COGNIGRON

Towards 10,000x more energy-efficient computer chips

Annual Report

CogniGron 2024

university of groningen

UEF Ubbo Emmius Foundation

Moving science forward.

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FOREWORD

I cannot be more proud of what CogniGron has achieved in 2024. I quickly highlight two achievements for the impatient reader: our first CogniGron Chip (TEXEL) by the BICS group of Elisabetta Chicca, and our first spin-off company (IMChip) by Tamalika Banerjee. But there has been so much more ongoing....

...indeed, we are steadily progressing towards our dream of building a brain-inspired computer and we can say this was the year of creating bridges. The CogniGron office and staff have worked hard on connecting bright minds across disciplines. Events such as the Brainspiration conference, our CogniGron Research Away Day, the Memristec Summer School, the Dutch NWA NL-ECO consortium meeting, without forgetting our CogniGron@work sessions every Monday and as many as 10 CogniGron seminars by visitors, have been organized by CogniGron only in 2024, and have brought many people in the brain-inspired computing community together, within Groningen, the Netherlands and worldwide.

Our members continue to do crucial original research and, this year, we have witnessed a total of five successful PhD thesis defences – Daniel Willhalm, Thorben Schoepe, Thomas Tiotto, Michelle Mastella and Ole Richter – of outstanding level, which make a total of 9 theses already defended from CogniGron PhD students. This is an invaluable contribution to CogniGron's main goal: training a new generation of scientists that will bridge the existing knowledge gap to develop a future-proof computer.

Moreover, something very special has happened this year: our dedication and vision has made it possible for CogniGron to receive new funding from the Ubbo Emmius Foundation (UEF), which we were able to announce on 6 December, timely coinciding with the Dutch festivity of Sinterklaas (when we celebrate Saint Nicholas bringing presents to the children). In this new phase, we want to build bridges towards societal impact, while still strongly supporting fundamental research: we have committed to create new relations and collaborations with industrial partners and intensify our focus on applications by means of a new demonstrator program.

We are very grateful to the UEF and thankful for everyone who has contributed to this year's achievements: people who have left and others who have joined. Without our passionate members, we wouldn't be where we are today. Very particularly, I like to acknowledge our Coordinating office led by Annechien Pronk and Sander Baesjou (see page 51) and their strong contributions in bringing CogniGron to what it is today.

Let's continue working towards building the future-proof computing ecosystem and our mission to develop 10,000x more energy-efficient computer chips.

Beatriz Noheda,
Scientific Director of CogniGron

BUILDING THE FUTURE

Learning from the brain

A different kind of computer

You won't notice it when you send a message or translate a text into your native language. Or search online for directions to your new friend's house. Or when you ask an LLM to complete your sentence. But somewhere, far from your desk, a data center is working overtime — burning energy to keep our digital world going. And the more we ask of our computers, the more they ask in return.

For decades, we've made computers faster, smaller, and more powerful. But we've reached a tipping point. The energy demands of AI, big data, and cloud computing are growing faster than our current technology can sustainably support. It's no longer just about performance. It's about designing computers that adapt to our needs, that can learn — just like we do.

At CogniGron, we believe the next leap in computing won't come from doing more of the same. It will come from a fundamentally different approach: inspired not by machines, but by minds.

Nature's Blueprint for Efficiency

The human brain uses a fraction of the energy of today's computers, yet it outperforms them in countless ways. It stores and processes information in the same place. It forgets, remembers, predicts — constantly adapting to its environment.

This biological brilliance is our blueprint.

Neuromorphic computing draws lessons from the brain to create a new kind of system: energy-efficient, adaptive, and radically future-proof. With self-learning materials, smart architectures, and interdisciplinary collaboration, we're building computers that don't just compute — they evolve.

A Structured Path from Insight to Impact

At the heart of our work lies a simple conviction: knowledge alone is not enough. To make neuromorphic computing truly transformative, we've developed a cyclical approach that continuously connects fundamental research to real-world outcomes — and back again.

This journey unfolds across three dynamic layers:

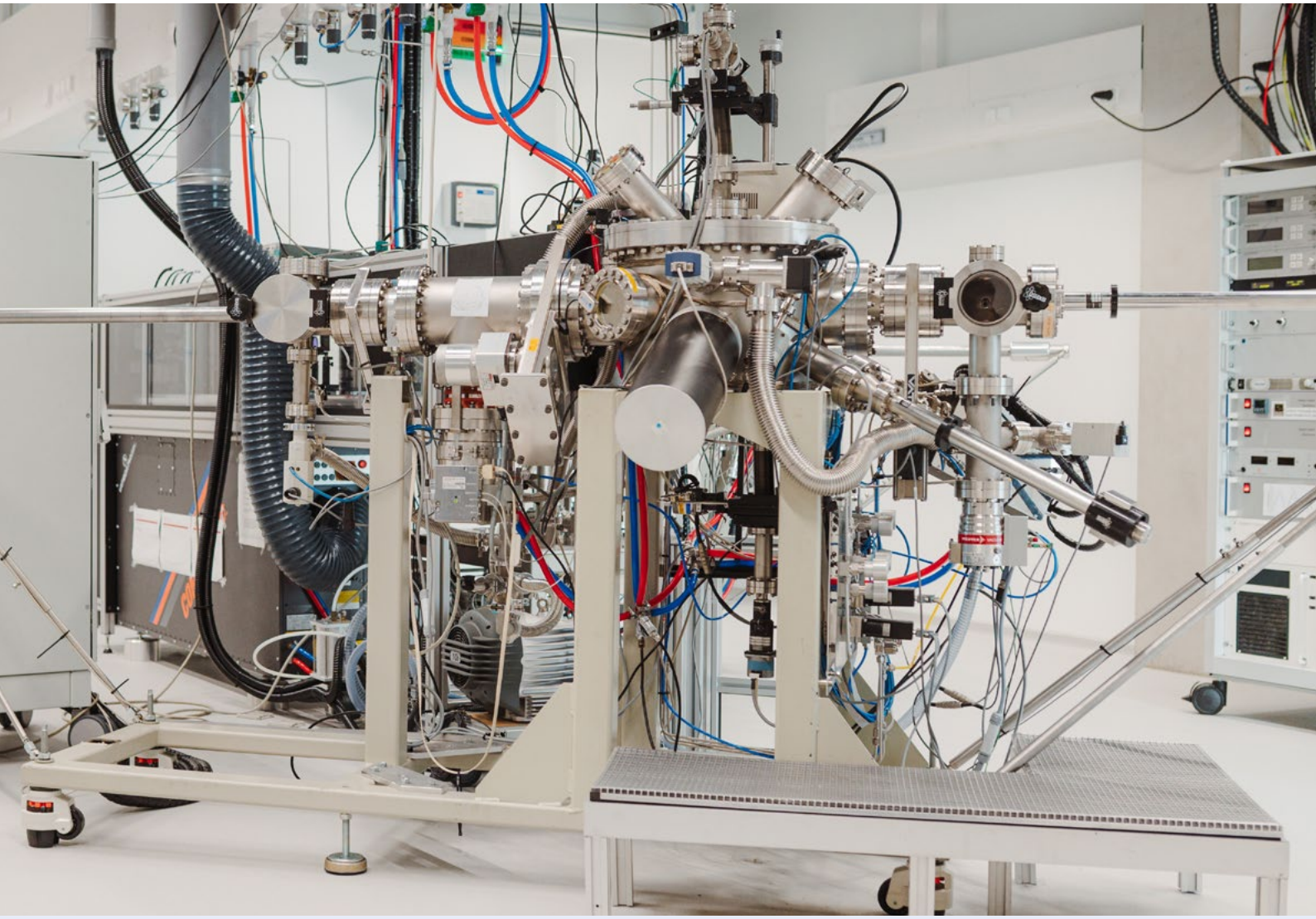
- Fundamental Research: We investigate the materials, physics, and principles behind cognition — laying the scientific foundation for radically different computer systems.
- Demonstrators: We translate theory into proof-of-concept systems that showcase what's possible when brains meet chips. These demonstrators bring abstract ideas to life and push the boundaries of what neuromorphic systems can do.
- Applied Research: Together with partners, we explore how these breakthroughs can solve real-world challenges — from edge AI and smart sensors to sustainable computing infrastructure.

By working across these layers, and guided by our four core research themes — cognitive materials, devices, circuits, systems, and AI-driven networks — we ensure a steady flow from insight to impact. Every breakthrough in the lab feeds into new possibilities for application, and each real-world challenge opens new scientific questions. This cycle is not linear, but alive — much like the systems we study.

Towards a Future-Proof Computing Ecosystem

Our ultimate goal is not just to create better chips, but to help build an ecosystem — one that is open, interdisciplinary, and focused on long-term sustainability. An ecosystem where scientific breakthroughs become shared building blocks. Where engineers, physicists, designers, and entrepreneurs work side by side. And where brain-inspired, energy-efficient computing moves from the lab into the world.

As we look ahead, we see computing evolving into something more organic: efficient, adaptive, and ready for what's next.



FROM VISION TO REALITY

With the Ubbo Emmius Foundation as a steadfast partner

At CogniGron, we are driven by ideas — but even the most powerful ideas need the right conditions to thrive.

Since our earliest days, the Ubbo Emmius Foundation has helped create those conditions. With their consistent support for interdisciplinary, forward-looking research, they have played a vital role in enabling our centre to grow — not just in size, but in depth, ambition, and direction.

Their long-term commitment makes it possible for us to invest in what matters most: fundamental research, young talent, and real-world application. From new PhD positions to groundbreaking demonstrator programmes, their backing touches every layer of our work.

This work is not abstract. As the digital world expands, so do the demands on our energy systems.

At CogniGron, we are reimagining how we compute — to develop technologies that are not only intelligent, but sustainable. We are laying the foundation for a future where digital tools are energy-aware, adaptive, and ready to meet tomorrow's challenges. And we are doing so with the next generation of researchers at the helm.

In 2024, we marked a tangible milestone: the **TEXEL chip**. Developed by the group of Prof. Elisabetta Chicca, this prototype is the first to combine all CogniGron disciplines — from materials science and physics to device design and AI — into one chip. It embodies our mission: to bring ideas together, and turn them into technology.

Beatriz Noheda, Scientific Director of CogniGron, and Joost Frenken, Dean of the Faculty of Science and Engineering, proudly presented the TEXEL chip to the Ubbo Emmius Foundation. Not as a conclusion, but as a moment of shared progress — a symbol of what becomes possible when ambition meets long-term partnership.

We thank the Foundation not only for their generosity, but also for their trust. With their continued support, we are not only imagining future-proof computing — we are building it.

UEF Ubbo Emmius Foundation

Moving science forward.

AREAS OF EXPERTISE

COGNIGRON

OUR EXP

ZERNIKE INSTITUTE FOR ADVANCED MATERIALS (ZIAM)

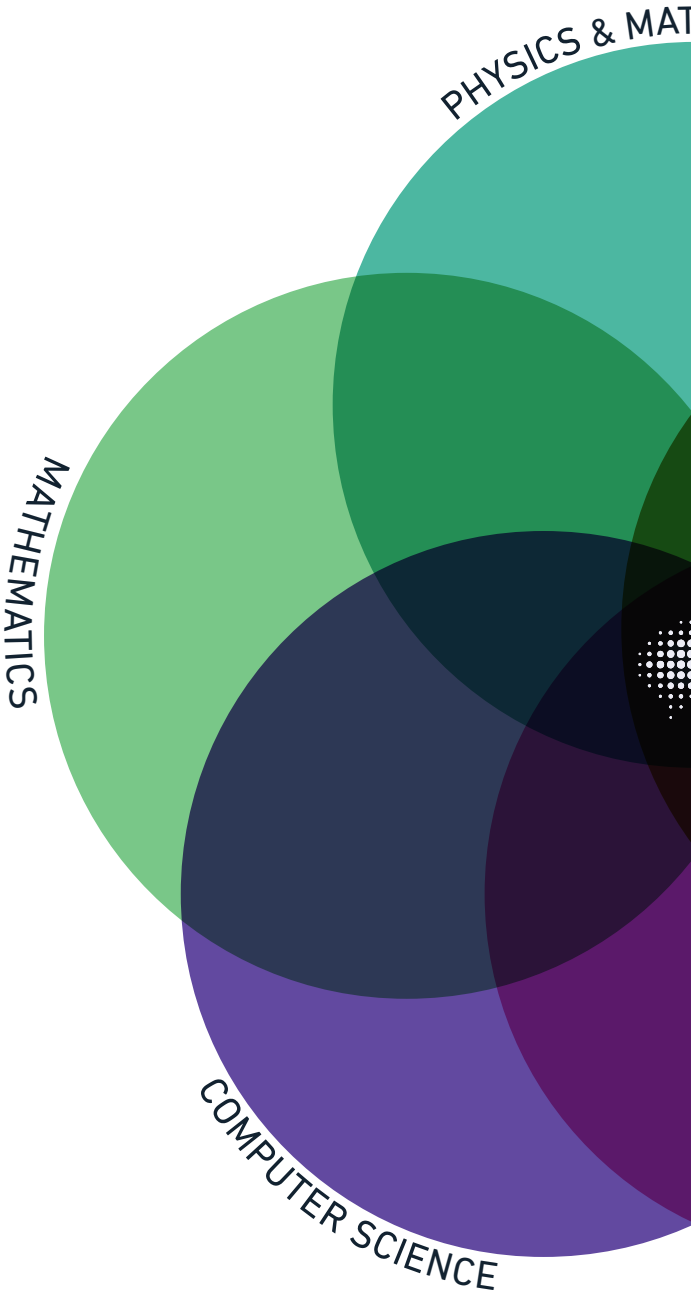
- **PHYSICS & MATERIALS SCIENCE**

BERNOULLI INSTITUTE FOR MATHEMATICS, CS & AI (BI)

- **MATHEMATICS**
- **COMPUTER SCIENCE**
- **AI & COGNITION**

ENGINEERING & TECHNOLOGY INSTITUTE (ENTEG)

- **ELECTRICAL ENGINEERING, ROBOTICS AND MECHATRONICS**



ERTISES

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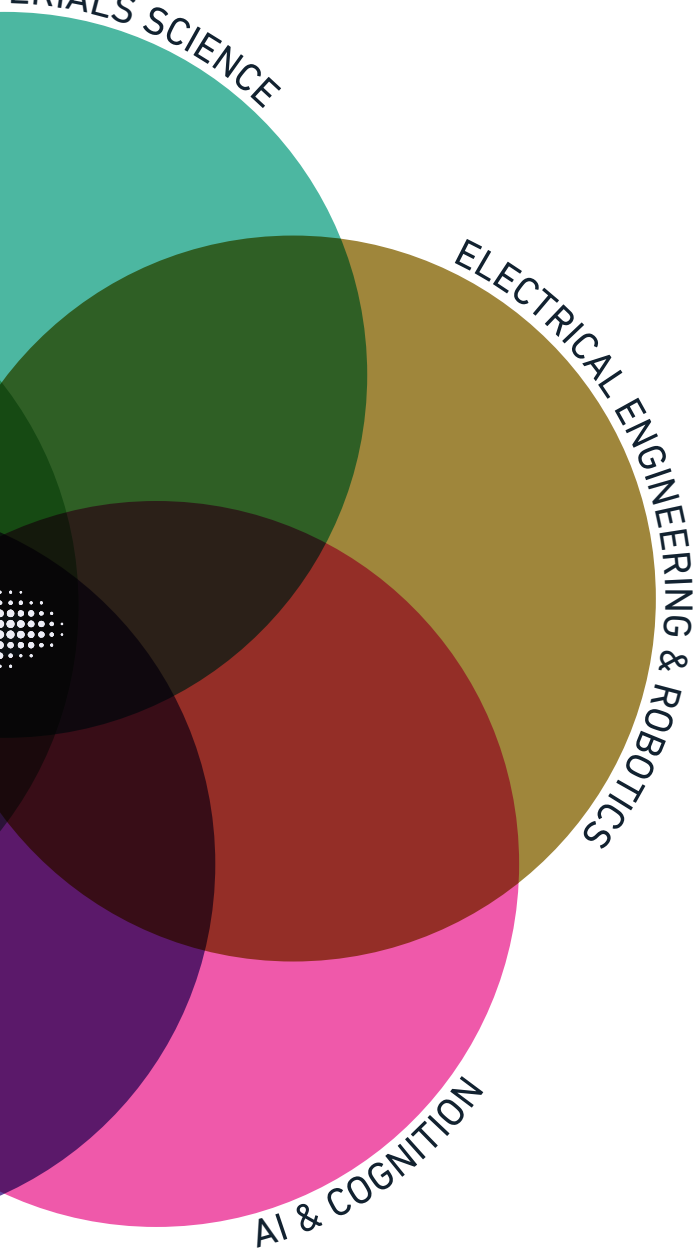


PHYSICS & MATERIALS SCIENCE

- Materials and Devices with nanoscale functionality
- Oxide electronics
- Carbon electronics
- Molecular electronics
- Spintronics
- Valleytronics
- Phase change materials
- Memristors
- Optoelectronics
- Ionic transport

MATHEMATICS

- Complex networks
- Dynamical systems
- Statistical networks
- Statistical mechanics
- Materials modeling
- Computer algebra
- Network synthesis theory

COMPUTER SCIENCE

- Systems engineering
- Neuromorphic computing
- Image processing/Computer vision
- Pattern recognition/Machine learning
- Computer algebra
- Security & privacy

AI & COGNITION

- Machine learning
- Computer vision
- Neuroscience
- Neural networks
- Neuromorphic computing
- Cognitive science

ELECTRICAL ENGINEERING, ROBOTICS AND MECHATRONICS

- Materials for mechatronics
- Electrical Engineering
- Robotics

OUR PEOPLE

Experts

PHYSICS AND MATERIALS SCIENCE

- Prof. Tamalika Banerjee
  Spintronics of Functional Materials
- Prof. Elisabetta Chicca
  Bio-inspired Circuits and Systems
- Dr. Erika Covi
  Cognitive Devices
- Prof. André van Schaik
  Neuromorphic Engineering and Computational Neuroscience
- Prof. Bart Kooi
  Nanostructured Materials and Interfaces
- Prof. Maria Loi
  Photophysics and Opto-Electronics
- Prof. Beatriz Noheda
  Solid State Materials for Electronics
- Prof. George Palasantzas
  Physics - Surface Interactions and Nanostructures
- Prof. Petra Rudolf
  Experimental Solid-State Physics

MATHEMATICS

- Prof. Bart Besselink
  Systems and Control Theory
- Dr. Gilles Bonnet
  Stochastic Studies and Statistics
- Dr. Serte Donderwinkel
  Probability Theory
- Prof. Marco Grzegorczyk
  Computational Statistics
- Dr. Hildeberto Jardón Kojakhmetov
  Mathematics, Interdisciplinary Applications
- Dr. Julian Koellermeier
  Computational Mathematics
- Prof. Arjan van der Schaft
  Applied Analysis
- Dr. Alef Sterk
  Dynamical Systems Theory
- Prof. Holger Waalkens
  Dynamical Systems Theory

In the course of 2024, Dr. Julian Koellermeier and Prof. Arjan van der Schaft left CogniGron.

ARTIFICIAL INTELLIGENCE

- Prof. Jelmer Borst
  Computational (Cognitive) Models
- Prof. Matthew Cook
  Cortex-inspired Computing
- Prof. Davide Grossi
  Cognitive Multiagent Systems
- Prof. Herbert Jaeger
  Computation in Cognitive Materials
- Prof. Lambert Schomaker
  Artificial Intelligence
- Prof. Niels Taatgen
  Artificial Intelligence
- Prof. Bart Verheij
  Computational Argumentation
- Dr. Marieke van Vugt
  Cognitive Modelling

In the course of 2024, Dr. Marieke van Vugt left CogniGron.

COMPUTER SCIENCE

- Prof. George Azzopardi
  Information Systems
- Prof. Michael Biehl
  Intelligent Systems
- Prof. Georgi Gaydadjiev
  Innovative Computer Architecture
- Dr. Farhad Merchant
  Innovative Computer Architecture
- Prof. Dirk Pleiter
  Innovative Computer Architectures
- Dr. Revantha Ramanayake
  Theory of Computation
- Prof. Jos Roerdink
  Scientific Visualization and Computer Graphics
- Prof. Fatih Turkmen
  Computer and Network Security
- Dr. Michael Wilkinson
  Digital image analysis and computer vision

ELECTRIC ENGINEERING, ROBOTICS AND MECHATRONICS

- Prof. Mónica Acuautla Meneses
  Materials for Mechatronics
- Prof. Ming Cao
  Multi-agent systems, autonomous robots, complex systems and networks

TECHNICAL STAFF

CogniGron depends on the skills and experience of several technicians that, in addition to ensuring smooth running of the lab, also have important roles in training young researchers.

- Dr. Majid Ahmadi
  CogniGron - Support Electron Microscopy
- Dr. Arjun Joshua
  CogniGron - Support Clean room/Nanolab
- Vincent Jassies
  Bio-inspired Systems and Circuits

NEW STAFF

CogniGron is excited that several new Principal Investigators have joined CogniGron during 2024. With their knowledge and research experience, they bring valuable expertise to our team.

Dr. Erika Covi

As of January 1st, 2024 Erika Covi joined our team as Assistant Professor Cognitive Devices. Erika is trained in electronic engineering and received her PhD in microelectronics (University of Pavia, Italy). After her PhD, she worked as postdoc (CNR-IMM, Italy), at the Politecnico di Milano (Italy), and since 2020 as Senior Scientist at NaMLab (Dresden, Germany). Her research interests lie at the intersection of emerging devices, circuit design, and brain-inspired computing. More specifically, they focus on exploiting the intrinsic physical characteristics of memristive devices to reproduce computational primitives of the brain in mixed neuromorphic-memristive systems.

Dr. Serte Donderwinkel

On 1 February, Serte Donderwinkel joined the team as an assistant professor in probability theory. After her BSc in Mathematics at the University of Groningen, she moved to the UK, where she completed a master's at the University of Cambridge and a PhD at the University of Oxford. She then did a short

postdoc at McGill University, before returning to Groningen.

Her research mostly focuses on the study of random trees and graphs. The common denominator of her projects is that they involve creative sampling procedures that, combined with tools from (stochastic) analysis, allow her to study the large-scale structure of the random object. At CogniGron, she will aim to put her theoretical background to use to improve the understanding of phenomena observed in real-world networks, such as phase transitions and self-organised criticality.

Dr. Farhad Merchant

As of July 1, 2024, Farhad Merchant has joined CogniGron as an Assistant Professor of Innovative Computer Architecture at the Bernoulli Institute, the University of Groningen.

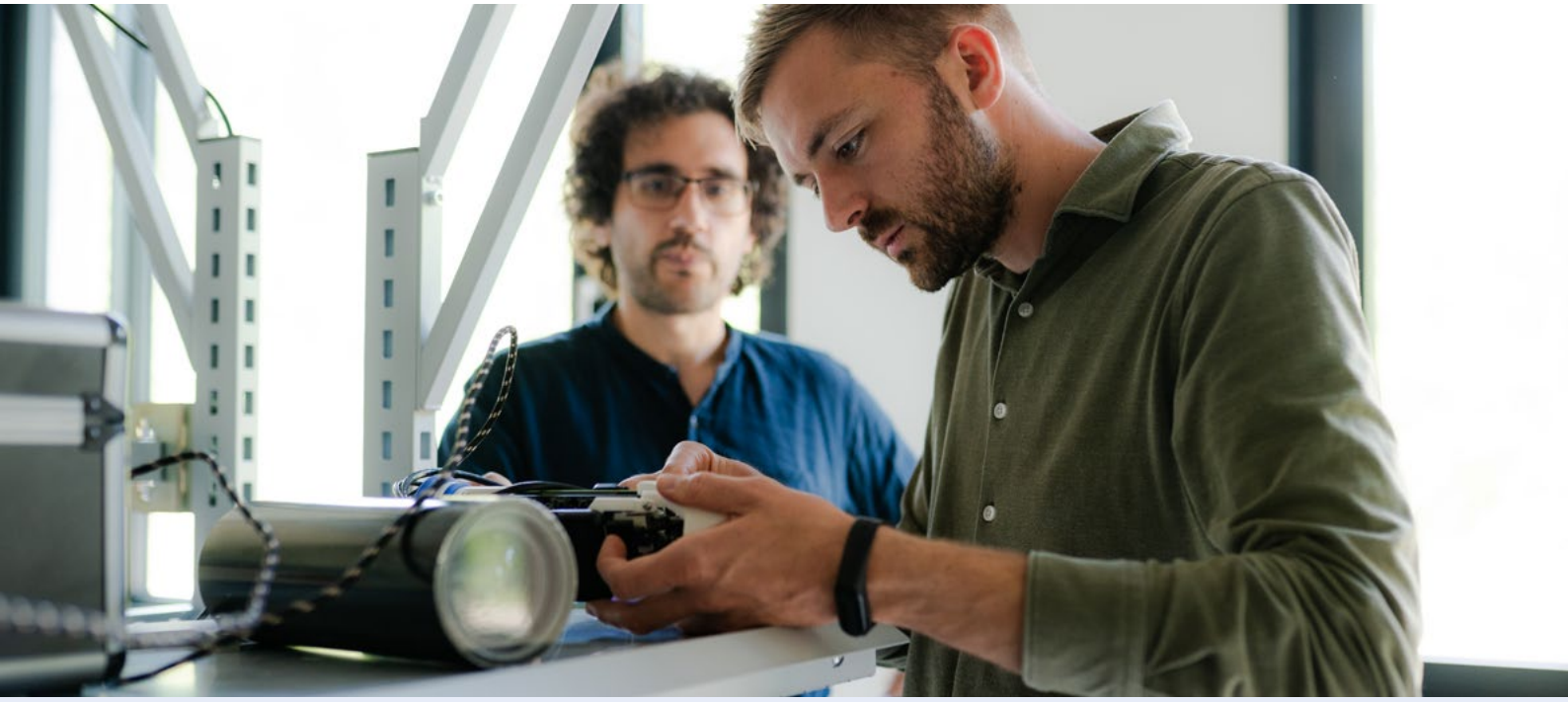
Farhad is trained in electronics engineering and received his PhD from the Indian Institute of Science, Bangalore. After his PhD, he worked in industry (Bosch Research) and academia (NTU and RWTH Aachen University), in various research roles such as researcher and post-doctoral research fellow. Farhad worked at Newcastle University as a Lecturer (Assistant Professor) from December 2022 until June 2024. His research interests are emerging technology-based computing and hardware-oriented security.

Honorary Professorship for Prof. Dr. André van Schaik

In November 2024, the University of Groningen (UG) appointed André van Schaik as an honorary professor at the Faculty of Science and Engineering. At CogniGron, he will work on neuromorphic circuit design and computational neuroscience, complementing the activities of Elisabetta Chicca, Erika Covi, Matthew Cook and others. The main project he has is on tactile sensing where they will have joint PhD students between the UG, Western Sydney University (WSU) and IIT in Genoa.

His collaborations with CogniGron researchers, his vision on neuromorphic computing and his leadership as Director of the International Centre for Neuromorphic Systems, at the WSU, have motivated his nomination as Honorary Professor. A memorandum of understanding between the two universities is already in place, and his appointment will further reinforce this collaboration between the two universities.

André is affiliated with Zernike Institute, as part of the BICS (Bio-inspired Circuits and Systems) group of Prof. Elisabetta Chicca, and his fields of expertise are Neuromorphic Engineering, Computational Neuroscience and Event-Based Vision.



OUTLOOK TO 2025

PROF. DIRK PLEITER

Starting in 2025, Dirk Pleiter officially will join the CogniGron team full time as professor of Computer Architectures, after he already joined the institute part-time in October 2024. He also has a part-time affiliation at the KTH Royal Institute of Technology in Stockholm, where he is a professor of HPC.

He started his career as a physicist, but after getting involved in the design of special-purpose high-performance computing (HPC) systems, he became a computer scientist.

Dirk's research focuses on the co-design of computer architectures (including HPC architectures) and digital infrastructures. HPC uses supercomputers to solve advanced computation problems. These computers are able to produce complex simulations in areas such as weather forecasting and climate research and thus require a lot of computing power.

At CogniGron, he aims to carry out research and development efforts related to the integration of neuromorphic computing devices in computer architectures, with a special interest in bringing neuromorphic and high-performance computing together.

ENGINEERING INTELLIGENCE FROM THE GROUND UP

By Amalie Fedorova

Meet Erika Covi: a researcher working at the intersection of circuits and devices, whose path from Italy to Germany and now Groningen has been driven by curiosity, collaboration, and a love of emerging memory technologies. Her work explores how devices that "remember" can be combined with traditional electronics to build intelligent, energy-efficient systems. At CogniGron, she's found the perfect place to bridge disciplines — and follow her dream of building hardware that learns.

Settling into life in Groningen, Erika admits she's still adjusting to the weather. "It's a bit colder and more humid than Italy," she says. But the city itself won her over right away. "It has a really good vibe — very student-centred and full of life. It actually reminds me of my hometown, Pavia, which also has a very old university." It's fitting, perhaps, that Erika now finds herself in another historic university city, surrounded by young minds and cutting-edge ideas.

Trained as a microelectronic engineer in Italy, Erika began her career designing analogue circuits — the kind of classic, silicon-based hardware that underpins much of today's technology. But it didn't take long for her to be pulled into the world of emerging materials. "They just looked so cool," she laughs, recalling her early encounters with new memory devices during her PhD. That initial spark turned into a full-blown research trajectory. Over the years, she deepened her understanding of the physics behind these devices and began exploring how they could be integrated into real-world systems.

Her postdoctoral and early research career led her from Italy's National Research Council to Politecnico di Milano, and later to Dresden, Germany. It was there, at the NaMLab, that she began actively merging conventional semiconductor technologies with novel memory materials. That ambition eventually earned her an ERC Starting Grant, allowing her to establish her own team. "We looked each other in the eyes and said, 'OK, let's do this together,'" she recalls of her team's decision to move to Groningen.

At CogniGron, Erika is now following her dream — literally. Her team is developing small, intelligent building blocks that combine circuits and emerging memories, laying the foundation for larger, more capable systems. This requires engineering robustness, but also creative experimentation. One area they're exploring is federated learning, a form of decentralised AI where multiple systems learn independently but share their insights — much like students studying together, each with different strengths.

But turning theory into hardware can be challenging. Erika points to the diversity of her team — not just in nationality, but in expertise — as both a strength and a

challenge. To build these kinds of neuromorphic systems you need experts from all kinds of backgrounds: from materials science and physics to circuit design and medicine. Creating a shared vocabulary in this environment is one of the first challenges. Erika shares her favourite anecdotes that capture these disciplinary differences. "One colleague asked me to send him my devices so he could run tests. For him, a device was something with an Ethernet plug. For me, it's a tiny piece of silicon you need to probe with microscopic needles!" Another time, a friend in neuroscience was delighted when two experimental samples behaved differently — just like monkeys with varying reactions in a behavioural study. Erika, on the other hand, needed reproducibility. While she appreciated that her work was considered as intelligent as a monkey, she still had to go back to troubleshoot the electronics. These exchanges, though occasionally confounding, are also deeply rewarding as they enable learning and growth.

And this learning process doesn't stop with colleagues. Before joining CogniGron, Erika missed the contact with students. Now, as a professor, she finds it one of the most inspiring parts of her work. "They are volcanoes of good ideas, and they have the advantage that since they have less experience, they dare more," she says. Sometimes, their ideas even outperform her original plan. It's also this energy

that fuels her. Not only the PhD students, but also bachelor's and master's students, help her get through difficult research days: "Having the possibility to share this journey with highly capable professionals, conceive ideas together and work together for something common."

Erika's long-term vision is to help develop hardware that is tailored to its algorithm — something she says is rarely the case today. "There are certain algorithms that are intrinsically much more efficient than the ones that are used in classic AI, but they become less efficient because the hardware is not thought through," she explains. By co-designing systems from the material level up, she hopes to make smart devices that are more energy-efficient, reliable, and capable of real-time learning. Potential applications range from rescue robotics and early medical diagnostics to assistive home technologies. In the long run, Erika's research is about making a direct, positive impact on the daily lives of people, through more reliable and efficient technology.

Ultimately, Erika's story is one of bridging worlds: old and new technologies, different disciplines, and international perspectives. With her unique expertise and collaborative spirit, she's not just imagining smarter systems — she's working with others to actually build them.

THE NEXT GENERATION

PhD students

NEWLY STARTED PHD STUDENTS IN 2024:

- Hitesh Chhabra (2024-2028)
  Spin and Charge Based Oscillators for Tactile Internet
  Spintronics of Functional Materials group (PIs: Tamalika Banerjee/ Elisabetta Chicca
  Funding source: CogniGron matching to Dutch Research Agenda (NWA) (NL-ECO)

- Vladimir Darbroodi (2024-2028)
  Reconfigurable Computing Systems
  Computer Architecture
  (PI: Farhad Merchant)

- Leah Dijkshoorn (2024-2028)
  Artificial Intelligence and Mathematics for Cognitive Devices
  Stochastic Studies and Statistics group (PI: Marco Grzegorczyk/ Bart Verheij)
  Funding source: Cross-disciplinary CogniGron PhD project (ID-CODe)

- Luca Fehlings (2022-2026)
  Integration of emerging memory devices into neuromorphic CMOS circuits
  Cognitive Systems (PI: Erika Covi)
  Funding source: EU European Research Council (ERC) Starting Grant (StG)

- Paolo Gibertini (2022-2026)
  Hybrid memristive-CMOS neuromorphic systems for edge computing
  Cognitive Systems (PI: Erika Covi)
  Funding source: EU European Research Council (ERC) Starting Grant (StG)

- Memoona Ismail (2024-2028)
  Edge of stability for enhanced memristive functionality
  Solid State Materials for Electronics group (PI: Beatriz Noheda)
  Funding source: EU HORIZON Marie Skłodowska-Curie Actions (MSCA) - Doctoral Networks (DN) (TOPOCOM)

- Ram Eshwar Kaundinya (2024-2028)
  Cognitive Architectures for Touch Based Applications
  Cognitive Modeling group (PIs: Niels Taatgen / Jelmer Borst)
  Funding source: CogniGron matching to Dutch Research Agenda (NWA) (NL-ECO)

- Henrieke Krijgsheld (2024-2028)
  Mathematical Methods of Neuromorphic Computing and Control
  Dynamical Systems, Geometry & Mathematical Physics group (PIs: Hildeberto Jardón-Kojakhmetov/ Ming Cao)
  Funding source: Cross-disciplinary CogniGron PhD project (MOTION)

- Giuseppe Leo (2024-2028)
  Stochastic Spiking Wireless Multimodal Sensory Systems Bio-Inspired Circuits and Systems group (PI: Elisabetta Chicca)
  Funding source: EU European Research Council (ERC) Synergy (SWIMS)

- Davide Maioli (2024-2028)
  Neuromorphic High Level Information Processing
  Cognitive Modeling group (PI: Matthew Cook)

- Himanshu Rai (2024-2028)
  Memristive models for faster material design cycles towards applications
  Spintronics of Functional Materials group (PIs: Tamalika Banerjee/ Julian Koellermeier)
  Funding source: Cross-disciplinary CogniGron PhD project (MEMO)

- Floor Schipper (2024-2026)
  The Geometry of Coupled Neurons towards Analog Computing
  Dynamical Systems, Geometry & Mathematical Physics group (PIs: Hildeberto Jardón-Kojakhmetov/ Ming Cao)
  Funding source: Cross-disciplinary CogniGron PhD project (MOTION)

- Albert Silvans (2024-2028)
  Physics and Statistics for Cognitive Devices
  Stochastic Studies and Statistics group (PIs: Marco Grzegorczyk/Beatriz Noheda)
  Funding source: Cross-disciplinary CogniGron PhD project (ID-CODE)

- Pablo Sorrentino (2024-2028)
  Security and Privacy in Neuromorphic Computing Device: Opportunities and Challenges
  Information Systems Group (PIs: Fatih Turkmen/ Tamalika Banerjee)
  Funding source: Cross-disciplinary CogniGron PhD project (NC-PRYSE)

- Haoran Yu (2024-2028)
  Ferroelectric memristors for energy-efficient computing
  Solid State Materials for Electronics group (PI: Beatriz Noheda/ Georgi Gaydadjiev)
  Funding source: CogniGron matching to Dutch Research Agenda (NWA) (NL-ECO)

- Bojian Zhang (2024-2028)
  Development, modelling, and characterisation of RRAM-based circuits for analog computing
  Cognitive Systems (PIs: Erika Covi/ Farhad Merchant)
  Funding source: Cross-disciplinary CogniGron PhD project (Neuroprivate)

- Yiming Zhang (2024-2028)
  Low Power Probabilistic-bits Enabled Reckoning
  Innovative Computer Architecture (PIs: Georgi Gaydadjiev/ Tamalika Banerjee)
  Funding source: Cross-disciplinary CogniGron PhD project (LOPPER)

STARTED BEFORE 2024:

- Steven Abreu (2021-2025)
  Computing in non-digital substrates
  Computing in Cognitive Materials group (PI: Herbert Jaeger)

- Jhon Kevin Astoquillca Aquilar (2021-2025)
  Synchronization in random networks
  Stochastics and Statistics group (PI: Holger Waalkens)
  Funding source: Cross-disciplinary CogniGron PhD project (NANOPER)

- Ishitro Bhaduri (2023-2027)
  Low power probabilistic-bits enabled reckoning
  Spintronics of Functional Materials group (PIs: Tamalika Banerjee/ Gaydadjiev)
  Funding source: Cross-disciplinary CogniGron PhD project (LOPPER)

- Remi Brandt (2020-2024)
  Neural networks with observable decisions
  Innovative Computer Architectures (PI: Georgi Gaydadjiev)

- Lijun Chen (2021-2025)
  Robust metal halide perovskites for solar cells and memristors
  Photophysics and Optoelectronics group (PI: Maria Loi)
  Funding source: China Scholarship Council (CSC)

- Radu Cimpean (2022-2026)
  The development of ordinary differential equation (ODE) theory and computational models for sense of smell
  Systems Control and Applied Analysis group (PIs: Alden Waters & Stephan Trenn)
  Funding source: Cross-disciplinary CogniGron PhD project (SMARTEN)

- Davide Cipollini (2021-2025)
  Adaptive random non-linear mappings for neural computing in ferroelastic films
  Artificial Intelligence group (PI: Lambert Schomaker)
  Funding source: EU HORIZON Marie Skłodowska-Curie Actions (MSCA) - Innovative Training Networks (ITN) (MANIC)

- Otavio Citton (2023-2027)
  Statistical physics of learning in layered systems of adaptive elements
  Intelligent Systems Group (PI: Michael Biehl)
  Funding source: Cross-disciplinary CogniGron PhD project (SPARROW-NETS)

- Madison Cotteret (2021-2024)
  Neuromorphic memristive VLSI architectures for cognition
  Bio-inspired Circuits and Systems group (PI: Elisabetta Chicca)
  Funding source: German Research Foundation (DFG) (NMVAC)

- Maxime Fabre (2021-2025)
  On-chip training on analog circuits with memristive devices and bio-plausible learning algorithms
  Bio-inspired Circuits and Systems group (PI: Elisabetta Chicca)

- Guillaume Pourcel (2020-2024)
  Theory of neuromorphic computing
  Computing in Cognitive Materials group (PI: Herbert Jaeger)
  Funding source: EU HORIZON Marie Skłodowska-Curie Actions (MSCA) - Innovative Training Networks (ITN) (POSTDIGITAL)

- Hugh Greatorex (2021-2025)
  Memristive time difference encoder
  Bio-inspired Circuits and Systems group (PI: Elisabetta Chicca)
  Funding source: German Science Foundation (DFG) (MemTDE)

- Ruben Hamming-Green (2021-2025)
  Combined volatile/non-volatile memristive ferroelectric arrays.
  Solid State Materials for Electronics group & IBM Research-Zurich (PI: Beatriz Noheda and Bert Offrein)
  Funding source: CogniGron-IBM fellowship

- Paul Hansch (2022-2026)
  Smart electronic olfactory system
  Photophysics and Optoelectronics group (PI: Maria Loi)
  Funding source: Cross-disciplinary CogniGron PhD project (SMARTEN)

- Marieke Heidema (2022-2026)
  Learning in memristive electrical circuits
  Systems and Control Theory Research group (PI: Bart Besselink)

- Anne-Men Huijzer (2019-2024)
  Memristor networks
  Systems and Control Theory Research group (PI: Bart Besselink)

- Fabian IJpelaar (2022-2026)
  Qualitative modeling, simulation and exploration of multi-phenomenal materials dynamics
  Computing in Cognitive Materials group (PI: Herbert Jaeger)
  Funding source: Cross-disciplinary CogniGron PhD project (Q-MAT)

- Azminul Jaman (2020-2024)
  Towards a cognitive computer architecture based on memristive devices: developing short- and long-term memory
  Spintronics of Functional Materials group (PI: Tamalika Banerjee)
  Funding source: Cross-disciplinary CogniGron PhD project (MEMSTO)

- Foelke Janssen (2022-2026)
  Qualitative modeling, simulation and exploration of multi-phenomenal materials dynamics (Q-Mat)
  Solid State Materials for Electronics group (PI: Beatriz Noheda)
  Funding source: Cross-disciplinary CogniGron PhD project (Q-MAT)

- Philipp Klein (2020-2024)
  Learning in neuromorphic systems
  Bio-inspired Circuits and Systems group (PI: Elisabetta Chicca)

- Safiere Kuijpers (2023-2027)
  Memristive models for faster material design cycles towards applications
  Computational & Numerical Mathematics group (PI: Julian Koellermeier)
  Funding source: Cross-disciplinary CogniGron PhD project (MEMO)

- Mian Li (2020-2024)
  Morphological image analysis of conduction maps
  Scientific Visualization and Computer Graphics (PIs: Michael Wilkinson & Jos Roerdink)
  Funding source: EU HORIZON
  Marie Skłodowska-Curie Actions (MSCA) - Innovative Training Networks (ITN) (MANIC)

- Jesse Luchtenveld (2021-2025)
  Analogue phase-change memory cells for neuromorphic computing
  Nanostructured Materials and Interfaces group & IBM Research-Zurich (PIs: Bart Kooi and Abu Sebastian)
  Funding source: CogniGron-IBM fellowship

- Michele Mastella (2020-2024)
  Neuromorphic embedded processing for touch
  Bio-inspired Circuits and Systems group (PI: Elisabetta Chicca)
  Funding source: EU HORIZON Marie Skłodowska-Curie Actions (MSCA) - Innovative Training Networks (ITN) (NEUTOUCH)

- Ton Juny Pina (2022-2026)
  Neuromorphic odor classification
  Bio-inspired systems and circuits group (PI: Elisabetta Chicca)
  Funding source: Cross-disciplinary CogniGron PhD project (SMARTEN)

- Jan Rieck (2019-2024)
  Memristor networks from self-assembled domain walls in oxides
  Solid State Materials for Electronics (PI: Beatriz Noheda)
  Funding source: EU HORIZON Marie Skłodowska-Curie Actions (MSCA) - Innovative Training Networks (ITN) (MANIC)

- Julien van der Ree (2021-2024)
  Nanoparticle based percolating networks towards neuromorphic computing
  Physics - Surface interactions and Nanostructures group (PIs: George Palasantzas/ Bart Kooi)
  Funding source: Cross-disciplinary CogniGron PhD project (NANOPER)

- Ole Richter (2020-2024)
  Neuromorphic integrated systems for network stability and homeostasis
  Bio-inspired Circuits and Systems group (PI: Elisabetta Chicca)

- Saad Saleh (2020-2024)
  New switching architectures with memristors for neuromorphic computing
  Computer Networks group (PI: Boris Koldehofe)

- Mart Salverda (2018-2023)
  Neuromorphic phenomena in thin film perovskite oxides
  Solid State Materials for Electronics (PI: Beatriz Noheda)

- Jordi Timmermans (2022-2026)
  Nb-doped SrTiO3 memristive interfaces for bio inspired computing
  Artificial Intelligence group (PI: Lambert Schomaker)
  Funding source: Cross-disciplinary CogniGron PhD project (MEMSTO)

- Thomas Tiotto (2020-2024)
  Towards a cognitive computer architecture based on memristive devices: developing short- and long-term memory
  Artificial Intelligence group (PI: Niels Taatgen)
  Funding source: Cross-disciplinary CogniGron PhD project (COGMEM)

- Karoline Tran (2020-2024)
  Carbon nanotube-based neuromorphic electronics
  Photophysics and Optoelectronics group (PI: Maria Loi)

- Willian Soares Girão (2020-2024)
  Neuromorphic circuits for novel devices
  Bio-inspired Circuits and Systems (PI: Elisabetta Chicca)
  Funding source: EU HORIZON Marie Skłodowska-Curie Actions (MSCA) - Innovative Training Network (ITN) (MANIC)

- Peter van der Wal (2023-2027)
  Robust learning of sparse representations: brain-inspired inhibition and statistical physics analysis
  Information Systems group (PI: George Azzopardi)
  Funding source: Cross-disciplinary CogniGron PhD project (SPARROW-NETS)

- Daniel Willhalm (2020-2024)
  Large deviations in stochastic geometry
  Topological Data Analysis and Data Science group (PI: Tobias Muller)

- Jingtian Zhao (2023- 2027)
  Ferroelectric memristive devices
  Solid State Materials for Electronics (PI: Beatriz Noheda)
  Funding source: Chinese Scholarship Council (CSC) fellowship

Postdoctoral researchers

NEWLY STARTED POSTDOCTORAL FELLOWS IN 2024:

- Dr. Martin F. Sarott (2024-2025)
  Reservoir Computing with ferroelectric devices
  Solid State Materials for Electronics group (PI: Beatriz Noheda)
  Funding source: EU HORIZON CL4 Digital Emerging programme (CONCEPT) and CogniGron stimulus grant.

- Dr. Horatio Cox (2024-2026)
  Crystalline Oxides For Next Generation Computation and Emerging Photonic Technologies
  Solid State Materials for Electronics group (PI: Beatriz Noheda)
  Funding source: EU HORIZON CL4 Digital Emerging programme (CONCEPT)

- Dr. Fernando Quintana Velázquez (2024-2026)
  Highly integrated Hardware-Software Co-Development for Adaptive AI
  Cognitive Systems (PI: Erika Covi)

STARTED BEFORE 2024:

- Dr. Alejandro Pequeño Zurro (2023-2027)
  Tactile Internet: remote sensing with neuromorphic technology
  This project has received funding from the Dutch NWA Project NL-ECO.
  Bio-inspired Circuits and Systems (PI: Elisabetta Chicca)
  Funding source: Dutch Research Agenda (NWA) (NL-ECO)

- Dr. Nicoletta Risi (2022-2024)
  Optimizing spiking neural networks with gradient-based and online learning algorithm
  Bio-inspired Circuits and Systems group (PI: Elisabetta Chicca)

- Dr. Gaurav Vats (2023-2025)
  SMART: Synchronised neuro-Memristive Architecture for Reinforced learning Technology
  Solid State Materials for Electronics (PI: Beatriz Noheda)
  Funding source: EU HORIZON Marie Skłodowska-Curie Actions (MSCA) - Individual fellowship (IF) (FAST; grant agreement ID: 892669)

COGNIGRON TALENT NETWORK (CTN)

Starting as a PhD student in a large multi-disciplinary research organisation can be an intimidating undertaking. Peers are scattered across different buildings, and language barriers between fields may trouble communication and collaboration. The CogniGron Talent Network (CTN) facilitates events to socially and scientifically connect young researchers. Besides organising the activities, the CTN board also provides input to the CogniGron Coordinating Office to offer the PhD point of view to CogniGron.

On a monthly basis, CTN organizes Introductory scientific meetings in which selected scientific topics within one of CogniGron's disciplines are explained by young researchers for young researchers. As the topics are explained on a basic level, all CogniGron's PhD students and postdocs can contribute to the discussions. CogniGron PI's are not invited for these meetings, as it has been seen that this helps young researchers to speak more openly about their knowledge gaps.

Besides connecting scientifically, connecting socially adds significantly to feeling at home within the CogniGron community. Therefore, bimonthly social events are organised which are aimed at stimulating mutual (scientific) understanding and most importantly, focus on leisure activities together with other CogniGron PhD students and postdocs.

In 2024, the CogniGron Talent Network was led by Otavio Citton, Safiere Kuijpers, Jan Rieck and Jordi Timmermans. In the course of 2024, Martin Sarott replaced Jan Rieck as CTN board member.

First board of the CTN: (left to right) Jordi Timmermans, Jan Rieck, Otavio Citton and Safiere Kuijpers.

HIGHLIGHTS

In the news

A MILESTONE: TEXEL CHIP PRESENTED

The first neuromorphic chip, developed by Elisabetta Chicca's group within CogniGron, was officially presented to the Ubbo Emmius Foundation. This symbolic moment highlights how fundamental and interdisciplinary research can lead to tangible results.

The TEXEL chip is described in more detail in Greatorex et al., 2024 (**https://arxiv.org/abs/2410.15854**).

Presentation of the TEXEL chip to the Ubbo Emmius Fonds. From left to right, Liesbeth Nagelkerke-Mulder, board member UEF and chair of the Grant Committee, Remco Kowenhoven, director UEF, Beatriz Noheda, director CogniGron, and Joost Frenken, dean Faculty of Science and Engineering.

NEW PIs JOIN THE COGNIGRON TEAM

In 2024, three new PIs joined CogniGron: Erika Covi, Serte Donderwinkel, and Farhad Merchant. Each of them brings unique expertise and research experience. Together, we are building an interdisciplinary community that breathes innovation.

OUR FIRST COGNIGRON RESEARCH AWAY DAY

PIs and PhD students gathered at the Puddingfabriek for an inspiring day full of in-depth discussions, connection, and taking steps forward together. It was a wonderful opportunity to strengthen the community and share ideas outside the lab walls. In addition to science, there was also space for professional development during an innovation brainstorm session.

HONORARY PROFESSORSHIP FOR ANDRÉ VAN SCHAIK

In November 2024, the University of Groningen (UG) appointed André van Schaik as an honorary professor at the Faculty of Science and Engineering. We are happy to welcome him to CogniGron, where he will work on neuromorphic circuit design and computational neuroscience, complementing the activities of Elisabetta Chicca, Erika Covi, Matthew Cook and others. The main project he has is on tactile sensing where they will have joint PhD students between the UG, Western Sydney University (WSU) and IIT in Genoa.

FIRST COGNIGRON START-UP COMPANY: IMCHIP[N]

From research to reality: CogniGron's first-ever startup is here! CogniGron's PI Tamalika Banerjee (left in the picture) launched IMChip.nl, bringing us one step closer to energy-efficient computer chips.

The IMChip startup builds in-memory chips for high-performance computing, offering:

- 1000x higher performance/Watt/
- 200x less energy consumption
- 100x lower latency

As we translate our research to new technologies like these, we strive to bridge the gap between science and society, moving forward on our futu-re-proof computing journey.

MOVING INTO NEW FERINGA BUILDING

At last, the time had come: the old Nijenborgh building was exchanged for the brand-new Feringa building on the Zernike Campus in Groningen. From now on, a large part of Groningen's researchers in neuromorphic computing can be found here. And if anyone happens to lose their way, the CogniGron lab spaces are easy to recognize by the logo displayed next to the doors.

CONFERENCES AND SUMMERSCHOOL

CogniGron (co-)organized several events in 2024 highlighting the international and national inter-disciplinary research. In Groningen, Brainspiration, a two-day conference took place at the Forum Groningen with engaging lectures and parallel sessions. Moreover, the 2024 MemrisTec Summer School took place at Groningen and was a week packed with both educational and fun activities for students of electrical engineering, computer science, materials sciences, physics. Lastly, there was the Neuromorphic computing ecosystem kick-off in Eindhoven, where entrepreneurs, researchers and policymakers gathered for building a collective roadmap for brain-inspired computing.

HIGHLIGHTED PAPERS

WHITE PAPER ON NEUROMORPHIC COMPUTING IN THE NETHERLANDS

CogniGron contributed to the white paper 'Neuromorphic Computing in the Netherlands' that outlines the potential of brain-inspired computing. It also explores the current state of neuromorphic computing efforts and expertise in the Netherlands, revealing a vibrant community of top-tier research institutions, tech-driven industries, national programs and startups. This diverse network provides a strong foundation for advancing efforts in neuromorphic computing, from researching innovative materials to applying this paradigm in specific scientific use cases and beyond.

The white paper proposes establishing a national coalition to develop a shared vision and roadmap with all relevant parties and in close collaboration with Topsector ICT. Read and learn more about neuromorphic computing in the Netherlands:

https://www.ru.nl/sites/default/files/2024-11/whitepaper-neuromorphic-computing-final_pdf.pdf

RESEARCH FROM ELISABETTA CHICCA'S GROUP PUBLISHED IN NATURE COMMUNICATIONS

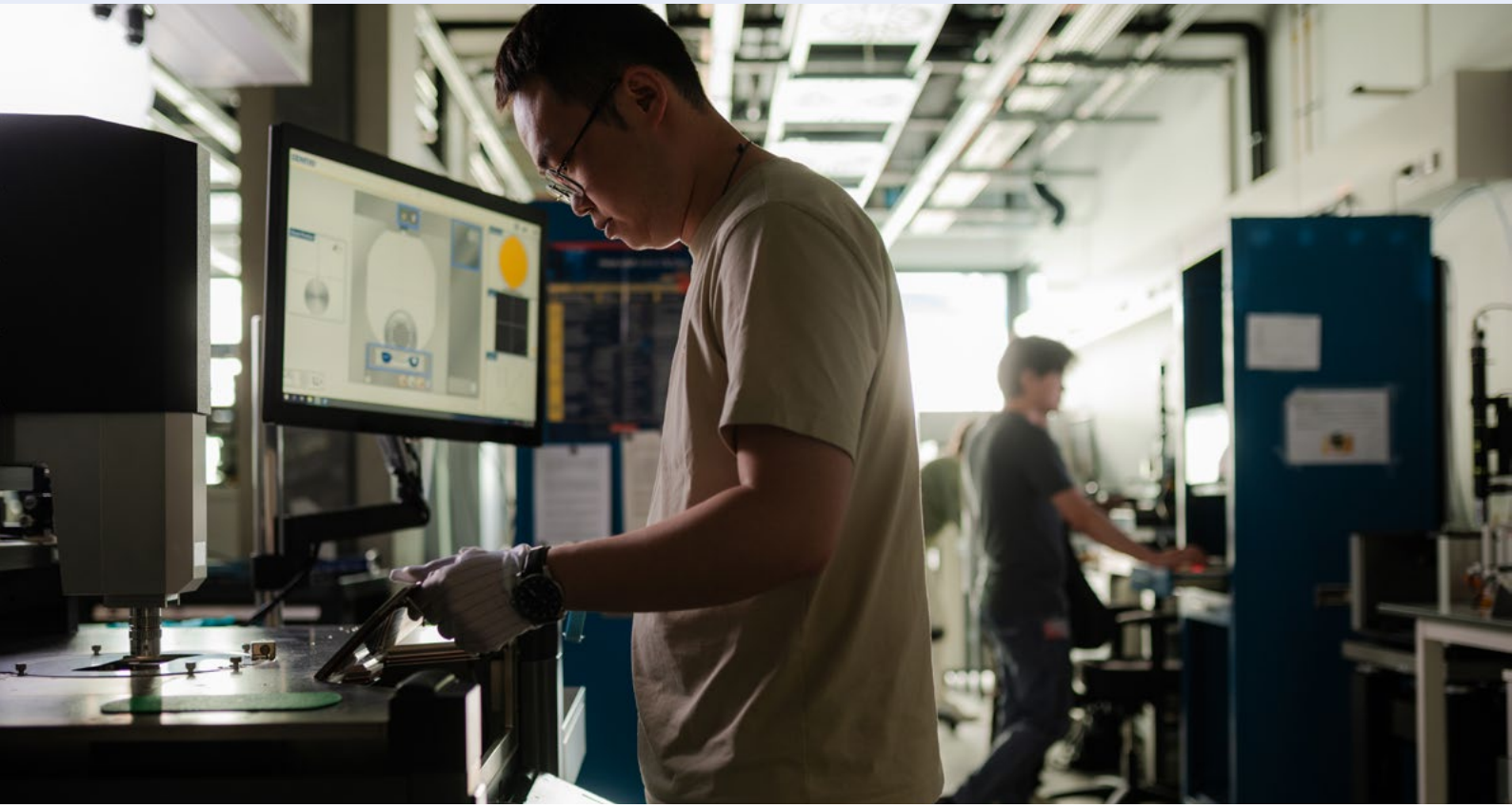
Could it be that tiny bugs with limited brain power, yet great navigational abilities, will lead to the next breakthrough in energy-efficient computing?

CogniGron's Elisabetta Chicca explains how her team built a robot to analyse obstacle avoidance in insects. The research was published in Nature Communications earlier this year:

Finding the gap: neuromorphic motion-vision in dense environments

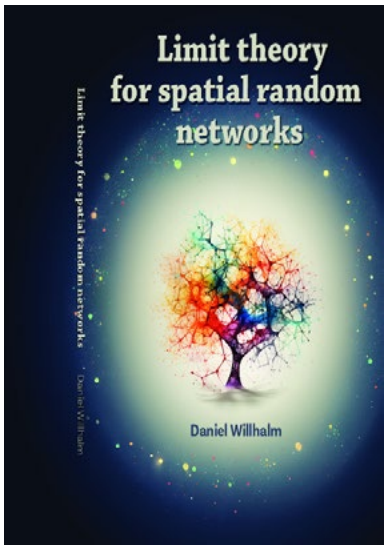
T Schoepe, E Janotte, MB Milde, OJN Bertrand, M Egelhaaf, E Chicca

Nature Communications 15 (1), 817



Awarded PhD degrees

LIMIT THEORY FOR SPATIAL RANDOM NETWORKS

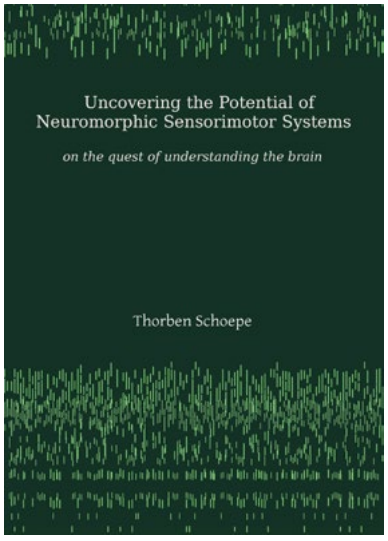


PhD candidate: Daniel Willhalm
Defended: 16 April 2024
Supervisors: Prof. Tobias Müller, Dr. Christian Hirsch

Abstract:

This thesis deals with the study of the asymptotic behavior of certain measurements derived from random clouds of points scattered in space. Such measurements can be related to the topological nature of points such as Betti numbers or the geometric nature and relate to the length of connections formed between those points. The dissertation is divided into three chapters, each of which is based on a separate publication. Chapter 1 focuses on the quantification of the probability of rare events that are identified through an untypically high measurement related to edge lengths in very large graphs formed on a random point cloud. In Chapter 2, we extend our investigation to high-dimensional random geometric graphs, where the number of expected connections decreases exponentially with the dimension of the space. Finally, Chapter 3 focuses on the quantification of the probability of rare events that are identified through an untypically low measurement related to graphs formed based on a very large random point cloud. We provide a general framework for the study of rare events for measurements based on topological or geometric features derived from a random point cloud in different density scenarios.

UNCOVERING THE POTENTIAL OF NEUROMORPHIC SENSORIMOTOR SYSTEMS on the quest of understanding the brain



PhD candidate: Thorben Schoepe
Defended: 29 April 2024
Supervisors: Prof. Elisabetta Chicca, Prof. Lambert Schomaker

Abstract:

In this thesis we investigate how embodied cognition might take place in insects and vertebrates by developing fully spiking neuromorphic sensorimotor systems. These embodied systems successfully perform a variety of tasks including sound source localization, obstacle avoidance and straight line navigation. Our results provide many new hypotheses about embodied cognition. For example how time scales of decision making could be implemented, how a mixture of goal directed movement and random exploration help finding a pathway and how global optic flow controls the movement velocity. Only very few other fully spiking closed-loop systems have been developed so far. Thus, this thesis might serve as a starting point for exploring the functionality of embodied cognition in fully spiking neuromorphic sensorimotor systems.

FROM MEMRISTORS TO MINDS

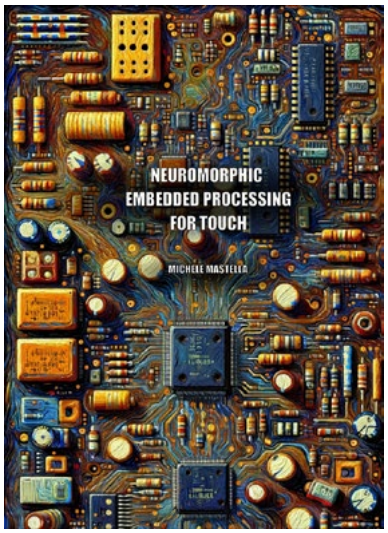
- Enabling End-to-End Neuromorphic Systems with Spiking Neural Networks

PhD candidate: Thomas Tiotto
Defended: 4 June 2024
Supervisors: Prof. Niels Taatgen, prof. Tamalika Banerjee, Prof. Jelmer Borst

Abstract:

This thesis explores advanced computer systems that mimic the human brain, known as neuromorphic systems. We focus particularly on integrating special components called memristive devices into networks that operate similarly to neural networks in the brain. These devices can change their behavior based on the electrical signals they receive, which is similar to how connections between neurons in the brain adjust when learning. The thesis delves into using a specific type of memristor made from a material called $SrTiO_3$ (Nb:STO) that acts like the synapses in the brain. These memristors can adjust their electrical resistance in response to input signals, mimicking the adaptability of biological synapses.
From a broader perspective, the thesis presents a model that simulates how the brain's memory works. This model incorporates features that allow it to maintain and manage information effectively, helping the brain-like computer system remain stable and flexible in handling tasks. Overall, this work helps bridge the gap between the physical hardware of these brain-like computers and the software that runs them.

NEUROMORPHIC EMBEDDED PROCESSING FOR TOUCH



PhD candidate: Michele Mastella
Defended: 10 Sep 2024
Supervisors: Prof. Elisabetta Chicca, Prof. Niels Taatgen

Abstract:

Touch, one of our primary senses, allows us to explore and understand the physical world around us. Robots and prostheses struggle to replicate the nuanced sense of touch found in humans. In this thesis, we demonstrate how, using neuromorphic principles inspired by neuroscientific literature, we can address these limitations. In the first part of the thesis, we investigate how taking inspiration from mechanoreceptors can inform the design of novel sensors capable of encoding pressure into spike patterns. Following this, we explore the decoding of these signals using networks composed only of spiking neurons and synapses, drawing inspiration from biological findings. The resulting architectures show dynamics qualitatively resembling evidence from neuroscientific experiments. Finally, we demonstrate how the networks we designed can be translated onto CMOS hardware for future deployments in real-world agents.

This work lays down a compelling example of drawing inspiration from biology to enhance the design of artificial agents with tactile capabilities.

SYNAPTIC CIRCUITS AND FUNCTIONS IN BIO-INSPIRED INTEGRATED ARCHITECTURES

- Designing and advancing neurosynaptic physical-time systems a practical introduction and survey

PhD candidate: Ole Richter
Defended: 15 October 2024
Supervisors: Prof. Elisabetta Chicca, Prof. Herbert Jaeger

Abstract:

Based upon the most advanced human-made technology on this planet, CMOS integrated circuit technology, this dissertation examines the design of hardware components and systems to establish a technological foundation for the application of future breakthroughs in the intersection of AI and neuroscience. This dissertation is driven by the quest to harness biological and artificial neural principles to enhance the efficiency, adaptability, and intelligence of electronic neurosynaptic and neuromorphic hardware systems. It investigates the hardware design of bio-inspired neural components and their integration into more extensive scale and efficient chip architectures suitable for edge processing and near-sensor environments.

Exploring all steps to the creation of a custom chip, this work selectively surveys and advances the state-of-the-art in bio-inspired mixed-signal subthreshold integrated design for neurosynaptic systems in a practical fashion. Further, it presents a novel asynchronous digital convolutional neuronal network processing pipeline integrated with a vision sensor for smart sensing. In conclusion, it sets forth a series of open challenges and future directions for the field, emphasizing the need for a robust, future-proof base for bio-inspired design and the potential of asynchronous stream processor architectures.

OUR RESEARCH

Research Projects

CROSS-DISCIPLINARY PHD PROJECTS

In this first phase of CogniGron, staff can participate and contribute to CogniGron by having a PhD student funded via the programme. A requirement is that staff and team members fully commit to the scientific goals and work plan of CogniGron. In addition, projects that are submitted jointly by two PIs and strengthen the collaboration between different disciplines are prioritised. A four-page proposal is submitted for each project. The proposal should clarify how the research directly addresses the main goals of CogniGron and how it will contribute solutions beyond the state of the art. In addition, the proposal should explain how it will make use or enhance the collaboration between different disciplines and institutes. The proposals were reviewed by the CogniGron program board and, if needed, by the external scientific advisory panel.

PROJECTS AWARDED IN 2024:

Bio-inspired neuromorphic touch-sensing system (NEUROTACT)

Humans perceive and identify its environment by touch, but this sensation requires sophisticated physical and neuronal mechanisms that involve physical stimuli, mechanoreceptors in the skin, bioelectrical signals and neuronal information processing, et cetera. Thus, multidisciplinary research is crucial to successfully develop and emulate artificial touch-sensing systems and their implementation in daily life applications. Therefore, we propose the development of bio-inspired neuromorphic sensing systems interfacing the tactile capabilities of flexible piezoelectric sensors with dedicated neuromorphic systems. We will focus on the fabrication and integration of flexible sensors, circuit interfaces and neuromorphic spiking neuronal networks.

Project leaders: Mónica Acuautla Meneses (Engineering) and Elisabetta Chicca (Electronics)
PhD students to be recruited in 2025

The multiple timescales of neuromorphic systems and control (MOTION)

A neuromorphic device can be regarded as a multi-scale input-output system comprised by a network of interconnected neurons. Our project will develop a mathematically rigorous approach to analyze dynamic networks involving multiple timescales to improve our understanding of neuromorphic devices. In particular, we will a) better understand how complex ensembles of neurons behave, and b) ask how one can design such ensembles for specific purposes utilizing tools from systems and control engineering. Making use of recent advances in perturbation theory, system's theory and control, group theory, graph theory, mean-field and reduction techniques, we will contribute to the design of reliable neuromorphic controllers.

Project leaders: Ming Cao (Engineering) and Hildeberto Jardón-Kojakhmetov (Mathematics)
PhD students to be recruited in 2025.

Opportunities and challenges of the state-of-the-art Neuromorphic Computing devices for security and privacy (NC-PRYSE)

Inspired from how the human-brain works, neuromorphic computing has the promise that many of the AI tasks can be performed in orders of magnitude more efficiently in terms of energy consumption and computational requirements than the current AI solutions. In this cross-disciplinary project, we aim to investigate the security of neuromorphic chips against side channel attacks and their suitability for implementing security-critical functionality. Starting the investigation at the level of circuits, our particular focus will be on memristor-based designs (and the commonly used materials in their construction), their security relevant properties (e.g., stochasticity and indistinguishability) and some of the high level choices during their design/usage. Our project can contribute to better choices in the design/implementation of memristor-based neuromorphic devices, at the stage before their large-scale industrial production and adoption takes place.

Project leaders: Fatih Turkmen (Computer science) and Tamalika Banerjee (Materials science)
PhD student to be recruited in 2025.

Privacy preserving architecture using novel cognitive ReRAM devices (Neuroprivate)

The emergence of the Internet of Things (IoT) has provided a large surface for bad actors to carry out various types of attacks, ranging from denial of service to side-channel attacks. The obvious solution to this challenge is to apply homomorphic encryption to this sensitive data to ensure that the leaked information is useless for an attacker. However, the homomorphic encryption in its present form with the classical CMOS-based hardware incurs unacceptable area and energy footprints. In this project, we incorporate post-CMOS technology, such as Resistive Random Access Memory (ReRAM), coupled with innovative computer architecture design to achieve the energy-efficient homomorphic processing element. Fast device and array models will be built to be incorporated into a system-level simulation and energy estimation framework that will eventually be validated against the hardware prototype for its accuracy.

Project leaders: Erika Covi (Electronics) and Farhad Merchant (Computer science)
PhD students to be recruited in 2025.

RUNNING PROJECTS:

Low power probabilistic bits enabled reckoning (LOPPER) (awarded in 2023)

The collaborative goal of this project is to achieve a proof of concept of an in-memory random number generator using probabilistic bits as well as probabilistic hardware for solving optimisation problems efficiently.

Project leaders: Tamalika Banerjee (Materials science) and Georgi Gaydadjiev (Computer science)
PhD students: Ishitro Bhaduri and Yiming Zhang

Implementation and design of cognitive devices (ID-CODE) (awarded in 2023)

The understanding and control of existing cognitively relevant hardware is still limited. We will build on existing research on innovative materials, such as HfO2 based memristors, to develop new statistical techniques and analysis pipelines to investigate their behaviour. In parallel we will address the problem of aligning, learning and reasoning in cognitive hardware design. For the design of new cognitive devices we will develop new artificial intelligence methods that are meaningful in the target domain and make sense of the data. The two projects are connected by a shared mathematical modelling technique, namely Bayesian networks. Bayesian networks are a flexible and easy-to-interpret tool for modelling the dependencies in complex data.

Project leaders: Marco Grzegorczyk (Mathematics), Bart Verheij (Artificial Intelligence), Beatriz Noheda (Materials science)
PhD students: Albert Silvans and Leah Dijkshoorn

Robust learning of sparse representations: brain-inspired inhibition and statistical physics analysis (SPARROW-NETS) (awarded in 2022)

Sparsity is among the key factors that contribute to high energy-efficient processing in the brain. Neuroscientists believe that inhibition is a crucial property that results in sparse and thus highly energy efficient representations. Sparsity and inhibition are the focus of this project, consisting of two key objectives: the investigation of push-pull inhibition embedded in convolutional and spiking neural networks, and the systematic study of learning processes in model situations.

Project leaders: George Azzopardi (Artificial Intelligence) and Michael Biehl (Computer Science)
PhD students: Otavio Citton and Peter van der Wal

Memristive models for faster material design cycles towards applications (MEMO) (awarded in 2022)

Long development cycles for memristive devices and materials are inhibiting innovation due to large parameter spaces, complex manufacturing processes, and necessary measurement series. This limits physical insight, performance, and applications of memristors. The project tackles this challenge by a close interaction of mathematical modelling and material science, in which newly acquired experimental data and models from material scientists are used in a closed design loop together with state-of-the-art mathematical techniques. The goal of this project is to combine mathematical and material models to improve understanding of memristive materials, speedup memristor design and extend memristors' application areas.

Project leaders: Tamalika Banerjee (Materials science) and Julian Koellermeier (Mathematics)
PhD students: Safiere Kuijpers and Himanshu Rai

Smart electronic olfactory system (SMARTEN) (awarded in 2021)

The use of so-called electronic noses has spread widely in many industrial sectors thanks to their ability to detect chemicals in very small concentrations. In the healthcare sector, this technology is starting to play a key role as a rapid and low-cost diagnostic tool for many diseases. In this project we are specifically interested in the development of electronic noses for lung cancer detection.

Project leaders: Elisabetta Chicca (Electronics), Maria Loi (Physics) and Alden Waters/Stephan Trenn (Mathematics)
PhD students: Radu Cimpean, Paul Hansch and Ton Juny Pina

Qualitative modelling, simulation and exploration of multi-phenomenal materials dynamics (Q-MAT) (awarded in 2021)

Current approaches to computing based on digital hardware have limitations and call for novel alternatives. The aim of this project is to pioneer a new qualitative physics formalism, together with a qualitative physics engine that is able to simulate a wide range of phenomena while being fast to run, replacing numerical accuracy by qualitative validity.

Project leaders: Herbert Jaeger (Artificial Intelligence) and Beatriz Noheda (Materials science)
PhD students: Foelke Janssen and Fabian IJpelaar

Nanoparticle based percolating networks towards neuromorphic computing (NANOPER) (awarded in 2020)

Nanoparticle percolating networks exhibit interesting switching behaviour and potentiation, which are characteristics of the brain with neurons and synapses. In this project, phase change material nanoparticles are designed, synthesised and mathematically modelled. These materials are expected to have a richer network activity and therefore excellent materials used for neuromorphic computing.

Project leaders: George Palasantzas & Bart Kooi (Physics), Holger Waalkens & Daniel Valesin (Mathematics)
PhD students: Jhon Kevin Astoquillca Aquilar and Julien van der Ree

Nb-doped SrTiO3 memristive interfaces for bio-inspired computing (MEMSTO) (awarded in 2019)

This project studies the physics of interface-based memristive devices on semiconducting SrTiO3 substrates and develops phenomenological models to predict the performance of such devices.

Project leaders: Tamalika Banerjee (Materials science) and Lambert Schomaker (Artificial Intelligence)
PhD students: Azminul Jaman and Jordi Timmermans

Towards a cognitive computer architecture based on memristive devices: developing short- and long-term memory (COGMEM) (awarded in 2019)

The goal of this project is to build a pattern-completion memory, which we believe is a critical component in developing novel cognitive computing architectures. We will accomplish this by building a neural network in which memristive devices act as synapses, and potentially also as soma. One of the two sub-projects focuses on the development of networks, while the other focuses on the materials.

Project leaders: Niels Taatgen and Jelmer Borst (Artificial Intelligence), Tamalika Banerjee (Materials science)
PhD student: Thomas Tiotto

Memristor networks from self-assembled domain walls in oxides (WALLNET) (awarded in 2019)

This project investigates materials that self-organise in conducting networks that can transmit signals and host memory elements in a similar way to biological neurons and synapses.

Project leaders: Bart Besselink and Arjan van der Schaft (Mathematics), Beatriz Noheda (Materials science)
PhD students: Anne-Men Huijzer and Jan Rieck

COGNIGRON FELLOWSHIPS

Staff can also participate and contribute to the CogniGron research programme through a PhD student who works in close collaboration with external partners, preferably industry partners with a strong track record or interest in cognitive systems and materials. The goal of these CogniGron Fellowships is to strengthen interaction with industry. Additionally, it will give the PhD student the opportunity to take an inside view and collaborate with a world-leading industrial partner on cognitive computing. The primary supervisor will hold a position at the Faculty of Science and Engineering and the PhD degree will be awarded by the University of Groningen.

COGNIGRON-IBM FELLOWSHIPS

Two CogniGron-IBM fellowships were awarded. CogniGron has partnered with IBM in these projects to work on novel materials for neuromorphic computing.

Combined volatile/non-volatile memristive ferroelectric arrays

The project aims to develop synaptic devices, similar to those in the brain, based on ferroelectric materials. In particular, the goal is to build arrays of these (memristive) devices that can show both short-term and long-term potentiation and depression, which is important for the implementation of neural networks.

Project leaders: Beatriz Noheda (CogniGron), Sigi Karg and Bert Jan Offrein (IBM-Research Zurich)
PhD student: Ruben Hamming-Green

Analogue phase-change memory cells for neuromorphic computing

Phase-change memories are, to date, arguably the most advanced resistive memory technologies. Phase-change memories are also being explored for in-memory computing applications, such as performing logical operations as well as realising hardware substrates for neuromorphic computing. It has been shown that phase-change memory devices can emulate some of the key synaptic and neuronal functionalities, thus facilitating the realisation of ultra-low power and dense neuromorphic hardware. In this project, we propose a relatively new concept of phase-change memory.

Project leaders: Bart Kooi (CogniGron) and Abu Sebastian (IBM-Research Zurich)
PhD student: Jesse Luchtenveld

START-UPS

In 2024, IMChip was founded by CogniGron PI, Prof. Tamalika Banerjee. IMChip aims to tackle an important challenge. At the moment, the current generation of computers has three specific problems: (1) memory and processing are not in the same location, (2) it can take about one to two seconds for data to be retrieved from the cloud, and (3) after years of innovation, we are now reaching the end of what is possible with current materials.

IMChip will address this challenge by producing in-memory chips with a combination of old and new materials, in which memory and processing take place in the same location.

IMChip aims to offer new hardware that is easy to manufacture, sustainable, and can be mixed and matched with existing technologies. The first product that IMChip aims to develop and deliver is a chiplet, a small custom-made chip designed for a very specific task.

imchip.ai

KEY FACILITIES - FROM 'LAB TO FAB'

CogniGron aims to make fundamental advances towards a disruptive technology, and the efforts in this direction require sophisticated research facilities to synthesise and characterise materials and build devices. These facilities are in large part present at the University of Groningen. However, CogniGron has seen the opportunity to excel by supporting two advanced research facilities: the Electron microscopy centre and NanoLabNL.

ELECTRON MICROSCOPY CENTRE

The electron microscopy centre of the Zernike Institute for Advanced Materials was founded in 2019 to maintain and provide a coherent and accessible infrastructure for electron microscopy at the University of Groningen. The microscopy centre is made possible by and will primarily be used by the Zernike Institute for Advanced Materials and CogniGron. Electron microscopy is of key importance for the research of CogniGron as it facilitates studying the ultimate origin of memristive behaviour in the materials that will function as artificial (electronic) synapses or neurons.

To this end, CogniGron invested (together with the Zernike Institute for Advanced Materials) in the purchase of a new transmission electron microscope (TEM) that enables studying the structure of materials in unprecedented detail. One of its unique abilities is to produce images of both heavy and very light atoms simultaneously. The purchase also included a second system: a scanning electron microscope, combined with a focused ion beam, which allows scientists to study the general structure of materials (using an electron beam) and extract interesting sections using the ion beam for detailed study in the new TEM. Professor Bart Kooi is primarily responsible for running the new microscope. The daily activities at the TEM lab are running thanks to the expertise, dedication and involvement of Majid Ahmadi.

NANOLABNL: NANOFABRICATION FACILITY

NanoLabNL is a national consortium that was created to build, maintain and provide a coherent and accessible infrastructure for nanotechnology research and innovation in the Netherlands. However, with recent funding developments, maintaining the NanoLabNL facility through necessary updates — especially to keep up with developments in other countries in our region — is becoming a challenge.

The long-term stability of NanoLabNL is vital for CogniGron and we believe there is a need for CogniGron and NanolabNL to work together and make sure the facilities are up-to-date with the newest technological advances. Since the goal of CogniGron is closely related to developing novel electronic devices, for which the nanolithography and fabrication facilities provided by NanoLabNL are crucial, CogniGron has reserved funds to support NanoLabNL in the form of a new electron beam evaporator as well as a technician to support the new PhD students and staff who will be using the NanoLabNL facilities in Groningen. We are aware that more support is needed to maintain the NanoLabNL facilities in Groningen at international standards, and we are constantly working with the NanoLabNL management team to find solutions. Therefore, CogniGron has reserved a yearly budget for the running costs of NanoLabNL Groningen from 2021 until 2025 and CogniGron researchers can make use of the cleanroom facilities at no cost. Arjun Joshua supports the Nanolab activities of CogniGron researchers.

PUBLICATIONS

PEER-REVIEWED PUBLICATIONS

Addario-Berry, L., & Donderwinkel, S. (2024). Random trees have height O(n). **The Annals of Probability,** 52(6), 2238–2280. https://doi.org/10.1214/24-AOP1694

Ahmadi, M., Atul, A., De Graaf, S., Van Der Veer, E., Meise, A., Tavabi, A. H., Heggen, M., Dunin-Borkowski, R. E., Ahmadi, M., & Kooi, B. J. (2024). Atomically Resolved Phase Coexistence in VO2 Thin Films. **ACS Nano, 18**(21), 13496–13505. https://doi.org/10.1021/acsnano.3c10745

Badillo, M., Taleb, S., Carreno Jimenez, B., Mokabber, T., Castanedo Pérez, R., Torres-Delgado, G., Noheda, B., & Acuautla, M. (2024). (001)-Oriented Sr:HfO2 Ferroelectric Films Deposited by a Flexible Chemical Solution Method. **ACS Applied Electronic Materials,** 6(3), 1809–1820. https://doi.org/10.1021/acsaelm.3c01725

Bonnet, G., Charbonneau, P., & Folena, G. (2024). Glasslike caging with random planes. **Physical Review E, 109**(2), 024125. https://doi.org/10.1103/PhysRevE.109.024125

Chen, L., Xi, J., Tekelenburg, E. K., Tran, K., Portale, G., Brabec, C. J., & Loi, M. A. (2024). Quasi-2D Lead–Tin Perovskite Memory Devices Fabricated by Blade Coating. **Small Methods, 8**(2), 2300040. https://doi.org/10.1002/smtd.202300040

Cipollini, D., Greatorex, H., Mastella, M., Chicca, E., & Schomaker, L. (2025). Fused-MemBrain: A spiking processor combining CMOS and self-assembled memristive networks. **Neuromorphic Computing and Engineering, 5**(2), 024002. https://doi.org/10.1088/2634-4386/adc6b5

Cipollini, D., Profumo, F., Schomaker, L., Milani, P., & Borghi, F. (2024). Conduction mechanisms in a planar nanocomposite resistive switching device based on cluster-assembled Au/ZrOx films. **Frontiers in Materials, 11,** 1385792. https://doi.org/10.3389/fmats.2024.1385792

Cipollini, D., Swierstra, A., & Schomaker, L. (2024). Modeling a domain wall network in BiFeO3 with stochastic geometry and entropy-based similarity measure. **Frontiers in Materials, 11,** 1323153. https://doi.org/10.3389/fmats.2024.1323153

Cotteret, M., Greatorex, H., Ziegler, M., & Chicca, E. (2024). Vector Symbolic Finite State Machines in Attractor Neural Networks. **Neural Computation, 36**(4), 549–595. https://doi.org/10.1162/neco_a_01638

Goossens, A. S., Samanta, K., Jaman, A., Boubaker, W., van Rijn, J. J. L., Tsymbal, E. Y., & Banerjee, T. (2024). Symmetry-driven large tunneling magneto-resistance in SrRuO3 magnetic tunnel junctions with perpendicular magnetic anisotropy. **Physical Review Materials, 8**(9), L091401. https://doi.org/10.1103/PhysRevMaterials.8.L091401

Hamming-Green, R., Van den Broek, M., Bégon-Lours, L., & Noheda, B. (2024). Mixed volatility in a single device: Memristive non-volatile and threshold switching in SmNiO3/BaTiO3 devices. **Frontiers in Materials, 11,** 1356610. https://doi.org/10.3389/fmats.2024.1356610

Koellermeier, J., Krah, P., & Kusch, J. (2024). Macro-micro decomposition for consistent and conservative model order reduction of hyperbolic shallow water moment equations: A study using POD-Galerkin and dynamical low-rank approximation. **Advances in Computational Mathematics, 50**(4), 76. https://doi.org/10.1007/s10444-024-10175-y

Lawrence, C. P. (2024). Realizability of Parity Logic in Finite Cellular Automata. **Complex Systems, 33**(1), 125–132. https://doi.org/10.25088/ComplexSystems.33.1.125

Li, M., Rieck, J., Noheda, B., Roerdink, J. B. T. M., & Wilkinson, M. H. F. (2024). Stripe noise removal in conductive atomic force microscopy. **Scientific Reports, 14**(1), 3931. https://doi.org/10.1038/s41598-024-54094-w

Pedersen, J. E., Abreu, S., Jobst, M., Lenz, G., Fra, V., Bauer, F. C., Muir, D. R., Zhou, P., Vogginger, B., Heckel, K., Urgese, G., Shankar, S., Stewart, T. C., Sheik, S., & Eshraghian, J. K. (2024). Neuromorphic intermediate representation: A unified instruction set for interoperable brain-inspired computing. **Nature Communications, 15**(1), 8122. https://doi.org/10.1038/s41467-024-52259-9

Quintana, F. M., Perez-Peña, F., Galindo, P. L., Neftci, E. O., Chicca, E., & Khacef, L. (2024). ETLP: Event-based three-factor local plasticity for online learning with neuromorphic hardware. **Neuromorphic Computing and Engineering, 4**(3), 034006.

Richter, O., Wu, C., Whatley, A. M., Köstinger, G., Nielsen, C., Qiao, N., & Indiveri, G. (2024). DYNAP-SE2: A scalable multi-core dynamic neuromorphic asynchronous spiking neural network processor. **Neuromorphic Computing and Engineering, 4**(1), 014003. https://doi.org/10.1088/2634-4386/ad1cd7

Rijn, J. J. L. van, Bhaduri, I., Ahmadi, M., Noheda, B., Kooi, B. J., & Banerjee, T. (2024). Domains with Varying Conductance in Tensile Strained SrMnO3 Thin Films Using Out-of-Plane Electric Fields. **Advanced Functional Materials, 34**(41), 2404150. https://doi.org/10.1002/adfm.202404150

Schaft, A. van der, Besselink, B., & Huijzer, A.-M. (2024). Kron Reduction of Nonlinear Networks. **IEEE Control Systems Letters, 8**, 556–561. https://doi.org/10.1109/LCSYS.2024.3398194

Schoepe, T., Janotte, E., Milde, M. B., Bertrand, O. J. N., Egelhaaf, M., & Chicca, E. (2024). Finding the gap: Neuromorphic motion-vision in dense environments. **Nature Communications, 15**(1), 817. https://doi.org/10.1038/s41467-024-45063-y

van der Ree, A. J. T., Ahmadi, M., Ten Brink, G. H., Kooi, B. J., & Palasantzas, G. (2024). Stable Millivolt Range Resistive Switching in Percolating Molybdenum Nanoparticle Networks. **ACS Applied Materials & Interfaces, 16**(47), 65157–65164. https://doi.org/10.1021/acsami.4c12051

CONFERENCE PAPERS

Fehlings, L., Gibertini, P., Quintana, F.M., & Covi, E. (2024). Emerging memory technologies for neuromorphic edge computing **Proceedings of MATSUS Spring 2025 Conference (MATSUSSpring25)**. https://doi.org/10.29363/nanoge.matsus-spring.2025.098

Gibertini, P., Fehlings, L., Mikolajick, T., Chicca, E., Kappel, D., & Covi, E. (2024). Coincidence Detection with an Analog Spiking Neuron Exploiting Ferroelectric Polarization. 2024 **IEEE International Symposium on Circuits and Systems (ISCAS), 1–5.** https://doi.org/10.1109/ISCAS58744.2024.10558196

Hamming-Green, R., Ram, M. S., Falcone, D. F., Noheda, B., Offrein, B. J., & Bégon-Lours, L. (2024). Multi-Level, Low-Voltage Programming of Ferroelectric HfO2/ZrO2 Nanolaminates Integrated in the Back-End-Of-Line. 2024 8th **IEEE Electron Devices Technology & Manufacturing Conference (EDTM), 1–3.** https://doi.org/10.1109/EDTM58488.2024.10511719

Lopez, L. F. C., Koellermeier, J., Maes, V., & Samaey, G. (2024). Moment models for neutral particles in high-collisional regimes for plasma edge simulations. **AIP Conference Proceedings, 2996**(1), 190002. https://doi.org/10.1063/5.0187540

Maes, V., Dekeyser, W., Koellermeier, J., Baelmans, M., & Samaey, G. (2024). The Fredholm alternative with application to the derivation of Hilbert expansion based fluid models for plasma edge modelling. **AIP Conference Proceedings, 2996**(1), 040010. https://doi.org/10.1063/5.0187449

Mastella, M., Greatorex, H., Tiemens, T., Cotteret, M., Richter, O., & Chicca, E. (2024). Event-Driven Frequency Decomposition with Spiking Phase-Locked Loops. **2024 58th Asilomar Conference on Signals, Systems, and Computers, 1517–1521.** https://ieeexplore.ieee.org/abstract/document/10942668

Saleh, S., Goossens, A. S., Shu, S., Banerjee, T., & Koldehofe, B. (2024). Analog In-Network Computing through Memristor-based Match-Compute Processing. IEEE INFOCOM 2024 - **IEEE Conference on Computer Communications, 2518–2527.** https://ieeexplore.ieee.org/abstract/document/10621228

Saleh, S., Shu, S., & Koldehofe, B. (2024). dAQM: Derivative-based active queue management. **2024 IFIP Networking Conference (IFIP Networking), 77–85.** https://ieeexplore.ieee.org/abstract/document/10619831/

Schoepe, T., Drix, D., Schüffny, F. M., Miko, R., Sutton, S., Chicca, E., & Schmuker, M. (2024). Odour Localization in Neuromorphic Systems. **2024 IEEE International Symposium on Circuits and Systems (ISCAS), 1–5.** https://doi.org/10.1109/ISCAS58744.2024.10558186

PREPRINTS

Bonnet, G., & Gusakova, A. (2024). Concentration inequalities for Poisson U-statistics. **arXiv.** https://doi.org/10.48550/arXiv.2404.16756

Cipollini, D., & Schomaker, L. (2024). Tree networks of real-world data: Analysis of efficiency and spatiotemporal scales. **arXiv.** https://doi.org/10.48550/arXiv.2404.17829

Donderwinkel, S., & Kolesnik, B. (2024). Sinaĭ excursions. **arXiv.** https://doi.org/10.48550/arXiv.2403.12941

Fehlings, L., Ali, M. H., Gibertini, P., Gallicchio, E. A., Ganguly, U., Deshpande, V., & Covi, E. (2024). Heracles: A HfO2 Ferroelectric Capacitor Compact Model for Efficient Circuit Simulations. **arXiv.** https://doi.org/10.48550/arXiv.2410.07791

Greatorex, H., Richter, O., Mastella, M., Cotteret, M., Klein, P., Fabre, M., Rubino, A., Girão, W. S., Chen, J., Ziegler, M., Bégon-Lours, L., Indiveri, G., & Chicca, E. (2024). TEXEL: A neuromorphic processor with on-chip learning for beyond-CMOS device integration. **arXiv.** https://doi.org/10.48550/arXiv.2410.15854

Heidema, M., Waarde, H. van, & Besselink, B. (2024). Learning in memristive electrical circuits. **arXiv.** https://doi.org/10.48550/arXiv.2409.15136

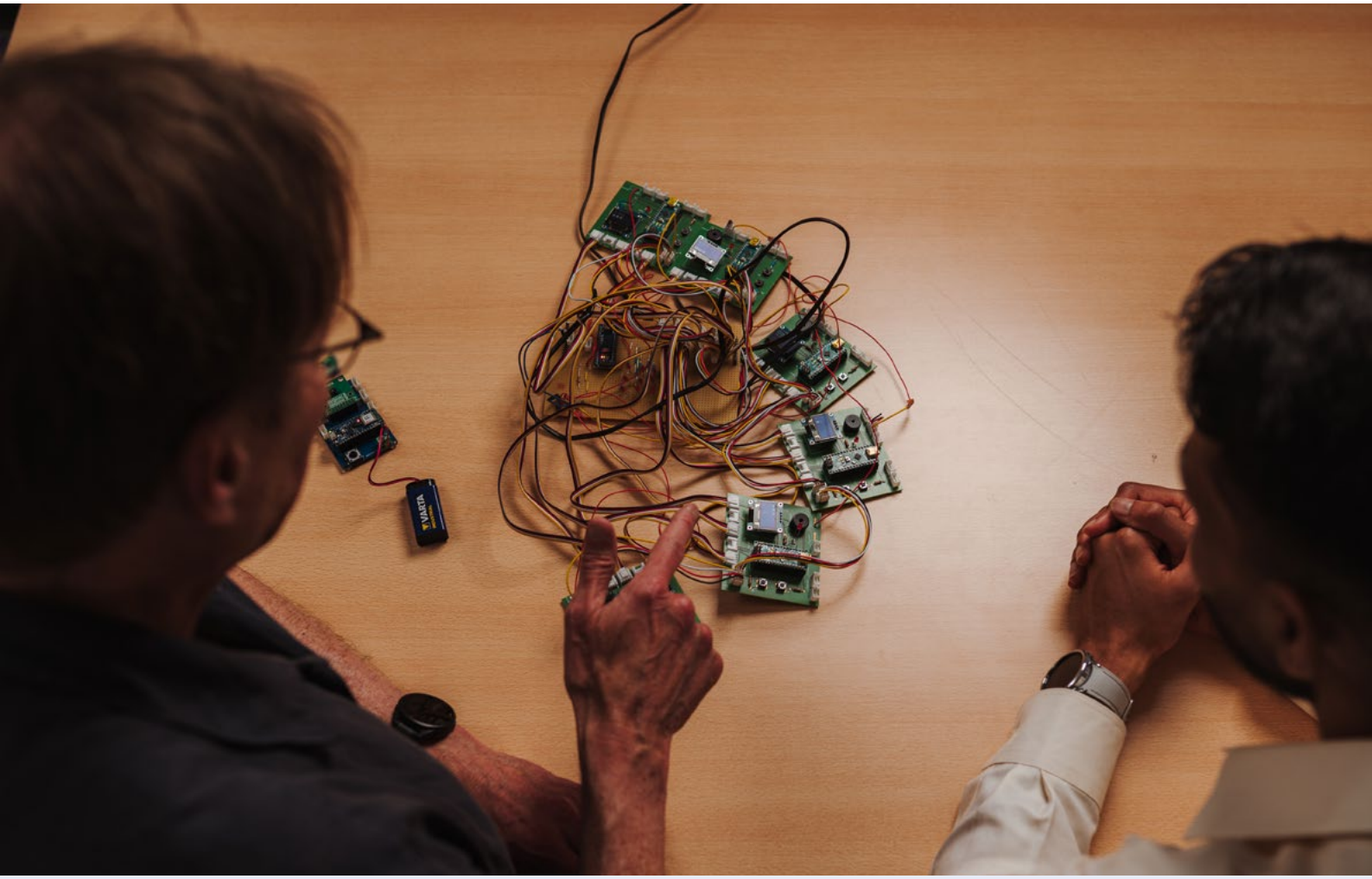
Maes, V., Bossuyt, I., Vandecasteele, H., Dekeyser, W., Koellermeier, J., Baelmans, M., & Samaey, G. (2024). Predicting the statistical error of analog particle tracing Monte Carlo. **arXiv.** https://doi.org/10.48550/arXiv.2404.00315

Mastella, M., Tiemens, T., & Chicca, E. (2024). Texture Recognition Using a Biologically Plausible Spiking Phase-Locked Loop Model for Spike Train Frequency Decomposition. **arXiv.** https://doi.org/10.48550/arXiv.2403.09723

Prili, S., Bragaglia, V., Jonnalagadda, V. P., Luchtenveld, J., Arciprete, F., Kooi, B. J., Sebastian, A., & Syed, G. S. (2024). Understanding the Growth and Properties of Sputter-Deposited Phase-Change Superlattice Films. **arXiv.** https://doi.org/10.48550/arXiv.2411.19343

Veen, T. van der, Cohen, Y., Chicca, E., & Dürr, V. (2024). A spiking neural network model for proprioception of limb kinematics in insect locomotion. **bioRxiv.** https://doi.org/10.1101/2024.09.27.615365

Veen, T. van der, Dürr, V., & Chicca, E. (2024). Encoding of movement primitives and body posture through distributed proprioception in walking and climbing insects. **bioRxiv.** https://doi.org/10.1101/2024.09.27.615364



PARTNERS

Strategic partnerships

Strategic partnerships play a crucial role in advancing scientific research and technological innovation. CogniGron believes in the power of working together, between different disciplines, but also between different institutions.

WESTERN SYDNEY UNIVERSITY AND UNIVERSITY COLLEGE LONDON

Two such significant collaborations in the field of neuromorphic computing are with Western Sydney University (WSU) and University College London (UCL). After setting up a formal agreement between the International Centre for Neuromorphic Systems, led by Prof. André van Schaik at WSU in 2021, CogniGron has set up an agreement with UCL in 2022 with Prof. Tony Kenyon's team. The partnership with UCL and WSU brings together experts fostering a multidisciplinary approach to address the challenges and potential of neuromorphic computing. These strategic partnerships create a unique opportunity to push the boundaries of neuromorphic computing. Through joint research projects, knowledge sharing and collaborative initiatives with UCL and WSU, we can accelerate the education of a new generation of researchers and the development of innovative algorithms, hardware architectures, and applications that leverage the power of neuromorphic computing.

NEUROTRONICS CENTRE AT KIEL UNIVERSITY

In 2022 we started organising joint workshops and conferences with the CRC 1461 – Neurotronics Research Centre at Kiel University, led by Prof. Dr. Hermann Kohlstedt. The CRC 'Neurotronics: Bio-inspired Information Pathways' will explore and propel the research of novel hardware technologies as a cornerstone for novel bio-inspired computing architectures paving the way towards an unconventional information processing. They envision impacts in various research fields in science and technology, such as robotics and brain implants.

SYNSENSE LOCATED IN ZURICH

In 2023, SynSense and CogniGron started a collaboration to evaluate the low-power neuromorphic sensory processors from SynSense. The CogniGron research groups will use the Speck™ low-power vision system to develop visually guided closed-loop systems. They will also evaluate the Xylo™ microWatt Audio processing platform to explore auditory scene analysis applications. SynSense is a world-leading neuromorphic engineering company. It provides custom-tailored, ultralow-power silicon design solutions for industrial and consumer machine-learning inference applications. As a "full-stack" neuromorphic engineering company, SynSense delivers complete solutions, including custom IP, hardware, and software configurations to meet specific application needs. SynSense was founded in March 2017 in Zürich Switzerland, based on groundbreaking advances in neuromorphic computing hardware developed at the Institute of Neuroinformatics of the University of Zurich and the ETH Zurich.

COGNIGRON ACTIVITIES

Strengthening communities, building connections

In 2024, CogniGron actively contributed to community building at both local and national levels. Through strategic meetings, academic gatherings and international events, we strengthened internal collaboration and helped shape the growing neuromorphic computing ecosystem.

NL-ECO CONSORTIUM MEETING (6–7 FEBRUARY)

The NWA (Dutch Research Agenda) NL-ECO programme launched with a two-day meeting at Radboud University Nijmegen, bringing together researchers, industry experts and societal partners. The event featured talks by pioneers in spintronics, photonics and materials science, offering a comprehensive overview of energy-efficient information technologies.

Key discussions focused on programme strategy, stakeholder engagement and interdisciplinary collaboration. Organisational aspects and shared ambitions were addressed to lay the groundwork for productive interactions across the consortium.

Networking sessions enabled participants to establish new connections and share ideas for future research. The meeting marked a strong start to the NL-ECO programme and affirmed its collaborative, national scope.

COGNIGRON RESEARCH AWAY DAY (27 JUNE)

The first of CogniGron's Research Away Days brought together researchers from across CogniGron for a full day of structured discussion and creative exchange at the Puddingfabriek in Groningen. PIs, PhD students and postdocs took part in brainstorming sessions on strategic themes, explored potential demonstrator ideas, and discussed opportunities for interdisciplinary collaboration.

A 'scientific speed dating' format encouraged quick idea-sharing and connection-building. The programme also included a reflective session on team dynamics and communication, enriching the collaborative work throughout the day.

The event provided a valuable space to align priorities, build partnerships and generate new ideas. Positive feedback confirmed its value as a platform for internal cohesion and innovation. The Research Away Day will return in 2025, further strengthening internal collaboration and strategic alignment.

NEUROMORPHIC ECOSYSTEM KICK-OFF MEETING (28 JUNE)

On 28 June, over 60 researchers, entrepreneurs and policymakers gathered in Eindhoven to shape a national vision for brain-inspired computing. The programme included talks, panel discussions and breakout sessions on promising applications and long-term collaboration.

A key outcome was the presentation of the white-paper Neuromorphic Computing in the Netherlands, which outlines the current landscape and advocates for a unified ecosystem approach.

Prof. Beatriz Noheda noted that "the time is ripe to define the entire neuromorphic computing ecosystem", reflecting the momentum felt throughout the event. Participants shared a clear sense of urgency and commitment to collaboration. The meeting concluded with concrete steps for follow-up and future meetings.

MEMRISTEC SUMMER SCHOOL (22–29 SEPTEMBER)

The MemrisTec Summer School, co-organised with TU Dresden, welcomed an international group of students to Groningen for a week of learning and exchange. The programme combined lectures, lab sessions and poster presentations, focusing on memristive devices and smart technical systems.

Participants from diverse backgrounds — including electrical engineering, computer science and materials science — engaged with international experts and explored emerging topics in neuromorphic computing.

Beyond the academic content, the school offered opportunities for intercultural exchange and community building. CogniGron was proud to contribute to this educational initiative, supporting the next generation of researchers in this rapidly evolving field.

BRAINSPIRATION 2024 (17–18 OCTOBER)

Held in Groningen, Brainspiration 2024 gathered over 100 researchers from the Netherlands and abroad for two days of discussion on brain-inspired computing. The event featured 13 talks and 12 poster presentations on topics ranging from quantum reservoir computing to energy-efficient information processing.

Speakers represented institutions from New Zealand, the United States and across Europe, reflecting the field's growing international reach. Keynote speaker Prof. Herbert Jaeger concluded the conference with a provocative talk titled Will it take another 2300 years until we really know what 'computing' means?

With lively discussions, new collaborations and strong interdisciplinary engagement, Brainspiration 2024 underscored the importance of community-driven progress. The next edition will be hosted by Radboud University Nijmegen in 2025.

COGNIGRON SEMINARS FOR INVITED SPEAKERS

We value the opportunity to invite experts from around the world to visit Groningen to gain a better understanding of the latest developments in this diverse and emerging field of Neuromorphic Computing. This also creates a sense of community, as well as to make CogniGron known to the international and national communities. In 2024, we had the following speakers:

- **Prof. Merlyne De Souza** (University of Sheffield, GB) - January 26th
  "Physical reservoir computing based on a nano-ionic solid electrolyte FET"
- **Dr Johan Mentink** (Radboud University, Nijmegen, NL)
  "Challenging the limits of magnetism – insights from theory and simulations" - March 1st
- **Prof. Pavan Nukala** (Indian Institute of Science (IISc), Bengaluru, IN) - March 14th
  "Neuromorphic materials: electromechanical neuristors and critical networks"
- **Prof. Bert Jan Offrein** (IBM-Research Zurich, CH) - March 19th
  "New materials and devices for power-efficient neuromorphic computing"
- **Dr Mina Khoei** (SynSense, CH) - April 4th
  "Neuromorphic technology for edge computing"
- **Dr Erika Covi** (University of Groningen, NL) - April 11th
  "Memristive and CMOS Technologies for Advanced Cognitive Systems"
- **Prof. André van Schaik** (Western Sydney University, AU) - April 23rd
  "DeepSouth, world's first supercomputer"
- **Prof. Emre Neftci** (Forschungszentrum Jülich, DE) - April 30rd
  "Meta-learning for Memristive Devices"
- **Prof. Barbara Webb** (University of Edinburgh, GB) - April 30rd
  "The neural basis of the honey bee dance language"
- **Dr Chris Broekema** (ASTRON, Dwingeloo, NL) - June 18th
  "Affordable and sustainable data- and compute-intensive radio astronomy"
- **Prof. Bernabé Linares-Barranco** (University of Seville, ES) - October 14th
  "Hardware for Neuromorphic Sensing, Processing, and Learning"
- **Prof. Christian Wenger** (Leibniz Institute for High Performance Microelectronics, DE) - October 15th
  "Towards Neuromorphic Computing With HfO2 Based Memristive Devices"

SCIENCE COMMUNICATION

EUROPEAN RESEARCHERS' NIGHT AT THE FORUM GRONINGEN (27 SEPTEMBER 2024)

A fascinating, on-site experiment called Making brain matter explaining the growth of neurons in the brain – facilitated by Joost Zoestbergen, Haoran Yu and Memoona Ismail from Prof. Beatriz Noheda's research group – attracted many visitors during the event.

Since the advent of AI, there has been a need for energy-efficient computers (brain-like computers) that consume less power. Taking inspiration from the human brain, we can implement a similar idea to computers. As materials scientists, Noheda's group is trying to look for materials to realize this idea. In the experiment, metal balls could form connections with beautiful branches, just like neurons in the human brain. The experiment highlights the efforts of a larger Dutch community represented by the NL-ECO consortium (NWA project).

The European Researchers' Night was co-funded by the European Commission (Horizon Europe Research and Innovation programme, grant agreement No.101162172) and was organized by the four Schools for Science & Society of the University, Studium Generale, University Museum, Young Academy Groningen, Science LinX, Forum Groningen and BKB | Het Campagnebureau.

left to right (Joost Zoestbergen, Haoran Yu, Memoona Ismael and Beatriz Noheda) in front of the Making brain matter exhibition at the Researchers night.

ARTICLE (IN DUTCH) IN TW ON ELISABETTA CHICCA'S WORK: INSECTS AS SOURCE OF INSPIRATION: THE HIDDEN POWER OF INSECT BRAINS IN ROBOTICS

How can insects, with minimal brain capacity, still navigate while flying? That question — particularly how brains function and what their structure is like — fascinates Elisabetta immensely. They formulated a hypothesis around this question and, together with colleagues, created a robotic replica of an insect. You can read the article here: https://tw.nl/insecten-als-inspiratiebron-de-verborgen-kracht-van-insectenbreinen-in-robotica/

COGNIGRON AT NOORDERZON - FESTIVAL OF PERFORMING ARTS & SOCIETY (31 AUGUSTUS)

What role does doubt play in science? Niels Taatgen designs smart materials based on the biology of the brain: tiny particles with the ability to think and learn independently. A chip based on this technology would be powerful enough to surpass hundreds, or even thousands, of generations of computers at once. How would this change our world?

In The Dubious Spectacle, theater duo Sjors & Ruud theatermakers explored the answer to that question with Prof. Niels Taatgen.

GOVERNANCE AND FUNDING

Governance

At the heart of our research centre lies a dynamic framework of leadership and oversight, designed to drive innovation, foster collaboration, and ensure the highest standards of performance. From the timely guidance of our supervisory board to the tireless efforts of our programme board, each facet of our management team is crafted to create an environment of efficiency and continuous improvement to realise the ambitions and goals of CogniGron.

Scientific director

The success of CogniGron is rooted in the dedication and vision of its founding scientific director, **Prof. Beatriz Noheda**. The scientific director is responsible for the scientific programme and chairs the programme board. The director functions as the official representative of the centre and shapes the cutting-edge scientific programme.

Beatriz Noheda received her PhD in Physics from the Universidad Autónoma de Madrid, Spain. In 2003, after holding various positions at Saarland University, the Clarendon Laboratory in Oxford, Brookhaven National Lab in New York and the Vrije Universiteit in Amsterdam, she was awarded a Rosalind Franklin Fellowship by the University of Groningen, where she is now Full Professor. Noheda is a Fellow of the American Physical Society and recipient of the IEEE Robert E. Newnham Ferroelectrics Award. She has served as a member of numerous national and international committees and several editorial boards. She is the author of more than 150 publications and receives more than 10 invitations a year to speak at international conferences. Noheda's research focuses on understanding the relationship between the structure and functionality of thin films of ferroelectric and multiferroic materials, often used as memory elements. Her research, although fundamental in nature, is inspired by two main application areas that, together, she believes will enable the next technological revolution: piezoelectric energy harvesting for low-power electronics and the development of novel materials for adaptable electronics and neuromorphic computing.

Programme board

The programme board steers us toward groundbreaking discoveries. The programme board, chaired by the scientific director, is the driving force behind CogniGron's scientific strategy and daily operations. This team allocates the budget, determines the scientific strategy, and is responsible for the daily running of the scientific programme, as well as the recruitment of new staff. Chaired by the director, the programme board is composed of the following members:

- Prof. Tamalika Banerjee
  Professor Physics of Nanodevices
- Prof. Elisabetta Chicca
  Bio-Inspired Circuits and Systems
- Prof. Georgi Gaydadjiev
  Professor Innovative Computer Architectures
- Prof. Lambert Schomaker
  Professor Artificial Intelligence
- Dr. Alef Sterk
  Assistant Professor Mathematics
- Prof. Niels Taatgen
  Professor Artificial Intelligence and Chair of the Board of the Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence
- Prof. Moniek Tromp
  Professor Materials Chemistry
  Director Zernike Institute for Advanced Materials
- Prof. Ton Engbersen - Advisor to the Programme Board
  Professor Data Science Engineering

Changes to CogniGron Programme Board

Since September 2024, every three-months the PB meeting is extended with Prof. Matthew Cook, Dr. Erika Covi, Dr. Serte Donderwinkel, Prof. Herbert Jaeger, Prof. Bart Kooi, Dr. Farhad Merchant and Prof. Fatih Turkmen and from December 2024 onwards, Prof. Dirk Pleiter.

Supervisory board

- The Supervisory Board oversees the long term strategy of the research centre, and advises the scientific director on significant changes in focus and implementation of the programme. It is composed of the following persons:
- Drs. Hans Biemans
  Member of the Board of the University of Groningen
- Prof. Joost Frenken
  Dean of the Faculty of Science and Engineering, University of Groningen
- Dr. Esther Marije Klop
  Managing director of the Faculty of Science and Engineering, University of Groningen

Coordinating office

Through 2024, the CogniGron coordinating office consisted of:

- Managing directors (ad interim): Annechien Pronk and Sander Baesjou (Realisatiekracht.nu)
- Scientific Coordinator (ad interim): Dr. Hilde de Gier and Freerk Reitsma
- Managing Assistant: Clelia Richters-Teodoro and Annemijn Hillbolling
- Communication officer (ad interim): Isabella Bazuin and Ine Kjosas

Scientific advisory panel

CogniGron is proud to have an elite team of researchers to form the international scientific advisory panel. Their expertise and vision on brain-inspired concepts and technologies are of great value and guidance in delineating new scientific directions.

- **Prof. Giacomo Indiveri**
  Professor Neuromorphic Cognitive Systems and Director of the Institute of Neuroinformatics
  UZH / ETH Zurich, Switzerland

- **Prof. Julie Grollier**
  Professor Nanodevices for Bio-Inspired Computing and Chair of the interdisciplinary research network GDR BioComp
  CNRS/Thales, France

- **Dr. Heike Riel**
  IBM Fellow, Department Head Science & Technology
  IBM Zurich, Switzerland

- **Prof. Ivan Schuller**
  Professor Nanoscience and Director of QMEENC (Quantum Materials for Energy Efficient Neuromorphic Computing)
  Department of Physics and Centre for Advanced Nanoscience, University of California, San Diego, USA

- **Prof. Rainer Waser**
  Professor of Electrical Engineering and Information Technology at RWTH Aachen University, Germany, and Director of the Peter Grünberg Institute, Julich, Germany

- **Prof. Yoeri van de Burgt**
  Assistant Professor in Microsystems group
  Institute of Complex Molecular Studies (ICMS), TU Eindhoven, Netherlands

- **Prof. Wilfred van der Wiel**
  Professor of Nano Electronics and Director of the Centre for Brain-Inspired Electronics (BRAINS)
  University of Twente, Netherlands

- **Prof. Chris Eliasmith**
  Professor Philosophy and Systems Design Engineering, and cross-appointed to Computer Science and Director of the Centre for Theoretical Neuroscience
  University of Waterloo, Canada

- **Prof. Susan Stepney**
  Professor of Computer Science
  University of York, United Kingdom

- **Prof. Tony Kenyon**
  Professor of Nanoelectronic & Nanophotonic Materials
  University College London, United Kingdom

EXTERNAL FUNDING

We are aware of the unique position that we have and are committed to obtaining the maximum benefits by developing strategic partnerships by means of national or international consortia and taking advantage of the available matching schemes, as long as the partnerships do not compromise our focus. CogniGron is actively participating in or coordinating externally funded projects.

EU FUNDING AWARDED IN 2024

Contracts for Control System Design (COCOS)

This project has received funding from the European Research Council under the grant agreement no. 101169999

- CogniGron awardee: Bart Besselink
- Amount: € 1 984 840,00

ARCHitectures based on unconventional accelerators for dependable/energY efficienT AI Systems (ARCHYTAS)

This project has received funding from Europe Defense Funds Research actions on digital transformation 2023.

- Coordinator: IVECO Defense vehicles, Italy
- CogniGron participant: Erika Covi
- Amount: € 817.165,00

Materials for Smarter AUTonomous sensOrs (MASAUTO)

This project has received funding from the EU Horizon Europe programme under the Marie Skłodowska-Curie grant agreement no. 101168161

- Coordinators: Prof. Luís Marques and Dr. José Silva (University of Minho, Portugal)
- CogniGron participant: Beatriz Noheda
- Amount: € 274 370,40

ERC- Synergy grant: Transforming IoT Sensory Systems for a Sustainable Future (SWIMS)

This project has received funding from the European Research Council under grant agreement no. 101119062

- Coordinator: Gerhard Fettweis (TU Dresden, Germany)
- CogniGron participant: Elisabetta Chicca
- Amount: € 2.714.222,50

Materials for Neuromorphic Circuits (MANIC)

This project has received funding from the EU Horizon 2020 Innovative Training Networks programme under Marie Skłodowska-Curie grant agreement no. 861153

- Coordinators: Beatriz Noheda (Groningen) and Bernd Gotsmann (IBM-Research Zurich, Switzerland)
- CogniGron participants: Beatriz Noheda, Elisabetta Chicca, Lambert Schomaker, Michael Wilkinson, Jos Roerdink
- Amount: € 1.091.836,00

Post-Digital Computing (Post-Digital)

This project has received funding from the EU Horizon 2020 Innovative Training Networks programme under Marie Skłodowska-Curie grant agreement no. 860360

- Coordinator: Sergei Turitsyn (Aston University, UK)
- CogniGron participant: Herbert Jaeger
- Amount: € 531.239,76

Crystalline Oxides for Next Generation Computing and Emerging Photonic Technologies (CONCEPT)

This project has received funding from HORIZON Research and Innovation Actions / HORIZON-RIA under grant agreement no. 101135946

- Coordinator: Henrik Hovde Sønsteby (University of Oslo, Norway)
- CogniGron participant: Beatriz Noheda
- Amount: € 423,110.00

Reconfigurable Superconducting And Photonic Technologies Of The Future (Respite)

This project has received funding from the EU Horizon 2020 Pathfinder programme under grant agreement no. 101098717

- Coordinator: Delft University
- CogniGron participant: Bart Kooi
- Amount: € 395.198,75

Memristive and multiferroic materials for emergent logic units in nanoelectronics (MELON)

This project has received funding from the EU Horizon 2020 Research and Innovation Staff Exchange programme under grant agreement no. 872631

- Coordinator: Igor Lukyanchuk (University of Picardie Jules Verne, France)
- CogniGron participant: Beatriz Noheda
- Amount: € 308.200,00

Topological Solitons in Ferroics for Unconventional Computing (TOPOCOM)

This project has received funding from the EU Horizon 2020 programme under the Marie Skłodowska-Curie grant agreement no. 101119608

- Coordinators: Dennis Meier (Norwegian University of Science and Technology, Norway)
- CogniGron participant: Beatriz Noheda
- Amount: € 274.370,40

Insect-Brain Inspired Neuromorphic Nanophotonics (Insectneuronano)

This project has received funding from the EU Horizon 2020 European Innovation Council programme under grant agreement no. 101046790

- Coordinator: Anders Mikkelsen (Lund University, SE)
- CogniGron participant: Elisabetta Chicca
- Amount: € 272.990,00

NATIONAL FUNDING

Netherlands Initiative for Energy-Efficient Computing (NL-ECO)

This project has received funding from within the Dutch NWA-ORC scheme under grant agreement no. NWA.1389.20.140

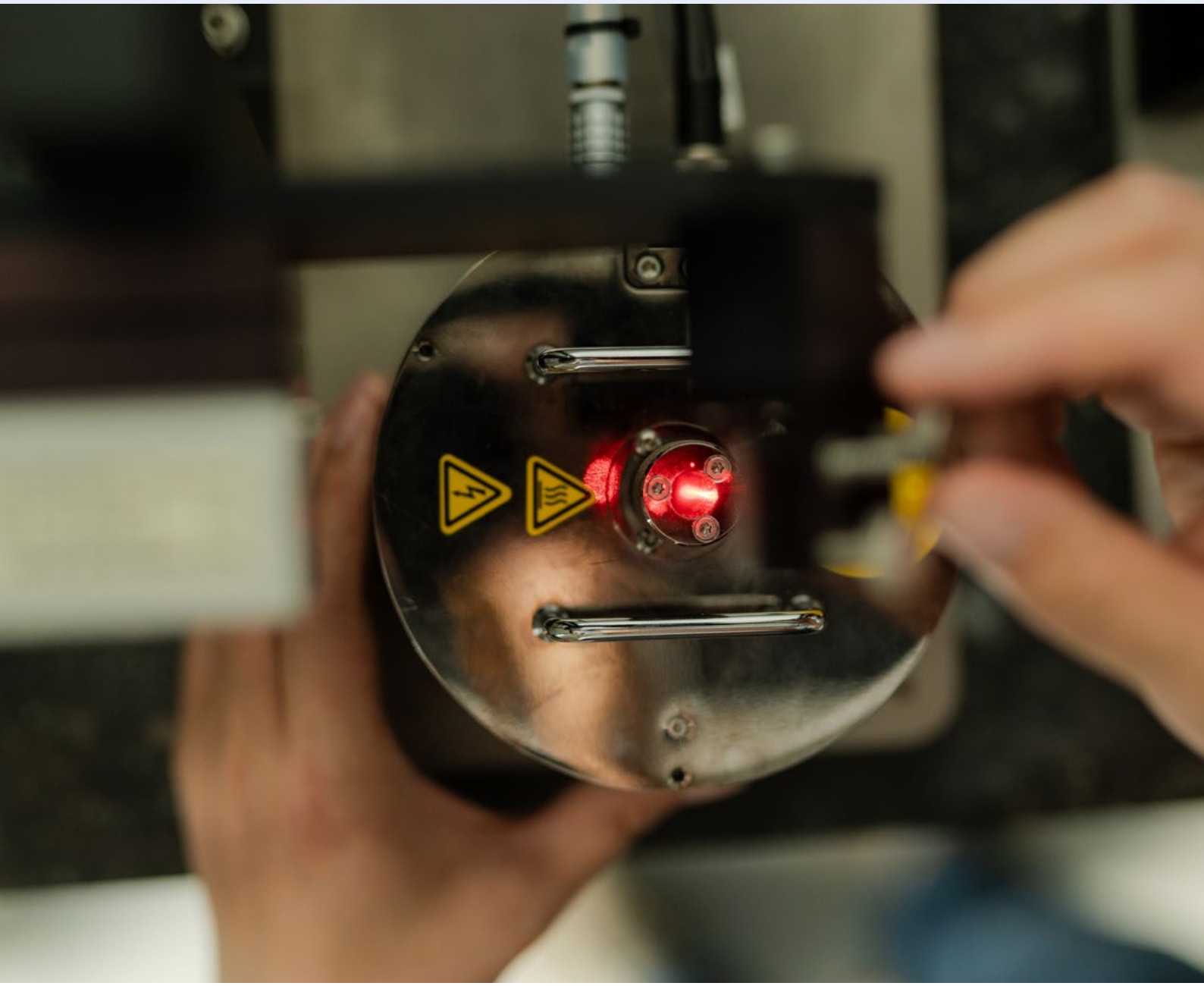
- Coordinator: Hans Hilgenkamp (University of Twente, NL)
- CogniGron participants: Beatriz Noheda, Tamalika Banerjee, Georgi Gaydadjev, Niels Taatgen and Elisabetta Chicca.
- Amount: € 971.211,00

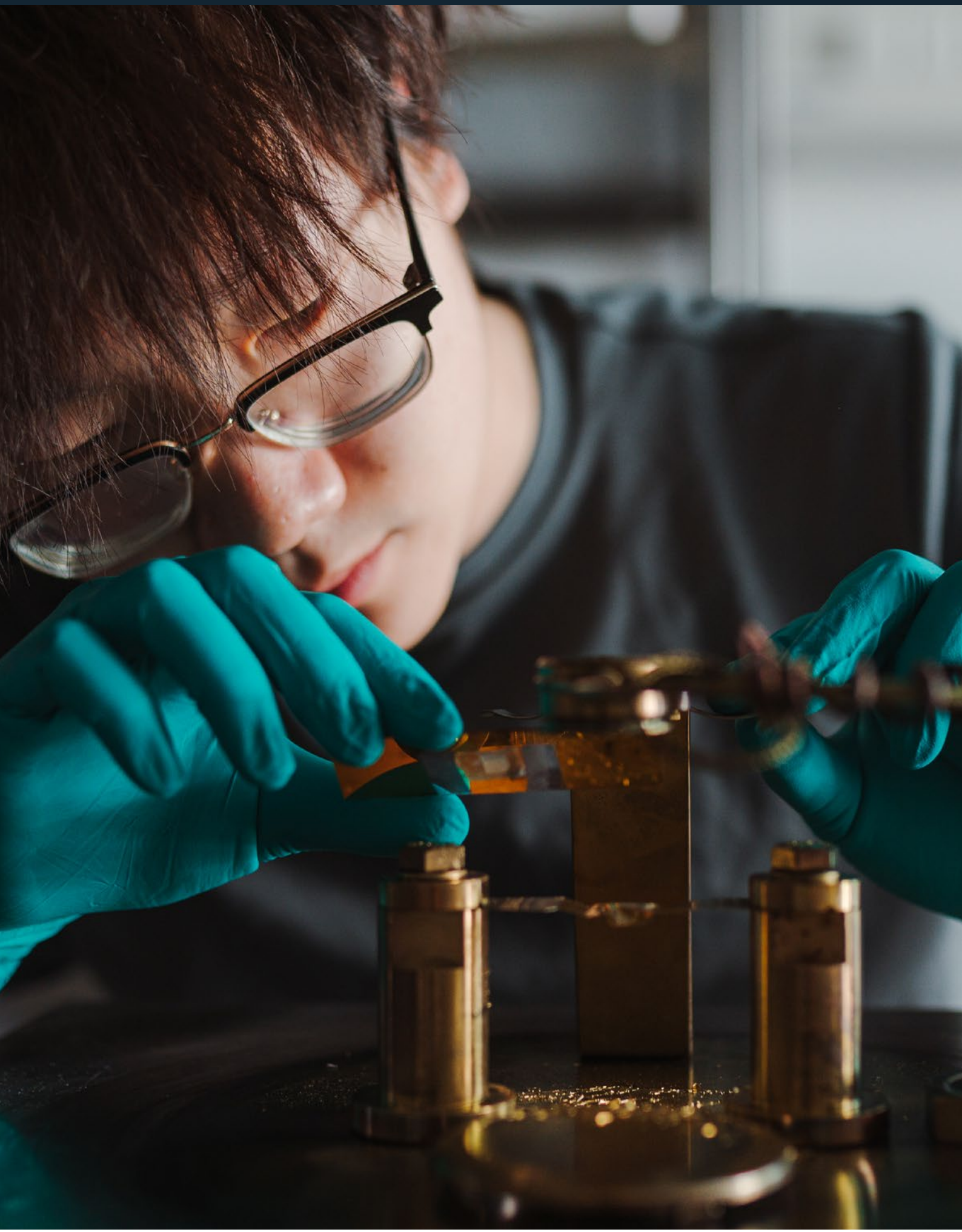
OTHER INTERNATIONAL FUNDING

Memristive Time Difference Encoder (MemTDE)

This project has received funding from the German Science Foundation (DFG) under individual research grant agreement no. 441959088

- Applicant: Elisabetta Chicca
- CogniGron participant: Elisabetta Chicca
- Amount: € 278.750,00





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Photography: Douwe de Boer, Egbert de Boer (p. 51/52), Silvio Zangerini (p. 8)

Layout: Michel Montsma (GPNo)

Print: Canon