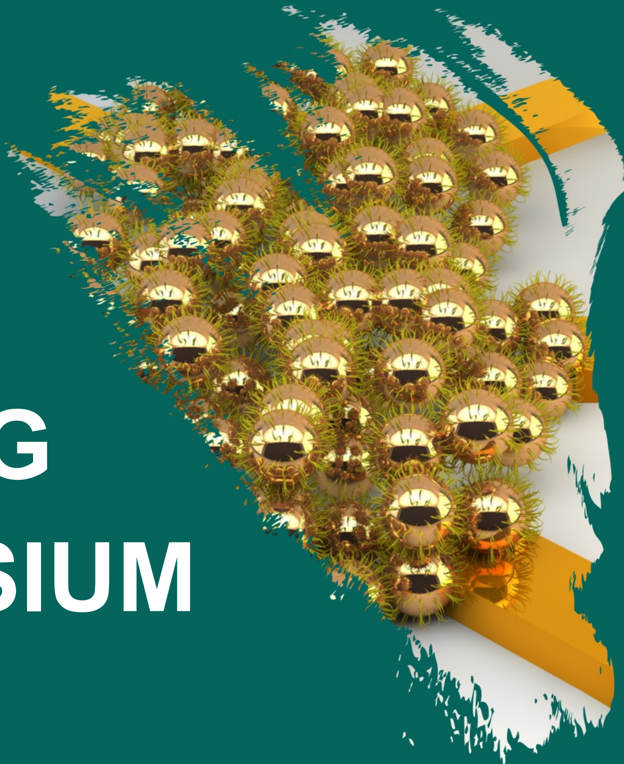
BRAINS OPENING SYMPOSIUM



27th of March 2019

Vrijhof - Amphitheater

Programme booklet

CENTER FOR BRAIN-INSPIRED NANO SYSTEMS

UNIVERSITY OF TWENTE.

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Foreword

Welcome to the official opening of the Center for Brain-Inspired Nano Systems (BRAINS) at the University of Twente!

The human brain is one of the most fascinating systems, if not the most fascinating system that natural evolution has produced. Admittedly, nature had billions of years at its disposal to come up with the highly interconnected network of neurons that not only enables us to survive in a continuously changing environment, but that also provides us with the creativity to come up with completely new concepts. The digital computer is such a concept, which has completely revolutionized our lives. Although the brain is often compared to the computer (as it was to a clock or a telephone switchboard in the past), there are important differences. Whereas the computer is good at logical operations and computations, the brain is particularly strong at interpreting the outside world and coming up with interpretations. Perhaps the most striking difference is that the brain's hardware is plastic, allowing it to learn new things.

With the fast rise of Artificial Intelligence, it is about time to turn our attention to the brain for getting inspiration on how to design the next generation of computing hardware. Although there is probably more we do not know than that we do know about the brain, it is clear that nature has come up with solutions for some information processing tasks that are far superior to our present-day technology. In particular, the remarkable energy efficiency of the brain provides an open invitation for making our future information society sustainable. This has been the motivation for the launch of the BRAINS Center for Brain-Inspired Nano Systems at the University of Twente.

Today, at the BRAINS Opening Symposium, experts with backgrounds from neuro-science and neurophysiology, electrical engineering, physics and nanotechnology will provide us with an exciting overview how inspiration from the brain can help us to lay the scientific foundations for a new generation of powerful, energy-efficient computing hardware. We hope you will thoroughly enjoy the journey through this rapidly evolving multidisciplinary field.


Hans Hilgenkamp and Wilfred van der Wiel

About BRAINS

Our mission is to develop efficient hardware for information processing.

The Center for Brain-Inspired Nano Systems (BRAINS) was established in 2018, combining core expertise in nanoscience and nanotechnology with expertise from computer science, artificial intelligence and neuroscience, to lay the scientific foundations for a new generation of powerful, energy-efficient computing hardware. Artificial and biological neural networks, in particular the brain, form a main inspiration. It is our ambition to understand the key features underlying the functioning of the brain, and translate those into hardware. Our research includes, but is not limited to reconfigurable, memristive and adaptive materials, artificial neurons and synapses, evolution in materio and neuromorphic architectures. We look at the connection between our hardware and conventional (CMOS) electronics, and at the interface with biological systems. Societal implications and philosophical aspects are studied.

BRAINS is an inter-faculty center of the University of Twente with over 10 principal investigators from the MESA+ Institute for Nanotechnology, the Digital Society Institute and the Faculty of Behavioural, Management and Social sciences. The center aims to provide coherence and visibility. With its focus and critical mass BRAINS hopes to be a valuable partner in national and international consortia.

BRAINS

CENTER FOR BRAIN-
INSPIRED NANO SYSTEMS

PROGRAMME

27th of March 2019 * Vrijhof - Amphitheater

13:30 - 13:45 **Opening**

Wilfred van der Wiel and Hans Hilgenkamp, Directors BRAINS
Thom Palstra, Rector University of Twente

13:45 - 14:15 **Fleur Zeldenrust (RU)**

Efficient computations in the brain

14:15 - 14:45 **Federico Corradi (IMEC)**

Neuromorphic computing: a new generation of computing technologies that work like the brain

14:45 - 15:15 **Yoeri van de Burgt (TU/e)**

Organic Electronics for Neuromorphic Computing

15:15 - 15:45 **Break**

15:45 - 16:15 **Maria Antonietta Loi (RUG)**

Carbon Nanotube: from nano-transistors to neuromorphic devices

16:15 - 16:45 **Tao Chen (UT)**

Neuromorphic computation with dopant networks in silicon

16:45 - 17:00 **Closing words**

17:00 - 18:00 **Drinks**

13:45 - 14:15

Dr. Fleur Zeldenrust
Assistant Professor at the Department of Neurophysiology, Donders Institute for Brain, Cognition and Behaviour, Faculty of Science, Radboud University, Nijmegen

Title: *Efficient computations in the brain.*

Abstract: The brain is a unique system, in that it does not only show dynamics, but these dynamics also have a function. It still outperforms any computer we can make, both in energy consumption but also in flexibility. In this presentation, I will explore how the relation between dynamics and function in neural networks can be studied, and how this interaction is determined by structural properties: the connectivity of the network and the properties of each of its nodes. As a model system we use the rodent somatosensory or 'barrel' cortex, the part of the brain that receives input from the whiskers. By viewing the brain as a computer performing algorithms, computational neuroscientists have been capable of deepening our understanding of how complex processes such as perception arise and how the structure of the brain might be optimised to perform these.

Bio: Fleur Zeldenrust, assistant Professor at the Department of Neurophysiology, Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, studies how the physical structure of the brain (its ‘hardware’) shapes its information processing and vice versa: how the computations needed for information processing (the ‘software’) are adapted to the physical structure of the hardware. In her ‘Biophysics of Neural Computation’ group, she studies the relation between the physical properties of the brain and its information processing: how are neurons and networks formed so that they can perform functions such as perception? Which characteristics of neurons and networks enhance or limit information transfer? With a training in both Physics and Neuroscience, she has a broad interest in quantitative solutions to all types of scientific problems, but her expertise (PhD at the University of Amsterdam, postdoctoral work at the École Normale Supérieure in Paris) is in the field of Computational Neuroscience.

14:15 - 14:45

Dr. Federico Corradi
Research Scientist at IMEC

Title: *Neuromorphic computing: a new generation of computing technologies that work like the brain.*

Headline: At IMEC we are studying ways to mimic the brain's computational power in silicon microchips. This is because the chaotic, slow, and inhomogeneous neural systems inside our heads is a highly adaptable and efficient computer capable of achieving incredible things in a very little power budget.

Abstract: Neuromorphic computing is a promising approach for developing new generations of smarter and adaptive computing technologies that can drastically change the way in which we think of computers, and in which we interact with artificial systems. In this approach, brain-inspired models of neural computations, based on massively parallel networks of low-power silicon neurons and synapses are implemented in electronic microchips. This talk will describe recent understanding of neural computation as well as recent efforts in building microchips based on more bio-realistic models of spiking neurons. These novel devices represent the third generation of neural networks which not only allows us to investigate at the theoretical level the possibilities of using time as a resource for computation and communication but can also shed light in the way in which our own brain works.

Bio: Federico Corradi (Ph.D) is a research and development scientist at the non-profit research organization Imec-nl, Eindhoven, The Netherlands. He received a B.Sc. degree in Physics (2007) from Università degli studi di Parma, a M.Sc. degree (cum laude) in Physics (2010) from La Sapienza University, Rome, a Ph.D. degrees in Natural Sciences (2015) from the University of Zürich, and a Ph.D. in Neuroscience (2015) from the ETH Neuroscience Center Zürich. His research activities are at the interface between neuroscience and neuromorphic engineering. His research is focused towards a new generation of computing architectures based on bio-inspired neural networks, his contribution in the field includes novel online learning circuits for highly integrated neuromorphic electronic systems.

14:45 - 15:15

Dr. Yoeri van de Burgt
Assistant Professor at Eindhoven University of Technology (TUe)

Title: *Organic Electronics for Neuromorphic Computing.*

Abstract: Neuromorphic computing could address the inherent limitations of conventional silicon technology in dedicated machine learning applications. Recent work on large crossbar arrays of two-terminal memristive devices has led to the development of promising neuromorphic systems. However, delivering a compact and efficient parallel computing technology that is capable of embedding artificial neural networks in hardware remains a significant challenge.

Organic electronic materials have shown potential to overcome some of these limitations. This talk describes state-of-the-art organic neuromorphic devices and provides an overview of the current challenges in the field and attempts to address them. We demonstrate a novel concept based on an organic electrochemical transistor and show how crucial challenges in the field such as stability, variability and linearity can be overcome.

Bio: Yoeri obtained his PhD at Eindhoven University of Technology in 2014 on carbon nanotubes. Then he briefly worked in Switzerland at a high-tech startup, after which he obtained a Postdoctoral Fellowship at Stanford University (USA), to work on organic neuromorphic materials and electro-chemical transistors. At the end of 2016 he returned to Eindhoven as an assistant professor. He has been a visiting professor at the University of Cambridge (UK) and was recently awarded an ERC starting grant.

15:45 - 16:15

Prof. Dr. Maria Antonietta Loi
Zernike Institute for Advanced Materials,
University of Groningen, The Netherlands

Title: *Carbon Nanotube: from nano-transistors to neuromorphic devices.*

Abstract: Carbon nanotubes have been considered for many years one of the few materials that can eventually substitute silicon, when the physical limit of the miniaturization of the silicon transistor channel length will be reached. In my presentation I will first discuss as we have solved one of the main problems inherent with the manipulation of carbon nanotubes, fabricating field effect transistors in a highly reproducible fashion by chemically self-assembly semiconducting carbon nanotubes. Then I will discuss if this nanomaterial can have a role in the fabrication of artificial neurons and in the future development of neuromorphic electronics.

Bio: Maria Antonietta Loi studied physics at the University of Cagliari in Italy where she received the PhD in 2001. In the same year she joined the Linz Institute for Organic Solar cells, of the University of Linz, Austria as a postdoctoral fellow. Later she worked as researcher at the Institute for Nanostructured Materials of the Italian National Research Council in Bologna, Italy. In 2006 she became assistant professor and Rosalind Franklin Fellow at the Zernike Institute for Advanced Materials of the University of Groningen, The Netherlands. She is now full professor in the same institution and chair of the Photophysics and OptoElectronics group.

She has published more than 190 peer-reviewed articles on photophysics and optoelectronics of different types of materials. In 2012 she has received an ERC Starting Grant from the European Research Council. She currently serves as associated editor of Applied Physics Letters and she is member of the international advisory board of Advanced Functional Materials, Advanced Electronic Materials and Advanced Materials Interfaces. In 2018 she received the Physicaprijs from the Dutch physics association for her outstanding work on organic-inorganic hybrid materials.

16:15 - 16:45

Dr.Tao Chen
PostDoc researcher at the NanoElectronis Group and BRAINS at the University of Twente (UT)

Title: *Neuromorphic computation with dopant networks in silicon.*

Abstract: The biological brain solves complex computational problems much more efficiently than conventional digital computers owing to the parallel processing of information. In conventional computers, the energy efficiency is limited by the transfer of data back and forth between the processing unit and the memory, referred to as the Von-Neumann bottleneck. To overcome this bottleneck, building blocks of parallel computers based on CMOS (complementary metal oxide semiconductor) neurons, memristors, and oscillators have been proposed, inspired by neurobiology.

Parallel computation can also be realized by exploiting the physical properties of materials. Taking advantage of the nonlinear or dynamical properties of materials, data can be projected into a high-dimensional space efficiently, and become suitable for linear separation, which facilitates machine learning tasks such as the classification of speech and images. However, material systems usually project information to a high-dimensional space randomly. On the contrary, in the biological brain and in deep neural networks, data are processed with layers of trained filters/kernels. Learnable material-based kernels have not been reported so far.

We have recently exploited the nonlinearity of hopping conduction through an electrically tuneable network of boron dopants in silicon to realise a reconfigurable kernel machine, demonstrating good kernel properties by solving the canonical linearly inseparable exclusive OR (XOR) problem. The dopant network can also perform four-input binary classification, i.e. extracting four-pixel features. By pre-processing basic features as in the brain, the overall accuracy of a linear classifier in classifying the MNIST (Modified National Institute of Standards and Technology) database of handwritten digits reaches up to 96.0%, surpassing state-of-the-art results realised in other materials-based

computational systems. These results show that materials properties can be tuned to optimize computational performance, inspired by the brain, and establish the designless dopant networks as a small-footprint and energy-efficient building block for neuromorphic computing.

Bio: Dr. Tao Chen is a PostDoc researcher in the NanoElectronics Group and Center for Brain-Inspired Nano Systems (BRAINS)at the University of Twente. Tao obtained his B. Eng. in Precision Instrumentation from Wuhan University of Technology in 2007, M. Eng. in Microelectronics from Tsinghua University in 2010, and Ph.D. in Electrical Engineering from the University of Edinburgh in 2014. Previously, Tao worked on 2D material-based NEMS resonators for biomimetic applications during his Ph.D.. Later on, he worked in the Chinese Academy of Science as a PostDoc (2015-2016) and studied interlayer vibrations of graphene with optical spectroscopy. Now, in the BRAINS Center, Tao is exploring the physical properties of materials for neuromorphic computation.

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