Compressed Sensing Workshop

Universität Bremen

Important Information:

When?	17.03.2015, 9:00 - 17:30
Where?	Universität Bremen, MZH 1470
What?	Talks and discussion about compressed sensing
Who?	Everybody interested in CS (no registration fee)

http://www.ant.uni-bremen.de/misc/csw/

This workshop is open for all interested participants in the region that either want to know more about Compressed Sensing or want to connect to other researchers working in the field.

For registration please contact:

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Preliminary Program

09:00 – 09:15	Welcome
09:15 – 10:00	**Random and structured measurements in compressive sensing** Speaker: Götz Pfander (Applied Harmonic Analysis, Jacobs University)
10:15 – 11:00	**Sparse Representations and Compressed Sensing** Speaker: Emily J. King (ZeTeM, Universität Bremen)
11:00 – 11:20	Coffee Break
11:20 – 12:05	**Is the sparse neuronal coding in the brain related to compressed sensing?** Speaker: Klaus Pawelzik (Theoretical Neurophysics, Universität Bremen)
12:05 – 12:50	**Compressive Sensing, LDPC Codes, and Neural Networks** Speaker: Nazia Islam/Werner Henkel (Transmission Systems, Jacobs University)
12:50 – 14:00	Lunch
14:00 – 14:45	**Sporadic Communication: Compressive Sensing in the 5th generation mobile network** Speaker: Carsten Bockelmann (ANT, Universität Bremen)
14:45 – 15:30	**Compressed Sensing in Imaging Mass Spectrometry** Speaker: Andreas Bartels (ZeTeM, Universität Bremen)
15:30 – 15:50	Coffee Break
15:50 – 16:35	**Compressed Sensing and Nonlinear Neural Processing in Visual Cortex** Speaker: Christoph Zetzsche (Kognitive Neuroinformatik, Universität Bremen)
16:35 – 17:20	**Compressed Sensing Circuits - Topologies and Challenges** Speaker: Heiner Lange (Arbeitsbereich Kommunikationselektronik, Universität Bremen)
17:20 – 17:30	Closing Remarks

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09:15 – 10:00 Random and structured measurements in compressive sensing

Speaker: Götz Pfander (Applied Harmonic Analysis, Jacobs University)

Abstract:
In this introductory talk, the basic ideas underlying compressive sensing are outlined. The potential but also some of the limitations of compressive sensing are described. In this realm, the null space property as well as the restricted isometry property are defined and arguments for why Gaussian measurement matrices satisfy these properties are given. In addition, difficulties in establishing these key properties for structured measurement matrices, for example for time-frequency structured matrices, are discussed.

10:15 – 11:00 Sparse Representations and Compressed Sensing

Speaker: Emily J. King (ZeTeM, Universität Bremen)

Abstract:
In this talk, the intimate relationship between sparse representations and compressed sensing will be explored. This tutorial will complement the introductory talk given by Götz Pfander. A key hypothesis in the set up of a compressed sensing problem is the existence of a so-called sparsifying dictionary. There are many other underdetermined problems which are not compressed sensing per se but are similarly regularized. The increasing interest in compressed sensing has thus been complemented by a focus on sparsity, ℓ^1-norm, low rank matrices, and more. These concepts will be explained with examples given.

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11:20 – 12:05 Is the sparse neuronal coding in the brain related to compressed sensing?

Speaker: Klaus Pawelzik (Theoretical Neurophysics, Universität Bremen)

Abstract:
The neuronal activity in many areas of the brain (especially those for the higher functions) is quite sparse, with only a very small fraction of simultaneously active neurons who fire short pulses (action potentials; <1ms) at low rates (< 10Hz). This sparse coding underlies many impressive computations performed by the central nervous system including rapid object recognition, incremental learning, complex decision making and motor control, which are based on high dimensional inputs. Besides investigating these codes and their role in neuronal computations [1,2,3,4] neuroscience also faces the dual challenge to perform inferences about the neuronal networks in the brain and their dynamics from high dimensional experimental data. Also here effective low dimensionality and sparseness of the underlying causes were demonstrated and methods from compressed sensing already found some successful applications [see 5 for a review]. Taken together, methods related to sparse coding and compressed sensing appear promising for both, understanding coding and computations in the brain as well as as tools for the analysis and interpretation of experimental data. We will present examples for sparse coding and compressed sensing used in neuroscience and discuss future challenges.

[1] Lee, Hyekyoung, et al. "Sparse brain network recovery under compressed sensing." Medical Imaging, IEEE Transactions on 30.5 (2011): 1154-1165.
[2] Pernice, Volker, and Stefan Rotter. "Reconstruction of sparse connectivity in neural networks from spike train covariances." Journal of Statistical Mechanics: Theory and Experiment 2013.03 (2013): P03008.
[3] Barranca, Victor J., et al. "Sparsity and Compressed Coding in Sensory Systems." PLoS computational biology 10.8 (2014): e1003793.
[4] Palm, Günther. "Neural associative memories and sparse coding." Neural Networks 37 (2013): 165-171.
[5] Surya Ganguli and Haim Sompolinsky, "Compressed Sensing, Sparsity, and Dimensionality in Neuronal Information Processing and Data Analysis"; Annu. Rev. Neurosci. 2012. 35:485–508

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12:05 – 12:50 **Compressive Sensing, LDPC Codes, and Neural Networks**

Speaker: Nazia Islam/Werner Henkel (Transmission Systems, Jacobs University)

Abstract:
Links between compressive sensing and LDPC codes are somewhat known, at least to the extent of toy examples. Not many are aware of relations between LDPC codes and neural networks. We will shortly sketch the first pairing, but will concentrate a bit more on the second, where the Tanner graph of an LDPC code will be outlined as a standard neuron model on the variable node side, by a minimal reformulation on the check-node side. The check-node function will appear as another neuron layer, but in a kind of transform domain.

14:00 – 14:45 **Sporadic Communication: Compressive Sensing in the 5th generation mobile network**

Speaker: Carsten Bockelmann (ANT, Universität Bremen)

Abstract:
The omnipresent buzzwords **“**Machine-to-Machine communication”, “Internet of Things” and “Industrie 4.0” usually describe a future where billions of unsupervised machine devices communicate with each other to measure, estimate and control various aspects of life. The applications range from self metering, eHealth, industrial applications to so-called smart X (cities, meters, etc). One common denominator of these scenarios is the incredibly huge number of devices that communication systems will have to cope with. This challenge seems impossible to solve with todays infrastructure and technical solutions which motivated a variety of new research directions in communications. Current research is trying to solve the wireless access problem on multiple levels for cellular systems often described as 5G as well as localized systems similar to industrial communication standards like ZigBee, WirelessHART or plain WLAN.

This talk will focus on the topic of Sporadic Communication which describes a subclass of the above mentioned topics. Here, communication devices only send on occasion (time driven, periodically) and are usually silent most of the time. We will detail the connection of compressed sensing and the physical layer processing necessary to solve the outlined „access challenge“. First, the applicability of compressed sensing will be motivated and crucial differences to the common CS model assumptions will be pointed out. Then, we will demonstrate necessary changes compared to standard CS algorithms and novel solutions we proposed to adapt CS to sporadic communication.

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14:45 – 15:30 Compressed Sensing in Imaging Mass Spectrometry

Speaker: Andreas Bartels (ZeTeM, Universität Bremen)

Abstract:
Imaging mass spectrometry (IMS) is a technique of analytical chemistry for spatially-resolved, label-free and multipurpose analysis of biological samples, which is able to detect spatial distribution of hundreds of molecules in one experiment. The hyperspectral IMS data is typically generated by a mass spectrometer analyzing the surface of the sample. In practice, for a tissue slice, at each point on a grid on the sample 200--300 measurements are taken.Summing all measurements at a point together, the result is a grid where each pixel represents a mass spectrum at the according point. Therefore, measuring takes quite a long time.As the mathematical theory of compressed sensing (CS) has shown, under certain conditions it is possible to recover a signal from a number of linear measurements below the Shannon/Nyquist sampling rate. As a result of this pleasant surprise, many applications of CS in image processing and computer vision have been widely explored.In this talk, I will present a recently published compressed sensing approach to IMS which potentially allows for faster data acquisition by collecting only a part of pixels in the hyperspectral image and reconstructing the full image from this data. I will discuss sparsity aspects in IMS and present an integrative approach to perform both peak-picking spectra and denoising m/z-images simultaneously, whereas the state of the art data analysis methods solve these problems separately. A result concerning the robustness of the recovery of both spectra and individual channels of the hyperspectral image as well as numerical reconstruction results of a rat brain coronal section will be shown.

15:50 – 16:35 Compressed Sensing and Nonlinear Neural Processing in Visual Cortex

Speaker: Christoph Zetzsche, Tobias Kluth and Kerstin Schill (Kognitive Neuroinformatik, Universität Bremen)

Abstract:
The relation of "natural scene statistics", sparse coding and the nonlinear coding strategies of visual cortex are a long term research topic in our group. A related more recent topic is the specific form of information reduction that can be observed in the periphery of the visual field. Our interest in compressed sensing is motivated by possible relations to these topics, and the hope that this might help us in a better understanding of the visual system.
One of our approaches is to consider compressed sensing as means to counteract the combinatorial explosion of a nonlinear, overcomplete and sparse representation in cortical areas v2 and higher. In addition to the insights for neurobiology such a nonlinear architecture could also be of interest for nonlinear data compression applications. Furthermore we want to investigate whether the optimum property of randomness in the measurement vectors of compressed sensing could somehow explain the strange "random" feature combinations that are observed in the representation of the peripheral visual field. A compressed sensing approach here is also motivated by the status of this part of the visual system as an "information bottleneck".

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16:35 – 17:20 Compressed Sensing Circuits - Topologies and Challenges

Speaker: Heiner Lange (Arbeitsbereich Kommunikationselektronik, Universität Bremen)

Abstract:
While a huge part of the compressed sensing spectrum can be viewed at a relative high level of abstraction, in the end real word problems should be solved and as such compressed sensing has to work with real valued signals which are continuous and need to be digitized in order to be processed further. For this, electrical circuits are needed, that are tailored to the specific problem at hand.

This talk will give an overview of different approaches to implement a circuit for compressed sensing as well as list challenges that arise through the non ideal behavior of electrical circuits.