performing physical activities such as walking, running, and sitting is unavoidable during the long-term monitoring of chronic-care patients. These physical activities cripple the radio frequency (RF) signal between the implanted sensor nodes. This is because various body postures shadow the RF signal. Although shadowing itself may be short, a prolonged activity will significantly increase the effect of the RF-shadowing. This effect dampens the communication between implantable sensor nodes and hence increases the chance of missing life-critical data. To overcome this problem, we propose a link quality-aware medium access control (MAC) protocol called HACMAC, which adapts the access mechanism during different human activities based on the wireless link-quality. Our simulation results show that compared with the access mechanism suggested by the IEEE 802.15.6 standard, the reliability of the wireless communication is increased using HACMAC.

Visual Attention Modelling using Deep Neural Networks

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This work aims at integrating neuroscientific principles and modern machine learning techniques to form the basis for visual attention models using deep neural networks. The goal is to automatically learn a non-linear mapping from natural images to topological saliency distributions over the visual field and predict a meaningful sequence of eye fixations given this information. By dividing the complex task of attention modelling and visuo-motor integration into a series of simpler ones, each step can then be validated on empirical human data. Our contribution is the successful implementation of a saliency prediction model based on an encoder-decoder architecture for convolutional neural networks that accounts for the requirements of image-to-image mappings. The proposed method is capable of capturing relevant image features to accurately predict previously unseen human fixation patterns. Furthermore, a conceptual framework towards a closed-loop saccadic motor control system receiving continuous visual input is formulated.

Noisy Softplus: an Activation Function Enables Training Deep SNNs Off-line as ANNs

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The Spiking Neural Network (SNN) has not achieved the recognition/classification performance of its non-spiking competitor, the ANN, particularly when used in deep neural networks. Training SNNs by conventional ANN algorithms and mapping well-trained ANNs weights to SNNs are attracting attention in this field for its straight-forward mechanism. We proposed a new biologically-inspired activation function, Noisy Softplus, which is well-matched to the response firing activity of LIF (Leaky Integrate-and-Fire) neurons. Thus, any ANN employing Noisy Softplus neurons, even of deep architecture, can be trained simply by the traditional algorithm, for example Back Propagation (BP), and the trained weights can be directly used in the spiking version of the same network without any conversion. Furthermore, the training method can be generalised to other activation units, for instance ReLU, to train deep SNNs off-line. This research is crucial to 1) provide an effective approach for SNN training, and 2) increase the classification accuracy of SNNs using biological characteristics and close the gap between the performance of SNNs and ANNs.

Embedding Learning for Declarative Memories

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The major components of the brain's declarative or explicit memory are semantic memory and episodic memory. Whereas the se- mantic memory stores general factual knowledge, episodic memory stores sequences of events. In our approach we consider events to be quadru- ples i.e., triples in time. E.g., (Jack, receivedDiagnosis, Diabetes, Jan1) states that Jack was diagnosed with diabetes on January 1. Both from a cognitive and a technical perspective, an interesting research question is how episodic event data can efficiently be stored and how inductive inference can be performed. We propose that a suitable data representa- tion for episodic event data is a 4-way tensor with dimensions subject, predicate, object, and time. We demonstrate that the 4-way tensor can be decomposed, e.g., with a 4-way Tucker model, which permits both efficient storage and inductive generalization. We also propose that se- mantic memory can be derived from the episodic model by a projection of the time dimension, which can be performed efficiently using the learned model. We discuss both technical applications and potential relationships to the corresponding cognitive memories in the brain.

The third time lucky? Spiking Neural Network for the analysis of brain data

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A lot of challenges remains in the analysis of brain data: from spatial and temporal resolution in the acquisition to detecting new biomarkers which will allow predictive models. In last years many researchers haven been showed that most common methods used, such as correlations or independent component analysis (ICA), have some pitfalls in the dynamical analysis of fMRI. In this terms, approaches from AI seems promising alternatives. Here we present a new methodology based on Spiking Neural Networks to study dynamic evolution in brain-networks activity during long tasks fMRI experiments.

Soft Terrestrial Locomotion: challenging human intuitions with artificial evolutionary creativity

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In the last decades, the birth and development of Artificial Intelligences (AI) has led to neural networks algorithms which are able to compare and sometimes overcome human processing and reasoning capabilities. A new robotic frontier, called Evolutionary Robotics, which is an interdisciplinary research field, involving robotics, artificial intelligence, cognitive sciences, computational and evolutionary biology and artificial life, came into the world with the aim to apply optimization algorithms inspired by natural evolution to automatically design complete, adaptive and intelligent machines. The aim of this work is to compare the effectiveness of human creativity towards artificial intelligence design skills when they have to create efficient running soft robots. Three different soft robots are created and simulated under real physical environmental constraints and their travelled distances are compared to the ones covered by other three robots, resulting from the artificial intelligence algorithm, using the same set of possible materials and workspaces. The goal is defining the main possibilities and limits which artificial evolution creativity can have towards the human intuitive design. Briefly, three master students designed three different soft robots in a constrained volumetric workspace, exploiting different materials, which can be volumetric passive or active and have different stiffness properties. The designs were implemented in a VoxCad (Voxel Cad) environment, which is a voxel modelling and analysing software where multiple materials large deformation, collision detection and volumetric activation can be simulated in an underlying 3D dynamics physics engine (Voxelyze). In the next step, an artificial evolutionary algorithm was run many times; it was fed with the same workspace size and materials, the students used for their design, and its goals were to maximize the distance travelled by the robot and the structural void percentage and minimize the ratio of muscles in its morphology. The obtained results show that the products of the Artificial Evolution Intelligence (AEI) are faster than the corresponding human-guided designs, in all three material palettes. Nevertheless, almost all the AEI products seem not suitable for facing easily the reality gap compared to the human-designed morphologies, even though similar design principles have been exploited by both human and AEI. This study may led to more general results if more generations in the evolution algorithm were used to reach better offspring. Finally, this study may be useful to understand the differences between biological and artificial reasoning to perform a predefined task and allows to find new feasible and counterintuitive solutions based on a genetic algorithm which basically takes inspiration from and optimizes the way nature, and human brain too, faces problems.

Types of Cognition in Large scale cognitive brain systems and its Implications for futureHigh-Level Cognitive Machines

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This work summaries the actual knowledge about High-level Cognition process and its relation with brain systems and neural networks. Thus, it is possible to identify some paradoxes with an impact on the development of future technologies and artificial intelligence based in the study of complex systems: we may make a High-level Cognitive Machine sacrificing the principal attribute of a machine, the accuracy.

Shift-add-only exponential for the next generation SpiNNaker system

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Exponentially decaying values can be met in many parts of biological systems: Neuron membrane potential, biophysics of synapses, Spike-Timing-Dependent-Plasticity and more. As a result, for neuromorphic simulator designers, exponential is an important operation to have in order to simulate these phenomena accurately. In the first SpiNNaker system, exponential was designed in software which provided an easy to use but relatively slow and limited exponential. In my talk, I will describe a proposal to build a fast exponential unit in hardware that would be incorporated into the next generation SpiNNaker-2 system.

Modelling saccade planning and execution in the human brain towards improving robotic motor control

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Robotic navigation using visual input solely can be challenging even in a simple, uncluttered environment in regard to efficiency and performance. However, an average human is capable of navigating in a complex environment using visual inputs with impeccable accuracy. How does the human brain do this intricate task of recognising scenes and navigating efficiently? The first step is to analyse the scene for recognition of salient objects. This requires scanning the scene for identifying objects using their constituents such as edges or corners. The second step is to select an object of interest from the salient objects detected. This object is then localized and tracked through space and time. There are several ways of doing this using computer vision methods, but their performance differs greatly compared to a human brain's performance. Also, the object often travels in an unpredictable manner and human eyes can still track them with relatively better efficiency. Grossberg et al, 2012, discussed two systems – saccadic movements and smooth pursuit eye movements (SPEM) – that are used in conjunction for improving spatial localization of salient objects. Briefly describing the difference in these two systems - saccades are rapid eye movements that shift the fovea to peripheral visual inputs and smooth pursuit eye movements ensure an attended moving target is kept in a close neighbourhood of the fovea. These two systems are highly correlated in localization of moving targets. A neural model was developed to describe the saccade planning and execution involving areas MT, MST, FEF, LIP and SC of the visual pathway. As part of the CDP4 of the HBP, this neural model is simulated using the Python NEST library for virtual visual inputs. This model will eventually be tested on a robotic platform with vision sensors that function in a similar way to human eyes. By implementing the model on the robotic platform, the robot's control system can be improved upon by using saccades and SPEMs for superior object tracking and motion planning algorithms. Potential applications for simulating computational models of the visual system for virtual inputs involve comparing performance of these models to that of the brain from high-field fMRI data and other neuroimaging methods. This could possibly lead to understanding of the complex microcircuits in the brain and identifying computational deviations in visual disorders such as hemispatial neglect.

Reliability of effective connectivity from fMRI resting-state data: discrimination between individuals

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Neuroimaging studies traditionally analyze data at the group level, without considering individual characteristics. However, recent studies have stressed the relevance of subjectspecific analysis. In particular, efforts have been made to assess the variability and reliability of brain connectivity based on fMRI data to characterize individuals. Brain connectivity is typically calculated as the statistical dependence between the activity of brain regions - for example using Pearson correlation - giving matrices of functional connectivity (FC). To understand the causal interactions between regions that generate the observed FC patterns, the concept of effective connectivity (EC) has been developed. EC reflects many biophysical mechanisms such as neurotransmitters, excitability, etc., and captures spatio-temporal information of fMRI signals. We use fMRI resting-state data acquired from 6 subjects that underwent scanning for 50 sessions over 6 months, as well as data from 50 subjects that were scanned once. We calculate the whole-brain FC using a parcellation of 116 anatomical regions and estimate the EC for a dynamic model that reproduces the measured FC. This unique dataset allows us to evaluate the variability and reliability of the EC, taken as a fingerprint of fMRI activity, and to establish a comparison with the FC. Practically, we classify subjects from 1-6 sessions using their EC and FC. We train a linear classifier and are able to predict subject identity of remaining sessions. We achieve a very high identification accuracy (>90%) after training with 3 or 4 sessions with a duration of 5 minutes each. The better performance of the EC than the FC in discriminating between individuals demonstrates the importance of temporal information in fMRI signals and our model-based approach. The practical implication of these results go beyond the theoretical understanding of brain dynamics and is a first step toward the clinical applicability of EC. Our long-term goal is to provide a mechanistic explanation for neuropsychiatric disorders, allowing for the follow-up of subject-specific drug treatments or therapies based on EC measures from the non-invasive fMRI.

Design Automation of Nonlinear Neuromorphic Circuits in ABSYNTH

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ABSYNTH is an Analog Design Automation (ADA) tool which uses multi-objective and multi-parameter optimization techniques for synthesis of analog and mixed-signal systems. The design automation of linear systems is an established and still growing field. ADA for nonlinear systems, nevertheless, is less often pursued and is even more challenging to solve because of larger number of parameters and objectives. ABSYNTH has been demonstrated with competitive results on various common building blocks of sensor electronics, e.g., Miller-, Folded-Cascode-, Buffer-, and Instrumentation Amplifiers. The latest extension in ABSYNTH is the design automation of nonlinear circuits, especially neural circuits. The experiments were the sizing of a neuromorphic analog VLSI circuit and compared with a manual solution tediously obtained in previous work. The development of suitable cost functions received particular attention for the analysis of evolving circuits. Nominal design was the focus of the experiments in extrinsic evolution approach. The results of the experiments presented similar and better solutions compared to the manual design without need of any specialist and in extremely reduced design time.

Deep Natural Language Understanding

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Language is one of the most important aspects of human intelligence. With the ability to hear, speak and write, we can store and exchange information like no other species. Accordingly, large areas of our brain are dedicated to processing and understanding natural language. Replicating these capabilities in a machine would bring us a huge step closer to general artificial intelligence. Just think of a machine that can communicate like a human and can make sense of the vast amount of text data in the world. In this talk, I will give an overview of the current state of the art in Natural Language Understanding. I will highlight which tasks need to be solved and which models are being used. Particularly, I will show some of the latest approaches with deep neural networks.

Unsupervised Domain Adaptation for Vision and Sequence to Sequence Processing

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Building downstream algorithms for classification and regression using modern machine learning largely depends on the availability of sufficient labeled training data which covers most of the variance of the underlying distribution. Many problems in neuroscience and medicine however lack this property, since often only data from several labs and a limited number of subjects is available. Domain adaptation with deep learning recently arose as a method to pave the way for the transfer between dataset domains. In this talk, two novel approaches will be presented that are inspired by adaptation capabilities of the human brain and recent progresses in adversarial learning. The human brain is particularly well equipped to handle variations within stimuli and can accurately adjust its perception to outer circumstances, such as lighting, environmental circumstances, external movements and other influences that have a known impact on perception processes. For instance, color perception does not primary reflect the signal's actual wavelength, but largely also incorporates an expectation of an object's appearance. In this talk, results from two research projects will be discussed. Firstly, I will introduce the concept of Feature Aware Normalization, which allows to model internal perception processes in a deep learning system by incorporating arbitrary information about the world fed into the network, just as emerged in the human brain. This new network module was recently applied to the problem of color normalization in digital pathology, to remove variance emerging from the use of different imaging systems and staining protocols across datasets, achieving outstanding performance compared to current state-of-the-art approaches. The second part is concerned with generalizing this problem to arbitrary streams of time-series data, in particular EEG recordings. We extend the normalization procedure to the temporal domain and present a sequence-to-sequence transfer learning network that maps data from different domains into a common feature representation. Notably, no preprocessing as commonly done in EEG research was used at all; the network rather directly learns to disentangle temporal information in a high level latent space.

(No title)

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No abstract provided.

Deep driven fMRI decoding of visual categories

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Deep neural networks have been developed drawing inspiration from the brain visual pathway, implementing an end-to-end approach: from image data to video object classes. However building an fMRI decoder with the typical structure of Convolutional Neural Network (CNN), i.e. learning multiple level of representations, seems impractical due to lack of brain data. As a possible solution, this work presents the first hybrid fMRI and learnt deep features decoding approach: collected fMRI and deep learnt representations of video object classes are linked together by means of Kernel Canonical Correlation Analysis. In decoding, this allows exploiting the discriminatory power of CNN by relating the fMRI representation to the last layer of CNN (fc7). We show the effectiveness of embedding fMRI data onto a subspace related to deep features in distinguishing two semantic visual categories based solely on brain imaging data.

Multiple Equivalent Dipoles in Inverse Electroencephalography

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Within the context of this presentation, the following two case studies will be examined: Case study 1: An inverse EEG tool is presented exploiting multiple dipoles located on selected Brodmann Areas. Those areas represent main cortical functions, such as the motor, somatosensory, visual and audio cortex, enabling the interpretation of multiple brain structures' activity. In order to evaluate the inverse EEG tool, two EEGs were studied corresponding to an adult with dyslexia and one without. Both EEG's were acquired from adults performing a functional coherence task. Examining the dipoles' behaviour representing the cortical regions of interest, significant differences were observed. Namely, the equivalent dipoles extracted from the dyslexia case presented higher amplitudes as well as longer excitation times during the presentation of the stimuli. In general, the tool is able to describe the different cortical areas' activity and can be therefore utilized for a plethora of different case studies. (Submitted in the 30th IEEE International Symposium on Computer-Based Medical Systems - IEEE CBMS 2017, [3] of publications list). Case Study 2: Discrimination between the two different types of acute stroke (ischemic and hemorrhagic) is accomplished by the implementation the Inverse problem of electroencephalography technique. The study was based on electroencephalograms (EEGs) recorded from patients that had suffered from either ischemic or hemorrhagic stokes. The activity of the brain was simulated using a realistic head model excited by electric dipoles, which were allowed only to rotate about a fixed origin. Combining the calculated surface potentials of the head model and the electroencephalography (EEG) recordings, the inverse problem algorithm converged to a solution giving an equivalent dipole. Having a physiological head model, meaning that there were no pathological areas simulated within the brain, the resulted dipoles ended up including all the information about the pathologies and thereafter where able to distinguish each type of stroke. (Published in Biomedical Physics & Engineering Express, [1] of publications list).

Mathematics and the impaired mind: an idyllic relationship?

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In this presentation we will briefly pose whether the mathematical analysis of networks (complex systems' science) can help us to diagnose illnesses with anticipation to their most severe symptoms. In particular, we will be presenting some types of networks (with their corresponding simulations) and relating them to how some well-known phenomena appear to be susceptible to study with theoretical approaches.

Bio-inspired quadrupeds, from simulation to walking robots

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Understanding and reproducing locomotion is a very old interest of science and engineering. In the past century, this has taken a new meaning with the always increasing capabilities in designing quadruped and biped robots. Those platforms present at least two important advantages. First, through their agility and complexity, they are suited to operate in situations where today's wheeled robots still fail like exploration, rescue operations and social interactions. This need of a new kind of mobile platform has proven especially true during recent hazardous events like nuclear failure, earth shaking or building fires. Secondly, they are a very good tool for validation of hypothesis in biomechanics or neuroscience. Among the interesting research topics raised by those robots, we can cite the role of compliance and morphological complexity, which are believed to add robustness to external perturbations and to increase performance by externalizing the computation from a digital controller to the physical body. Another topic attracting a lot of efforts focuses on the relative importance of forward and feedback contributions in the controllers that provides robust movement and energy-efficient processing in the mammal's brain. A promising approach to solve all those issues consists in creating and experimenting with robots and artificial learning controllers directly inspired from biology and neuroscience. In this work, we show how we can use a spiking network model composed of randomly connected populations to create a Central Pattern Generators that acts as a controller. It will learn to produce multiple coordinated motor signals and make use of both feedback and frequency command to adapt to the current situation. We also provide a method to transfer efficiently the learning from simulations of 3D robot models and spiking neural networks with NEST to the real world. Finally, we test those approaches on a real quadruped compliant robot embedding a spiNNaker board.

Application Command Protocol a new system to spread commands to a Neuromorphic Multicore Platform

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In this work, we present a new network protocol and methodology to enhance both the configuration and the execution phases of the SpiNNaker Spiking Neural Network (SNN) simulator. We designed the Application Command Protocol (ACP) a new system to spread commands to the SpiNNaker platform. The ACP system accepts and process onboard a set of configuration primitives (data specification) encapsulated in custom packets, simplifying the management of chip memory. We optimised the two principal steps of the simulations on SpiNNaker through the embedding of the ACP logic in the executed applications. We designed two different ACP implementation: The first is applied inside the DS-E application and used during the SpiNNaker SNN Configuration phase. Whereas the second is embedded in a neuron application used during the SNN Simulation phase. The ACP implementation in the first application use a heavy interpreter and enables a more flexible and complete set of command to be used during the board configuration phase. While the ACP embedded in the second application is lighter and can be easily embedded in the neuron model applications, allowing the user to change parameters a run-time during the simulation. The achieved by the ACP interpreter embedded in the neuron model application have been assessed during the simulation of a SNN designed for classifying the handwritten numbers. Indeed, both the Training and Test phases were executed with important reductions in packet traffic and configuration time.

Bridging Computer science with neuroscience towards a new understanding of reasoning

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Our project studies the neuro-correlates of mathematical diagrammatic reasoning. Human brain are good at transforming abstract concepts, like mathematical theorem and entity relationships, into diagrams which facilitate understanding and reasoning about such concepts. For example, researchers show that for syllogism-solving tasks, group using Euler diagram to facilitate problem-solving have on average lower brain activations measured with fMRI than that of the group without using diagrammatic aid, indicating that diagrammatic reasoning reduces the cognitive load. Our aim is to study the neural correlates of such diagrammatic reasoning for a wide range of mathematical problems. We believe results of this study can then be used to guide researches in machine automated reasoning and build more capable and human-like reasoning system. Artificial Neural Network (ANN) has be shown to correspond to human neural activities at a significant level. One particular type of ANN, Convolutional Neural Network (CNN), has been particularly successful recently in image processing and speech recognition tasks. Recent research discovered significant correlations between CNN and brain activations of human testers when both are processing the same visual input. However little research has been done on modelling the reasoning engine, the pre-frontal cortex(PFC). This project studies neural activities in PFC, in combination with other cortical areas, while people are undertaking diagrammatic reasoning, and develop mathematical models that correlate human neural activities to artificial neural systems. We are recently developing new architectures of artificial neural networks that performs various diagrammatic reasoning tasks. One such architecture, combining state-of-the-art Recurrent neural network, Variational Auto-encoder and Generative Adversarial Network, is able to reason about entity relationships using Venn diagrams. This neural network reads a sequences of Venn diagrams representing set relationships, and encode them into a high-dimensional variational neural code. This neural code is then decoded by a generative reasoning network to output Venn diagram that fills the missing relationships. We aim to extend this architecture to more complex diagrams including diagrammatic proof of mathematical theorems, such as Pythagoras theorem. As our architecture produces a high-dimensional artificial neural code in the reasoning process. We can perform correlational analysis between the artificial neural codes and real neural codes in our brain circuit. Today’s 7 Tesla fMRI technology allows us to have unprecedented resolution of the brain activities. We plan to conduct experiments that let human subjects perform the same reasoning tasks as our artificial neural network does. We can then utilize Bayesian analysis, graph and community theory to discover correlations between neural codes, and use the results to further improve our architecture.

Multi-Source Learning for Multi-subject Neuroimaging Data

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Multi-Source Learning for Multi-subject Neuroimaging Data Experiments in neuroscience often involve paradigms using complex stimuli and multiple data channels. In most cases, experimental data are acquired from different individuals. In order to extract high-level information from these neuroimages, machine learning methods have been increasingly used for data analysis in recent decades. To infer common principles for the whole population, a model should be able to provide out-of-sample generalization, which we can measure through the prediction error on data from new subjects. However, standard machine learning methods assume that the training and testing data are drawn from the same distribution, while data from different subjects are drawn from different distributions. Therefore the major challenge that we face with such multi-subject data is to overcome the differences that exist between subjects. However, there is still lack of general machine learning setting for this challenge. Our proposal is therefore to use multi-source learning [Crammer et al. 2008] as a general setting to learn from data recorded in multiple subjects by stating that each subject is a different source of data. Using fMRI and MEG data recorded from a large number of subjects, we first confirmed that the strong betweensubject variability impairs the ability for classical machine learning algorithms to generalize to data from new subjects. Furthermore, we demonstrate that a simple multi-source learning strategy improves the generalization performances of such algorithms. Motivated by the results of these experiments, I will focus my PhD on designing more advanced multi-source learning methods for neuroimaging data. More precisely, my research aims at obtaining invariant representations across subjects, and we will use two different techniques to deal with the multi-source problem. First we will design a deep neural network architecture which could map several source domains into one target domain, while state-of-the-art deep learning algorithms map one source domain into one target domain [Glorot et al. 2011]. Secondly we will extend existing work that exploits optimal transport [Courty et al. 2016] to compute distances between probability distributions, so that the alignment of the representations could be performed in different source of data.

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Implementation of Dynamical Systems in Neural Networks puts Constraints on Learning

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Following the availability of experimental methods that allow simultaneous recording of multiple neurons in vivo, several studies have found that neural activity across different species and brain regions is constrained to a low-dimensional manifold. Lowdimensionality is not compatible with a homogeneous, randomly connected network but is indicative of some underlying structure of the network. In our work, we have shown that already existing frameworks for creating functional spiking neural networks also can be used to find a structure that gives rise to low-dimensional activity. In addition, using our application of these frameworks we explain why BCI-tasks are easier to learn when calibrated towards an "intrinsic", or natural, manifold of the neural state space than when calibrated outside of the manifold. In my short presentation I will give a brief review of experimental evidence of low dimensionality, a brief review of the Neural Engineering Framework and similar ideas for implementing dynamical systems in spiking neural networks, and finally show how the latter can be used to explain the former. This provides an example of how neural activity can be related both to the underlying network and to abstract functionality. Our solution also improves on previous attempts to explain low dimensionality, both in terms of explanatory power and biological compatibility.

Phase Response near fold-of-limit cycle bifurcation

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Describing neurons by systems of ordinary differential equations allows to investigate their properties using methods from nonlinear dynamics. For neurons with Type II excitability, the transformation from quiescence to tonic spiking can be linked to a fold-of-limit-cycles bifurcation, in which a stable and an unstable limit cycle appear simultaneously. Our goal is to investigate the filtering properties of the neuron in this physiologically interesting regime. In order to do so, we used a 2-dimensional persistent sodium & potassium model where the unstable branch arising from the fold-of-limit-cycles bifurcation collapses with the stable fixed point in a subcritical Hopf bifurcation. We investigate the Phase-Response-Curves (PRCs) of both the stable and unstable limit cycle. The PRC is the solution of a periodic boundary value problem and we use the (numerical) continuation software AUTO to solve it. In order to investigate whether the found PRCs were stereotypical for all fold-of-limit-cycles bifurcations, we further analyze a configuration of the 3-dimensional Wang-Buzsáki model where the unstable limit cycle originates from a big homoclinic loop bifurcation.

INference From Observational Research Methods (INFORM) Project: Adjusting biased estimates of treatment effects in nonrandomized studies

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Background: Randomized controlled trials (RCT) testing non-drug technologies are scarce due to a lack of legal requirement and durable patent protection that guarantee market exclusivity for profit. Reliance on nonrandomized studies (NRS) by health technology assessment (HTA) bodies is problematic due to inherent biases of the study design. Although existing tools assess the quality of NRS (Newcastle-Ottawa scale, ACROBAT-NRSi, STROBE, ROBINS-I), none address how actual study findings must be reinterpreted by knowledge users (decision makers, clinicians, researchers, patients) to derive realistic estimates of treatment effects. Objectives: The INference From Observational Research Methods (INFORM) project aims to create a tool for knowledge users to adjust biased estimates of treatment effects in NRS. We will 1) conduct a systematic review of low risk-of-bias (ROB) RCT and NRS of a select health intervention, 2) identify attributes of NRS associated with biased estimates of treatment and produce an algorithm to correct estimates, and 3) construct an easily accessible toolkit to guide knowledge users towards more appropriate interpretation of NRS.

Methods: (1) Systematic review. I will choose a health intervention with sufficient number of RCT and NRS to tease out associations between individual study attributes and treatment effects. I will develop search strategies to capture all eligible studies using MEDLINE, EMBASE, and CENTRAL. I will screen titles and abstracts using DistillerSR software. I will extract descriptive study information, intervention-specific outcomes, and all possible attributes associated with bias. I will perform classical and Bayesian meta-analysis using R. I will use common meta-analysis summary statistic (Cochrane's Q statistic, I2) to measure between-study variation and heterogeneity. I will pool outcomes according to study design: high ROB RCT, low ROB RCT, and NRS. (2) Algorithm. I will construct a hierarchical Bayesian random effects model to quantify how much bias is attributed to individual NRS attributes. I will produce a predictive algorithm to back-calculate treatment effects of NRS if individual parameters were adjusted to levels associated with less bias. (3) Toolkit. I will be part of a writing group composed of my supervisor, a statistician, and a senior graduate student that will publish the pooled results of 8 interventions in an international peer-reviewed journal. We will produce documents for technical and non-technical users, and develop a web-based interactive calculator to generate bias-adjusted treatment effects of a study.

Significance: Poor quality evaluation of non-drug technologies lead to inefficient use of healthcare resources and compromises patient safety. Web-based guidance documents and interactive calculators will aid practitioners, researchers, and patients to better interpret NRS results, and HTA bodies to better evaluate the quality of evidence and validity of efficacy claims.