Brandenburgische Technische Universität Cottbus - Senftenberg

Forschungscluster Kognitive Systeme

Workshop “Cognitive Health Technologies”

BTU Cottbus – Senftenberg, LG 3A, R. 324
August, 19 – 20, 2019

Monday, 19.08.

14:30 – 14:45 *Welcome*, Matthias Wolff

14:45 – 15:25 *Challenges for the next generation of contextualized health outcome measurement*, Mike Martin

15:25 – 16:05 *Dynamical social network models of healthy aging*, Peter beim Graben

16:05 – 16:45 *Eye movements in medicine: The need for semantic annotation,* Erich Schneider

16:45 – 17:30 Open discussion

19:00 Conference Dinner

Tuesday, 20.08.

09:20 – 10:00 *Context dependent statistical models using products of variables,* Steven Boker

10:00 – 10:40 *Pre-processed maximum likelihood and analytical solutions to maximum likelihood in dynamical structural equation models,* Timo von Oertzen

10:40 – 11:10 Coffee break

11:10 – 11:50 *Multimodal analyses of user behaviour in ambient assisted living – The Mova3D project,* Ronald Böck

11:50 – 13:20 Lunch

13:20 – 14:00 *Human activity recognition for proactive, context-aware assistance,* Stefan Lüdtke & Thomas Kirste

14:00 – 14:40 *BioLithoMorphie® - A toolbox for the construction of 3D biological morphologies,* Andreas Schober

14:40 – 15:10 Coffee break

15:10 – 15:50 *Vector symbolic architectures and neural automata,* Peter beim Graben

15:50 – 16:30 *Theseus reloaded,* Markus Huber & Ronald Römer

16:30 – 17:00 Open discussion

Organized by LS Kommunikationstechnik (T 0355 69-2128)

Titles and Abstracts

Multimodal analyses of user behaviour in ambient assisted living – The Mova3D project

Ronald Böck, Magdeburg

A major challenge of the society is nowadays the increase of elderly people living in their own apartments but being depended on external assistants. It is known that a familiar environment is beneficial for the health, especially in the context of incipient dementia. In contrast, those human beings need assistance, which supports in daily activities. This results in a high demand of caretakers, who should be able to cover a larger number of people in need, in multiple (widespread) locations. Besides the distance, no fulltime coverage can be guaranteed. Therefore, in the Mova3D project, a multimodal omnidirectional sensor is developed, which allows an analysis of participants and their daily activities. Based on audiovisual observations dangerous and emergency situations are detected automatically, resulting in emergency calls considering doctors and responsible persons. Further, during "normal" days the participant is supported in their activities in terms of reminders, service applications, etc. To achieve valid estimations, multimodal assessments of the participant are conducted (considering the current state of privacy protection and data security). The talk presents the project's ideas and the (prototypical) technical realization as well as latest results in the analyses considering the applied modalities.

Context dependent statistical models using products of variables

Steven Boker, Charlottesville

In order to fit adequate statistical models to within-person health time series data, we need to be able to allow time-varying context to modify the strength of associations between variables. A recent advance in nonlinear statistical modeling allows the specification of this type of model using the general framework of structural equation models. We specify and fit such a model to time delay embedded data and show how context variables can be used as moderators while retaining the noise rejecting properties of smoothing on a context-dependent attractor manifold.

Dynamical social network models of healthy aging

Peter beim Graben, Cottbus

In their 2015 *World Report on Aging and Health*, the World Health Organization (WHO) emphasizes "that healthy ageing is more than just the absence of disease. For most older people, the maintenance of functional ability has the highest importance." In that report, the keyword "functional ability" is defined as "health related attributes that enable people to be and to do what they have reason to value". Another central keyword, "intrinsic capacity" is understood as "the composite of all the physical and mental capacities of an individual." Clearly, "intrinsic capacity" and "functional ability" are both correlated with biological age. However, WHO crucially points out that healthy aging should maintain "functional ability" independently from "intrinsic capacity" and biological age. In my presentation I suggest to operationalize the key concepts "intrinsic capacity" as a control parameter and "functional ability" as an order parameter of dynamical systems. Abstracting from most peculiarities of healthy aging, I consider relaxing sleep during night and social synchronization during daytime as those attributes that people have reason to value. To this end, I propose a Kuramoto toy-model of externally forced stochastic phase-coupled oscillators for the sleep-wake cycle in a social dynamical network. In particular, I model "intrinsic capacity" as the individual's resistance against stochastic perturbations and "functional ability" as the individual's faculty to synchronize with social affordances. I simulate the network's dynamics for four different topologies. As a result, "functional ability" crucially depends on social cohesion even in the case of lower "intrinsic capacity". I conclude

that social cohesion in an open society facilitates healthy aging in comparison to more hierarchically organized societies (including totalitarian systems).

Vector symbolic architectures and neural automata

Peter beim Graben, Cottbus

Cognitive health technologies will crucially depend upon interpretable and explainable artificial intelligence (XAI) in order to be trusted by patients and medical experts. Current deep neural networks (DNN) are more-the-less black boxes that output a classification decision (e.g. a medical diagnosis) to a given input pattern (e.g. an array of symptoms) without any explanation. Building DNN-based XAI systems is therefore an intense research area. Yet, DNN are only a special field of neuro-inspired AI. Another field are vector symbolic architectures (VSA), established by Smolensky and Mizraji in the late 1980s and further elaborated, among others, by Gayler, Plate, Siegelmann, and myself until now. VSA have the capacity to decompose arbitrarily complex symbolic data structures, such as strings, trees, frames, or multisets into filler and role bindings. Mapping those atomic symbols to vectors in a high-dimensional linear space, two algebraic operations, "bind" and "bundle" can be implemented by suitable vector operations, such as tensor product and direct sum in order to obtain vector representations of the underlying data structures. When "bind" and "bundle" are faithfully implemented, the resulting vector space becomes the so-called Fock space that is usually employed in quantum field theory for the description of many-particle states. Cognitive operations, such as linguistic parsing are then represented as piecewise affine-linear maps, transforming one Fock space vector onto its successor. In Fock space, representation vectors can be faithfully decomposed into its compounds, making them fully interpretable. The same holds for cognitive operations that are hence completely explainable. One special kind of tensor product representations that is particularly suited for string processing is the one-dimensional Gödel encoding which leads straightforwardly to nonlinear dynamical automata and their neural implementations. I argue that neural automata are a very promising direction for future XAI research because they are not only fully explainable but also parsimoniously constructed in comparison to DNN (e.g. about 300 units for a universal Turing machine) and possibly biologically realizable with 3D-cell cultures. This may open up new developments for brain-computer interfaces and neuroprosthetic applications.

Theseus reloaded

Markus Huber & Ronald Römer, Cottbus

In early days of cybernetics C. E. Shannon introduced his maze-experiment-system for problem solving which used the background of the mythological figure Theseus. But Shannon's solution totally lags a concept of semantics. From a psychological point of view essential cognitive aspects were neglected. We briefly address the mythological and historical backgrounds to emphasize on those aspects and to show why we must overcome Shannon's conception and why we need methods to gain semantic structures. We modify the problem statement allowing Theseus the satisfaction of hunger and thirst and describe a method for the inference of semantic structures based on the distinction of controllables and non-controllables. The model presented is inspired by quantum field theory and represents the so-called inner stage of technical cognitive agents. It allows for planning of actions and for higher cognitive functions like coping and fantasy. Because the inferred semantic structures are formal mathematical objects they can be communicated by the use of translation processes. As the inner stage handles only semantic structures, it is independent of sensor and communication modalities. Hence, our model provides for both, sensor-sharing and sensor-bridging communication.

Human activity recognition for proactive, context-aware assistance

Stefan Lüdtke & Thomas Kirste, Rostock

About 1,5 million people in Germany suffer from a dementia. IT-based assistive systems can support those people in their daily lives, such that they can maintain their independence. Such assistive systems need to be situation-aware (i.e. supporting the actions taken by the user) and subsidiary (supporting only when required, to avoid the degradation of existing capabilities). This, in turn, requires that the assistive system can identify the activity and intention of the user. In this talk, we describe our efforts in developing activity and intention recognition methods based on causal, symbolic models of human behavior. In contrast to conventional activity recognition systems, these methods naturally allow to recognize the context of the activities (e.g. cognitive and environmental states), and allow to substitute training data by symbolic domain knowledge. We describe how efficient inference in the resulting large, categorical state space can be achieved by Marginal filtering, a novel, approximate inference algorithm. Furthermore, we describe how symmetries in the state space can be exploited by using lifted probabilistic inference methods. Finally, we present case studies of how those methods can be used: For the recognition of kitchen activities, outdoor navigation assistance for people with dementia, and activity management of people with dementia in a stationary care setting.

Challenges for the next generation of contextualized health outcome measurement

Mike Martin, Zürich

The semantic analytics of multi-scale (cognitive) health data is the new frontier of our understanding of healthy aging. Once we can extract semantic information (i.e., meaning) from health-related data of multi-scale measurements of health, the generation and test of contextualized individual healthy aging outcomes can be scaled to the level of populations. Healthy aging research marks a paradigm change in biomedical science. It needs to answer two main questions. One is about the frequency and likelihood of “illness symptoms” and their absence in the population. Estimators of population likelihoods are typically inferred from sampling individuals from the population. The other is about the likelihood of interventions helping a given individual to maintain or improve health and quality of life. A calculation of these likelihoods requires frequently measured activity data from each individual as well as the semantic analysis of these data. This allows to calculate both within-person likelihood models and population likelihood models. At present, we see increasing amounts of within-person time-series data available from all conceivable scales of health, from cells to organs, from behavior to cognition, within multiple contexts from within-person, between-person, and outside-of-person studies. In accordance with current WHO efforts to establish dynamical-systems grounded models of health, the collection and analysis of data needs to be informed by theoretical models of these data, their dynamics, and their semantic content. The key challenge of a paradigm shift towards a contextualized understanding of health is to exploit the health-related meaning of high-density data from individuals and populations at as many scales as possible. Simply due to the enormous amounts of these data, assigning interpretative values to the measurements has to be automated. Thus, automated segmentations, annotations, pattern identification, and pattern indicator calculations are needed to inform the measurement and interpretation of contextualized health. The presentation will lay out the new healthy (aging) paradigm proposed by WHO and its consequent key challenges to support its global implementation in the 2020-2030 “Decade of Healthy Aging”. These are to find ways to contextualize the automatic interpretation of healthy aging dynamics data and to find ways to upscale contextualization to all individuals and contexts in a population in an affordable and legally, ethically, technically, socially, and educationally acceptable manner.

Pre-processed maximum likelihood and analytical solutions to maximum likelihood in dynamical structural equation models

Timo von Oertzen, München

Structural Equation Models with Time Delayed Embedding have proven to be successful in estimating parameters of dynamical processes. As dynamical models in their original form are saturated, analytical solutions are available; and using some pre-processing, analytical solutions can also be formed for other models with some assumptions that are reasonable in psychological or medical applications. In this presentation, we will present Pre-processed Maximum Likelihood, and how it can be used to simplify maximum likelihood estimation processes, in particular for dynamical systems.

Eye movements in medicine: The need for semantic annotation

Erich Schneider, Cottbus-Senftenberg

The oculomotor system is the best-studied motor system in humans. Visual perception provides us with the illusion of a stable visual world that is seamless in time and space even when the stream of visual input during exploration is continuously disrupted by saccades. In between saccades, the oculomotor system ensures retinal image stabilization during head, object, and surround motion. Attempts to measure eye movements for diagnostic purposes are known since the late 1930s. Over the last few years eye tracking technology gained importance in the topographic diagnosis of patients with disturbances of the oculomotor system. In our past research we developed this technology further by extending it with an eye movement-driven robotic camera that allowed imaging of the highly dynamical retinal input in an ecologically valid and mobile setting. This enabled us to examine the effects of, for example, color vision deficits and, recently, amnestic mild cognitive impairment of spatial orientation on natural visual exploration. The manual annotation of the resulting retinal content video data as well as eye movement time series proved a time-consuming and challenging task. It showed the need for an automated semantic annotation of human motion data, if naturalistic tasks are to become part of clinical routine diagnostics.

BioLithoMorphie® - A toolbox for the construction of 3D biological morphologies

Andreas Schober, Ilmenau

According to the emerging concepts of mimicking cellular hierarchy using principles of 3D cell cultivation, biotechnical multiscale engineering and organ-on-a-chip devices we propose to extend the term synthetic biology to synthetic nanobiosystem engineering, which describe the construction of bio-systems and biohybrid systems by methods of engineering and material science. By the possibility to construct even macroscopic systems by the fusion of nano- and microsystems and controlling material properties even on the nanolevel efficiently, one can realize systems geometrically very close together to achieve new functionalities. The integration of different materials with different properties allows designs with complex functions, a procedure which is present in biological systems naturally. With the help of the BioLithoMorphie® toolbox and related methods we envision more and more realistic 3D tissue like structures in near future. By controlling the accurate nano-, micro- and macroscopic architecture and the fluidic properties the complex formation of tissues might be mimicked. Biological systems like e.g. organs (liver, brain, etc.) are hierarchical, compartmental and functional complex organized in the sense of interacting compartments of oligo and multicellular entities. The task is now to find the suitable bio-technical hybrid- or model-system for the right description level of the scientific or technical problem to be solved. By this, platforms for the examination for the conditions of self-organization of the generation of information and function in oligocellular systems should be achievable by biotechnical multiscale engineering.