Proceedings of the 1st Neuroengineering Retreat

May 14 - 17, 2017 in Fischen, Allgäu

M.Sc. Neuroengineering Program (MSNE)

Neuroscientific System Theory (NST)
Department of Electrical Engineering and Computer Science
Technical University Munich

Invited Talks

1. Thursday, May 11:
   Prof. Dr. Matthias Bethge, Bethge Lab, University of Tübingen
2. Friday, May 12:
   Prof. Dr. Heiko Neumann, Institut für Neuroinformatik, University of Ulm
3. Saturday, May 13:
   Dr. Dmitry Kireev, Institute of Bioelectronics, Forschungszentrum Jülich

Free Will and its Implications

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Each one of us think that we were free to behave differently than we behaved in the past, and also that we are the conscious source of our thoughts and emotions, and hence actions. Looking at it from a neuroscientific perspective, we can say that our thoughts are framed by the combination of: the events which happened with us by chance, and our decisions and the experiences caused by those decisions in the past. Let's consider a generic serial killer. His action to commit a new murder depends upon his brain activity, which in turn is shaped by his past (genes, childhood, education, kind of family. If he had free will, it means that he could have behaved differently. So, we can put blame on him. But there is no evidence to prove that a person is unbiased while making decisions. If one of us had gone through the same experience of life, may be we would also be like him. Nobody picks their parents, or the society in which they are born which develops their nervous system. Everyone's brain structure lead to different thoughts and hence different actions. If we think this way, then the tendency to put blame would disappear. No one is solely responsible for their actions. It does not mean that we free all the offenders, however it does put a point forth that we should be careful in the way we treat them. It should not come from a gesture of hatred but a hope of improvement. Above all, we may want to look around our sour relations in the past where we messed up by playing a blame game. Let's give it a second thought! Worth it :)

Artificial Intelligence in the context of Digital Health solutions

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The healthcare industry has a lot of stakeholders, e.g. general doctors, hospitals, which generate an incredible amount of data. Unfortunately, this data is not available to all stakeholders in form of an electronic health record, but rather single data pieces are distributed across many. Therefore, this limited access provides only limited insights to be generated out from the data. Luckily, there is an industry-wide trend in digitization of healthcare and thereby providing benefits to many: Better treatment options for patients, less costs for the health system and more time for the doctors dealing with its patients. Especially machine learning methods are used to investigate heterogeneous healthcare data for predictive analytics and automatization in patient workflow. A lot of startups are emerging in Digital Health, working close together with hospitals for immediate value proof. As high-tech startups often need a not unsignificant amount of money, a common roadmap for startup financing, especially university spinoffs, was shown. This is a call to action for all engineers interested in contributing to an increased level of healthcare quality.

Introduction to Moral Philosophy and Discussion of the Ethics of Neuro-Enhancement

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Reasoning about moral conduct can be very complex as several thought experiments that were given in the beginning of the talk illustrated. Therefore this reasoning must be done in a structured way, called moral philosophy or ethics. Central to ethics are moral theories out of which the positions of consequentialism/ teleology, deontology and virtue ethics were presented and related to the previous thought experiments. As a contrast to these traditional ethical theories we talked about Hans Jonas' seminal work on 'The Imperative of Responsibility: In Search of Ethics for the Technological Age' as a representative of modern ethics accommodated to the increased reach and impact of modern technology. Next, a short introduction was given to different fields and technologies that have the potential to enhance cognitive functions in humans, spanning from pharmacological nootropics and genetic technologies to Brain-Computer-Interfaces. In the subsequent discussion about the ethics of neuro-enhancement technologies the philosophical and the technical views came together when the different stakeholders and their moral arguments were analyzed.

Are we ready for human head transplantation ?!

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As the fusion of engineering technologies and medical sciences continues to advance health care and prove how effectively it can influence the progress of both fields, we keep pushing the limits and knocking non-stop on the doors of ethical dilemmas. In 2015, prof. Sergio Canavero, an Italian neurosurgeon, announces his promise to deliver the first human head transplant. Prof. Canavero plans with the help of Dr. Xiaobing Ren to implant the healthy head of the Russian volunteer to a healthy body of a brain-dead donor by the end of this year 2017. On one hand, the plan is to use a special diamond blade to cause the least possible damage to the spinal cord. On the other hand, the usage of a special substance called "PEG" together with spinal cord stimulation will help the healing of the spinal cord and fast regrowth of the neurons. Although prof. Canavero is extremely confident about the procedure, both the public and scientific society is negatively responding to the yet illegal surgery in many countries with the rising questions; Do we have the advanced technology to conduct such a challenging procedure? Are we ready to face the ethical and societal consequences?

Quantum Physics and Consciousness

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Consciousness has been a mystery for people of different specializations and backgrounds throughout history. The quest of understanding consciousness and defining it has triggered the interest of philosophers, neuroscientists and theologians that resulted in various theories and possible explanations that are being tested and updated the moment you're reading these lines! One way to approach this problem, is quantum physics. As strange and absurd as it seems, many scientists throughout history have tried to approach the problem of consciousness throughout the complexity of quantum physics and its properties and thus came up with theories suggesting existent quantum effects inside the brain of each one of us! The talk started with an introduction about consciousness, followed by a thorough explanation of the double-slit experiment, quantum entanglement and the observer effect to emphasize the importance of quantum effects and properties, and finally a recent theory about quantum cognition was discussed.

Improving Histopathological Tissue Classification with Transfer Learning and Bayesian Deep Learning

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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. When merging datasets and generalizing algorithms, it is often hard to deal with variance between subjects or datasets. Domain adaptation with deep learning recently arose as a method to pave the way for the transfer between dataset domains. The human brain is particularly well equipped to handle variations within the data and can accurately adjust its perception to outer circumstances, such as lighting, environmental circumstances, external movements and other influences on perception processes. 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. 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.

In collaboration with Daniel Bug at the Institute of Image Processing, RWTH Aachen University

Impact of Structural Plasticity in improving the learning rate of network and denoising the responses

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There has been relatively little research on structural plasticity in terms on computational modelling. It is quite unclear how structural plasticity works in conjunction with structural plasticity of synapses. In biology, it is well accepted that Long Term Potentiation is intermediated through the creation of new synapses. Also, the homeostatic mechanisms such as body temparature, blood pressure are carried out via creation/deletion of synapses. So, I delved in the research of such a modelling to see its impact in training our networks. I found a relevant paper, "Structural Plasticity Denoises Responses and Improves Learning Speed", published in Frontiers in Computational Neuroscience, 2016. The research is yet to complete. It is expected to get higher learning rate and less residual error after training the network via this approach.

Analogue circuit design of a portable nanoparticle detection device (POND) using printed sensors

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New strategies for electrochemical detection of syntactical release from cells can be simulated using nanoparticle impacts at a properly biased microelectrode. Upon oxidization of these nanoparticles, a charge transfer occurs resulting in a current spike, relating to particle size. The particle oxidization frequency relates to the concentration of nanoparticles in situ. In this project, a prototype circuit was designed, using Altium Designer, which utilizes three different instrumentation amplifiers, to construct a three-channel POND. The purpose of using different amplifiers is to assess the performance of each one of them in detecting the current spikes generated by oxidation of nanoparticles. The results of this project remain to be evaluated as the designs are still to be fabricated.

Lock-in Amplifiers and their Application in Fiber Photometry

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This project was concerned with simulations, characterisation and an evaluation of the noise performance of three different implementations of lock-in amplifiers (LIAs). LIAs are based on the principle of phase sensitive detection and have the main purpose of increasing the signal-to-noise ratio in an experimental set-up. Hence, they are widely used in a variety of research fields that deal with signals that are buried in large noise. We used LIAs in a fiber photometry set-up where we recorded fluorescent signals from brain regions in mice that express GCaMP. The noise characterisation measurements were not carried out in vivo but with a constant signal (green strip in front of the optic fiber). Several measurements were carried out to determine the best parameters (e.g. modulation frequencies, filter cut-off frequency, etc.) in terms of noise performance. Furthermore, I got introduced to multichannel extracellular recordings in awake behaving rodents, as well as to handling and surgery of the animals.

MSNE Research Project at the Chair of Cognition and Neural Plasticity, LMU Munich
Supervised by Prof. Dr. Anton Sirota

Spiking Neural Networks for Autonomous Robots

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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. In the research project, an LSM was used for the control of an autonomous mobile robot. In a future phase of the project an event-based dynamic vision sensor might be added, allowing for lower power consumption and higher computational efficiency as well as faster response time to dynamic changes in the environment.

Using Deep Neural Networks to Predict Bottom-up Saliency in Natural Videos

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Bottom-up saliency is a very important and active research topic for computer vision scientists. Researching bottom-up saliency aims at understanding the prominent features in an image or a video that trigger the observer to fixate their eyes on them. A lot of work has been done previously to detect saliency and predict fixation targets on images. However, little has been done on videos. In my research project, I used deep neural networks trained on classifying video actions to extract features from natural videos that had been watched previously by people while detecting their fixations using an eye tracker. These features in addition to the fixation targets were used to train a support vector machine (SVM) model that can then be used to classify features extracted from video frames to predict fixation targets.

Predicting Saliency in Videos using Two Stream Fusion Convolutional Neural Networks

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The goal of this project is to predict salient features in videos using convolutional neural networks accompanied with support vector machine. The convolutional neural network was a used to extract the features from the videos' frames. The data are originally collected from 54 subjects who watched different kind of Hollywood trailers, the fixation points of these subjects were measured using an eye tracker. This data along with the extracted features from the neural network are then used to train a support vector machine which then is used to predict the salient features.
The neural network consists of two towers, one trained on spatial information (original video frames), and the other is trained on temporal information (optical flow frames). The two towers are then fused together and a new convolution layer is learned on the spatio-temporal information using 3D convolution. The features were extracted from this convolution layer.

Conditional Autoregressive Neural Networks for multimodal time-series analysis

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Processing of physiological time-series is still a largely hand-crafted task. Unlike in fields like computer vision and speech processing, no standard pretrained deep learning architectures for feature extraction have been made available for standardized and robust processing of EEG data.
In this talk, a novel approach to data analysis is discussed by training a generative deep learning model for EEG time-series conditions on other modalities, such as ECG, EOG and EMG recordings.
This allows further research in a variety of applications, such as automated and robust artifact removal, anomaly detection and analysis of correlation and synchrony between time-series.

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