Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence

Faculty of Science and Engineering, University of Groningen, the Netherlands

The Bernoulli Institute is a vibrant community with an international outlook, which fosters talent in all its research areas and disciplines and is active in pure and applied science, and (multi)disciplinary research and teaching. The Bernoulli Institute comprises 16 research groups, distributed over three departments: mathematics, computer science and artificial intelligence.

Mathematics Department

1.1 Algebra

Our research focuses on geometry and its applications to number theory, mathematical physics and differential equations. In particular, this includes algebraic and arithmetic geometry, as well as supergeometry and quantisation. Some of our research is concerned with explicit methods in arithmetic geometry and complex multiplication theory.

Chair: prof. dr. Jaap Top (j.top@rug.nl)

Keywords: number theory, algebraic geometry

Dr. Pinar Kiliçer (p.kilicer@rug.nl)

Keywords: Algebraic number theory, algorithmic number theory, complex multiplication, algebraic curves, constructing low genus curves, reduction types of curves

Dr. Arthemy Kiselev (a.v.kiselev@rug.nl)

Keywords: geometry of quantisation, geometry of interaction, graph theory, Poisson geometry, integrable systems

Arthemy Kiselev develops and upgrades algebraic and geometric tools for the mathematical language of fundamental physics.

Dr. Ekin Özman (e.ozman@rug.nl)

Keywords: arithmetic geometry, algebraic number theory, rational points on curves, Brauer-Manin obstruction, modular curves, Q-curves, Prym varieties, invariants of curves over algebraically closed field of characteristic p and Galois towers of curves.

Prof. dr. Steffen Müller (j.s.muller@rug.nl)

Keywords: arithmetic geometry, explicit methods in diophantine geometry

Prof. dr. Cecília Salgado (c.salgado@rug.nl)

My field of research is arithmetic algebraic geometry. More precisely, I'm interested in problems around rational points on algebraic varieties, fibrations on curves and higher dimensional varieties, and applications to coding theory.

1.2 Computational and Numerical Mathematics

The group Computational and Numerical Mathematics is developing advanced mathematical and computational methods for the modeling of fluid flows occurring in applications that are important for society: turbulence modeling, cardiovascular modeling, and climate modeling.

Chair: Prof. dr. ir. Roel Verstappen (r.w.c.p.verstappen@rug.nl)

Keywords: scientific computing, computational fluid dynamics, turbulence, modeling complex fluid flows.

Prof. dr. Cristóbal Bertoglio (c.a.bertoglio@rug.nl)

My research field is the mathematical modeling and numerical simulation of the cardiovascular system. In the last years, my group has intensively worked using clinical data of different complexities for patient-specific cardiovascular modeling. This has also led to contributions in image reconstruction.

Dr. Julian Koellermeier (j.koellermeier@rug.nl)
Keywords: model reduction, rarefied gases, geophysical fluid flows, neuromorphic computing and memristors, shallow water equations, mathematical modeling, numerical simulation, hyperbolic balance laws and non-conservative finite volume models.

Prof. dr. ir. Fred Wubs (f.w.wubs@rug.nl)
Keywords: numerical mathematics

1.3 Dynamical Systems, Geometry and Mathematical Physics

Our research activities cover a broad and diverse spectrum of subjects in the fields of fundamental and applied dynamical systems theory, classical, statistical and quantum mechanics and their interfaces in the light of dynamics. Applications to life sciences, meteorology, physics and chemistry play a crucial role.

Chair: Prof. dr. Holger Waalkens (h.waalkens@rug.nl)
Keywords: dynamical systems theory (especially Hamiltonian and integrable systems) and mathematical physics

Dr. Tamás Görbe (t.f.gorbe@rug.nl)
My research focuses on Integrable Systems and their algebraic, geometric, and field-theoretic aspects

Dr. Hildeberto Jardón Kojakmetov (h.jardon.kojakmetov@rug.nl)
My research interests are dynamical Systems in the broad sense but especially those with multiple time scales. Besides, I am interested in developments on Control Theory, Mathematical Biology and Neuroscience, Networks and Complex Systems, among others.

Dr. Çagri Karakurt (c.karakurt@rug.nl)
Keywords: Low dimensional topology, symplectic geometry, contact geometry, Heegaard-Floer homology.

Prof. Dr. Oliver Lorscheid (o.lorscheid@rug.nl)
Keywords: algebraic geometry, algebra, number theory, combinatorics, matroids, tropical geometry, F1-geometry, quiver representations, automorphic forms

Together with Matt Baker and several (for parts, former) members of our groups (Manoel Jarra, Alejandro Mendez, Eduardo Vital Tong Jin, Philipp Griffins), we are formulating new foundations for matroid theory and tropical geometry, which includes new tools to study classical problems, such as representations of matroids. Some notable side projects are: jointly with Matt Baker, June Huh and Mario Kummer, we explore the relation to Lorentzian polynomials. Jointly with Nathan Bowler and Rudi Pendavingh, we provide a categorical framework for matroids with coefficients.

Together with Roberto Alvarenga and Valdir Perreira Junior, we develop an explicit understanding of automorphic forms for GL(3) over elliptic function fields.

Together with Omid Amini, we develop analytic geometry with orientations, with a possible application to the Macphersonian conjecture.

Dr. Nikolay Martynchuk (n.martynchuk@rug.nl)
Keywords: Integrable Hamiltonian systems (including symplectic geometry and topology of such systems), quantum mechanics, topological dimension theory

Prof. dr. Marcello Seri (m.seri@rug.nl)
Keywords: sub-Riemannian geometry, geometric mechanics, geometry-preserving numerical methods, spectral theory and their applications to problems in mathematical physics

Dr. Alef Sterk (a.e.sterk@rug.nl)
Keywords: nonlinear dynamical systems, attractors and their bifurcations, differential equations, analysis

I am a mathematician with an open mind for both theoretical and applied research. My current research focuses on the predictability and statistics of extreme events in dynamical systems with a particular emphasis geophysical models.

Prof. dr. Roland van der Veen (r.i.van.der.veen@rug.nl)
My research focuses on knot theory and its interactions with low-dimensional topology, representation theory, geometry and physics.

1.4 Probability and Statistics

The research activities of the probability and statistics unit span a wide range of topics in modern probability theory, theoretical and applied statistics, and discrete mathematics. These include percolation theory, random graphs, stochastic geometry, graphical models, statistical genetics and topological data analysis.

Chair: Prof. dr. Tobias Muller (tobias.muller@rug.nl)
Keywords: combinatorics, probability theory

Dr. Gilles Bonnet (g.f.y.bonnet@rug.nl)
Keywords: stochastic geometry, probability theory, convex and discrete geometry, random graphs/tessellations/polytopes, high-dimensional phenomena, point processes, extremal events

I explore the fascinating interplay between Probability and Discrete Geometry, and tackle a number of problems related to random geometric structures such as random Graphs, Tessellations and Polytopes. Among other things, part of my research is focused on extremal events in random geometric structures or on high-dimensional aspects of stochastic geometry.

Dr. Serte Donderwinkel (s.a.donderwinkel@rug.nl)
My research is in discrete probability theory. The common denominator of my projects is that they involve creative sampling procedures that, combined with tools from (stochastic) analysis, allow me to study the large-scale structure of the random tree or graph. Whether I am obtaining a large deviations principle, solving a counting problem with the probabilistic method or proving a metric space scaling limit, I always devote most attention to finding a smart way of sampling that unlocks the result that I am after.

Prof. dr. Marco Grzegorczyk (m.a.grzegorczyk@rug.nl)
Keywords: Bayesian statistics, Bayesian networks, statistical modelling

Collaborations & Network: UMCG, CogniGron, Groningen Institute for Pharmacy

The main expertise of my group is on Bayesian statistical modelling. In particular, we are interested in Bayesian networks and other graphical models for learning network structures from data.

Dr. Réka Szabó (r.szabo@rug.nl)
My research interests and experience are Interacting Particle Systems and Percolation Theory; I have worked especially on the Contact Process, Oriented Percolation Models, Probabilistic Cellular Automata and most recently on Bootstrap Percolation.

Prof. dr. Pieter Trapman (j.p.trapman@rug.nl)
Keywords: stochastic models for the spread of infectious diseases

1.5 Systems, Control and Optimization

The research program Systems, Control and Optimization (SCO) is devoted to the analysis, control and optimization of complex dynamical systems. The focus is on fundamental mathematical research, stimulated by collaborations with colleagues from the engineering and natural sciences. Mathematical systems and control theory deals with the modeling and control of open and interconnected systems evolving in time. The dynamical behavior is not only sought to be analyzed, but to be influenced (controlled) and optimized as well; by the addition of feedback loops, and by the interconnection to other dynamical systems (controller design), or the optimal selection of parameters. Furthermore, the systems point of view is emphasized, by viewing complex systems as networks of simpler components. From the optimization perspective, we study convergence and complexity of iterative algorithms, in connection with their underlying dynamics.

Chair: Prof. dr. Kanat Camlibel (m.k.camlibel@rug.nl)
Keywords: differential variational inequalities, complementarity problems, optimization, piecewise affine dynamical systems, switched linear systems, constrained linear systems, multiagent systems, model reduction, and geometric theory of linear systems

Prof. dr. ir. Bart Besselink (b.besselink@rug.nl)
Keywords: modular analysis and design of interconnected systems using contract theory, nonlinear electrical circuits with memristive elements for neuromorphic computing, model order reduction, applications in intelligent transportation systems, network dynamics and control, geometric modeling and control of multi-physics systems, mathematical systems theory

Prof. dr. Juan Peypouquet (j.g.peypouquet@rug.nl)
We investigate several aspects of the convergence analysis of continuous and discrete-time dynamical systems, with an emphasis in the study of convergence rates and complexity, especially in the presence of uncertainty, both from a theoretical perspective and through numerical analysis and simulations.

We study dynamics given by certain ordinary differential equations and inclusions, in order to design and analyze numerical optimization algorithms, aiming at producing fast algorithms for optimization problems with large volumes of data, and establish guarantees for their convergence rates and complexity. In particular, we shall study inertial methods with damping defined by the curvature, as well as inertial iterations of fixed-point type for more general equilibrium problems, envisioning applications in mechanics and game theory. These algorithms use only first order information, allowing them to consider problems with large volumes of data.

Our research focuses primarily on 1) geometric properties of the functions, such as metric regularity, error bounds, Lojasiewicz inequalities and second order information; 2) dynamical aspects, such as inertia, acceleration and relaxation; 3) restarting schemes in order to improve the convergence and performance of optimization algorithms that combine acceleration and stabilization mechanisms; and 4) the effects of intrinsic (by design) and extrinsic (by uncertainty) stochasticity.

Prof. dr. Stephan Trenn (s.trenn@rug.nl)
Keywords: control theory, mathematical modeling, model reduction, fault detection, discontinuous dynamical systems, modeling and control of energy grids

Dr. Henk van Waarde (h.j.van.waarde@rug.nl)
Keywords: direct data-driven control, system identifiability, kernel-based identification of (physical) dynamical system, experiment design, applications to networked systems and neuroscience

My research interests lie in the field of systems and control. I aim to develop a systems and control theory that is grounded on measured data. I work towards mapping raw data into models and control policies with rigorous guarantees on accuracy, stability and performance, while answering key questions such as: how much data is needed? how to handle noise? and how to perform control-relevant experiments?

Computer Science Department

2.1 Computer Architecture

Chair: Prof. dr. Dirk Pleiter (d.h.pleiter@rug.nl)

Keywords: Computer architectures, high-performance computing, co-design A central theme of my research is the co-design of computer architectures and technologies as well as digital infrastructures. This research aims to look into both, the design of future computers, including high-performance computing systems, and the design of applications to create the knowledge and understanding for shaping optimal solutions.

Dr. Farhad Merchant (f.a.merchant@rug.nl)

Keywords: emerging technology-based computing, hardware-oriented security

I work on the following two areas:

Computing-in-Memory (CiM): Also known as In-Memory Computing (IMC), this area focuses on using emerging technologies to enhance computing performance and achieve energy efficiency. An example of such an emerging non-volatile memory technology is resistive random-access memory. The aim is to use these technologies for neuromorphic computing in analog or digital domains.

Hardware-Oriented Security: My research encompasses both classical CMOS-based and emerging technology-based hardware security. I am particularly interested in topics such as malware detection, side-channel attacks, homomorphic encryption, physical unclonable functions, true random number generators, and more.

These two areas converge to enable the design of secure, reliable, and innovative computer architectures for future generations. For more details you can look at my google scholar profile.

Dr. Reza Zare Hassanpour (r.zare.hassanpour@rug.nl)

My primary research interests lie in the areas of computer networks, embedded systems, and the application of machine learning in embedded systems. I am particularly focused on exploring how machine learning can enhance the functionality and efficiency of embedded systems, as well as improving network performance and reliability in various computing environments.

2.2 Distributed Systems

Distributed Information Systems are concerned with the delocalization of computation on several hosts and their coordination via message passing. Looking at today's information systems, one notices that most of them, if not all, have some form of distribution. The key issues that emerge for research become those of addressing heterogeneity, scalability, and run-time adaptation. In the context of distributed systems, the group focuses on a number of sub-areas: Service-Oriented and Cloud Computing, Pervasive Computing, Middleware for Pervasive Computing and Adaptive Communications, Network-centric Real-time Analytics, and Sensor Networks. Interesting applications areas for the group are: Healthcare, Domotics and Smart Energy Systems.

Chair: Prof. dr. Alexander Lazovik (a.lazovik@rug.nl)

My main research interests include AI planning and discrete optimization in highly distributed environments, having the IoT as a main application domain. His research results have been field-tested in a number of existing buildings serving as living labs

Dr. Heerko Groefsema (h.groefsema@rug.nl)
Keywords: Automated formal verification, (regulatory) compliance, conformance, legislation, variability, synthesis of service compositions, business processes, workflows, digital twins.

Collaborations: Commonwealth Scientific and Industrial Research Organisation (CSIRO).

My research is focused on the automated verification of processes and workflows present in distributed systems. Within this setting, I develop formal mathematical techniques to automatically verify whether such processes conform and comply with regulatory requirements as imposed by legislation.

With increasing legislation that impacts key technologies, such as the AI act or GDPR, I aim to develop techniques with practical applications that solve real world challenges faced by industry. Although I apply formal mathematical techniques, I am particularly interested in bringing practical applications and solutions to industry and business.

Dr. Kawsar Haghshenas (k.haghshenas@rug.nl)
Keywords: Cloud Computing, Computer Systems, Applied Machine Learning, GreenAI

Collaborations & Network: University of Stuttgart, EPFL University, University of Tehran

My research is focused on warehouse-scale data centers that power both public and private clouds, hosting a wide range of services. As hardware and software in the cloud become increasingly heterogeneous, I aim to leverage machine learning techniques to improve cluster management. Additionally, with the rapid growth in the number and scale of AI tasks in the cloud, I am particularly interested in designing systems optimized for AI workloads in GPU clusters.

Dr. Dilek Düstegör (d.dustegor@rug.nl)

Keywords: anomaly detection, digital twin, pervasive computing, ambient intelligence, distributed decision making, technology enhanced education.

Collaborations & Network: Grenoble INP Genie Industriel, UvA, CIGIT Chinese Academy of Sciences, Universitat Politècnica de Catalunya (UPC), Aveco de Bondt, Hulo, EIT Digital, EIT Manufacturing.

My current research is focused on distributed decision making for smart environments, cyber-physical systems and digital twins, and pervasive computing for ambient intelligence, with a particular interest in sustainable applications for critical systems like water and energy management.

As an engineer (both in training and at heart), I have always been passionate about practical applications of theoretical knowledge to solve real-world problems and improve existing technologies. I root for the valorization of research, especially through the creation of societal values, which makes me wander at the frontier of academia and industry, through collaborations and the development of training for professionals.

2.3 Fundamental Computing

The Fundamental Computing group aims to contribute to the understanding of the logical and mathematical foundations of computing science and to realize a two-way transfer between this fundamental research and more applied areas of computer science.

Chair: Prof. dr. Jorge Pérez (j.a.perez@rug.nl)

Keywords: programming languages, program verification, concurrency, theoretical computer science, logic
Collaborations and network: Dutch Association for Software Engineering VERSEN, Institute for Programming Research and Algorithmics IPA, NeTCS, Técnico Lisboa (PT), Leiden University (NL), Imperial College (UK), Oxford University (UK)

Embedded in the Fundamental Computing group, my research targets the rigorous verification of communicating programs: computer programs that work by exchanging messages across networks, thus enabling systems that run on different computers to interact. To tackle this formidable challenge, my group and I investigate the foundations of type systems, techniques that avoid bugs by scrutinizing a program's instructions. A type system prescribes formation rules for programs, which allow us to mathematically prove that well-formed programs are correct. Our unique approach concerns type systems that enforce correctness by adopting principles from resource-aware logics, which allow reasoning about usage of resources.

Dr. Ivan Bliznets (i.bliznets@rug.nl)

Keywords: algorithms, satisfiability, fixed parameter tractable, fpt-algorithms, exact exponential algorithms

Prof. dr. Helle Hansen (h.h.hansen@rug.nl)

Logic and semantics of computation, in particular, modal logic, coalgebra, and algebra, and their applications in the formal specification and analysis of software systems.

Dr. Dan Frumin (d.frumin@rug.nl)

Keywords: logic, programming languages, type theory, program verification

My research is focused on verification of (concurrent) systems, using the tools of mathematical logic. I study the behavior of concurrent programs through formal semantics, and I am interested in formulating and verifying safety and security properties of the programs through this lens.

Dr. Revantha Ramanayake (d.r.s.ramanayake@rug.nl)

Keywords: non-classical logics, proof theory, substructural logic, modal logic, theorem proving, proof assistants

I specialize in the study of non-classical logics, with a particular focus on substructural and modal logics, through the lens of proof theory. My research interests include exploring the computational properties of these logics, such as establishing upper bounds using techniques like well-quasi-ordering and ordinal-indexed fast-growing function theory, and seeking generalizations of the fundamental proof theoretic property of cut-elimination ("cut-restriction").

2.4 Information Systems

Our research revolves around the three major flavors of information systems:

- Information systems with focus on process automation and workflow management, which are the backbone of modern enterprise systems in combination with service-oriented infrastructures. In particular, our focus is on both theoretical aspects of business processes in a cross-organisational setting, as well as technological aspects of the corresponding middleware and their software architecture and realizations. Exciting application fields are logistics and supply chain management, and eScience and scientific workflows. Current topic of research are: Adaptive service orchestrations and choreographies; Process performance monitoring and improvement, monitoring of KPIs of both orchestrations and choreographies; Data-driven process adaptation, IoT and Data Analytics; Blockchain enabled adaptive service choreographies for business and scientific applications

- Data-driven information systems with focus on image processing, pattern recognition and machine learning. In particular the research interests are in the fields of: Person identification by means of vision-based biometric features; Face analysis; Medical image analysis; Brain-inspired computer vision; Autonomous health monitoring systems with IoT; Automatic visual quality inspection

- Information systems often deal with (collect, store and process) sensitive data. Our group also performs research on data-centric security and privacy (S&P) at the intersection of authentication and authorization infrastructures, privacy-enhancing technologies (PET) and trust management. The particular research areas include: Formal Methods for (S&P) Analysis; Key Management and computation over encrypted data; PETs applied to (collaborative) machine learning; S&P for Medical Informatics (e.g. genomic privacy); Cloud, IoT and Edge Security; Applications of Blockchain (with a focus on S&P) to various domains

Chair: Prof. dr. Dimka Karastoyanova (d.karastoyanova@rug.nl)

Keywords: BPM and workflow management, autonomic process engineering, data-driven runtime process performance improvement, flexible workflows, collective adaptive systems and systems of systems, provenance for flexible eScience choreographies, service oriented architecture, enterprise application integration, scientific computing eScience

Prof. dr. George Azzopardi (g.azzopardi@rug.nl)

Keywords: Core Computer Science: Pattern Recognition, Predictive Analysis, Computer Vision, Machine/Deep Learning

Collaborations & Network: UMCG, CogniGron, University of Leon (SP), University of Salerno (IT), University of Malta, University of Stellenbosch (SA), University of Twente, Dutch Driving Authority RDW, IT Academy North Netherlands, ASTRON, Researchable

Interdisciplinary Applications: 1) Vision-based: Image/Video Analysis in Medical, Smart Farming, Radio-Astronomy and Forensic, 2) Non-vision based: Explainable AI for Predictive Modeling of Medical Phenotypes

My research team, consisting of five ongoing PhD students and a post-doc, is engaged in fundamental and interdisciplinary research. The PhD students Peter van der Wal (in collaboration with CogniGron) and Sabatino Esposito (in collaboration with the University

of Salerno), along with post-doc Guru Swaroop Bennabhaktula, focus on fundamental research. They are developing deep-learning algorithms inspired by the visual system of the brain, aiming to enhance their robustness and generalization capabilities, particularly for unseen (out-of-distribution) corruptions. The other three PhD students, Anusha Aswath, Steven Ndung'u Machetho, and Rafael Martínez García Peña, are involved in interdisciplinary projects. Anusha is developing algorithms for segmenting (sub)cellular structures in electron microscopy images, in collaboration with the Biomedical Science of Cells & Systems, UMCG. Steven is working on algorithms for classifying and retrieving sources in radio astronomy images, in collaboration with ASTRON and the University of Stellenbosch. Rafael is developing a computer-aided diagnosis system for hyperkinetic movement disorders from videos, in collaboration with the Movement Disorders department at UMCG. The post-doc Guru Swaroop Bennabhaktula is also engaged in forensic image analysis, working with the Dutch Driving Authority (RDW) to develop algorithms that detect face morphing attacks. Guru and I were honored with the Ben Feringa Impact Award in 2023, and I have also received an Impact Award from ENLIGHT for our research in this direction.

Dr. Fadi Mohsen (f.f.m.mohsen@rug.nl)

My research interests lie in the field of cyber security, particularly in web, computer and mobile phones security. My research investigates the security and privacy risks of third-party applications in computing system by analyzing the access control mechanisms, finding possible vulnerabilities, implementing countermeasures, and studying users' awareness and comprehension to the vulnerabilities and the countermeasures. Over the last year and a half I have been working on projects that involve using data and text mining techniques to detect Android malicious apps and recommend safe apps for mobile users to download on their phones.

Dr. Mirela Riveni (m.riveni@rug.nl)

Keywords: social computing and crowdsourcing, network science, computer networks, cloud computing, recommender systems

Currently, my work is focused on large-scale network analysis, and specifically disinformation detection and (dis)information spreading analysis, as well as polarization and eco chambers. Current use cases in which I work are from data in decentralized systems (i.e., the fediverse). I work with network science metrics, graph-based algorithms, ML, and NLP. I am also studying provenance in large scale network analysis and other related contexts such as: provenance of code, and provenance in workflows. Furthermore, bias and discrimination issues in recommender systems have been within my interest for years. A special focus of mine are privacy and ethical issues, on which I write and give talks as well. A fairly new research line of mine since I started working at the Information Systems Group, is applying network science in BPM and process mining.

Prof. Dr. Fatih Turkmen (f.turkmen@rug.nl)

Keywords: cybersecurity, privacy
Ongoing collaborations: TNO, KPN, Ahold, Albert Heijn

As part of the larger Information Systems group, my team works on cybersecurity and privacy related problems. Some of the focus areas include:

(1) Privacy Protection in Data-centric Systems: On one hand, we develop **privacy-preserving** variants of data-intensive computations such as machine learning algorithms by using cryptographic tools that include multi-party computing,

differential privacy and zero knowledge proofs among others. On the other hand, we develop techniques to detect attacks (e.g., memorization, membership inference) against such systems and develop defenses against these attacks while minimizing the impact on the overall performance. Our typical use case is genomic data processing and the overarching goal is to enable **decentralization**.

(2) Security Analysis of Complex Systems: In this line, we develop **empirical methods** such as fuzz testing to **test** systems against **security** related errors and vulnerabilities (e.g., side channels). The systems we consider vary between low level hardware such as neuromorphic circuits implementing spiking neural networks to high level software such as Web applications with many smaller components. Our long-term goal is two-fold: (i) to bring the concept of "**security by design**" into practice in emerging technologies such as neuromorphic computing before they become more complex and (ii) enable automated security analysis of complex systems such as Web-based applications.

2.5 Intelligent Systems

Our research group covers a variety of theory and application in the context of intelligent systems.

That includes deep learning for medical imaging, morphological filters for efficient and robust large scale image analysis for various domains (astronomy, remote sensing, agriculture, microscopy, etc) and agile sensing for cyber physical systems and robotics. We also investigate the theory of AI learning systems with frameworks from theoretical physics to understand the theory of deep learning among others.

Our group collaborates a lot with the medical field (Birmingham, UMCG), including different data modalities: images (CT, MRT, Xray, ...), genetic + proteomics, bodily fluid data (GCMS, etc.), time-series of treatment, ECG, in particular when dynamic models are involved.

Collaborations & Network: UMCG, University of Birmingham, ENTEG, Belsimpel, VerifAI, Slimmer AI, TNO, Circ, powerchanger, Philips, Arox Logistics, and cooperations in the agricultural sphere. Many European universities, as well as in the US.

Chair: Prof. dr. Kerstin Bunte (k.bunte@rug.nl)

I develop efficient and/or interpretable machine learning (ML) techniques targeted for difficult application domains. This includes ML including expert knowledge in form of mathematical models (mechanistic models, scientific ML) in science domains where such models exist (pharma, medicine, engineering, physics). Then developments of dimensionality reduction, feature selection, biomarker detection in various domains where information retrieval is important. I also investigate theory of ML in particular when data is limited ... I investigate and model the data that is unseen to understand over-parameterized models, for example for differential equation systems. I also investigate the application area of smart industry, where I am interested in robust and efficient solutions to analyze production processes and perception solutions for cyber-physical systems, here again when data is imperfect and scarce.

My last research line is in Astroinformatics where we develop efficient evolutionary computation algorithms incorporating game theoretic principles for the detection and modeling of faint astronomical structures.

Prof. dr. Michael Biehl (m.biehl@rug.nl)
Keywords: Machine Learning and Computational Intelligence, Deep theory and algorithm development for neural networks, Learning Vector Quantization and Relevance Learning, Statistical Physics and Scientific Computing, Theory of neural networks, dynamics of machine learning processes, Monte Carlo simulations of complex systems, Disordered systems, non-equilibrium growth processes

Dr. Jiapan Guo (j.guo@rug.nl)
Keywords: machine learning, pattern recognition, interdisciplinary data analysis, computer vision, medical imaging informatics
Collaboration and network: UMCG (NL), University of Twente (NL), Zhejiang University (China), Harvard Medical School (US)

I am embedded in the intelligent systems group in which we work on applying machine learning and pattern recognition on interdisciplinary (image) data analysis. In particular, I am interested in using deep neural networks for (multimodal) analysis of (visual) data.

Dr. Kailai Li (kailai.li@rug.nl)
Keywords: machine intelligence, state estimation and perception, multisensory autonomy in mobile robotics, agile sensing

Ongoing collaborations: Linköping University (Sweden)

My major research interest lies in agile sensing and trustworthy inference in the general domain of understanding physical and cyber-physical systems, with applications to sensor fusion, robotic perception, and learning dynamical systems. I am also interested in developing planning and control methods for uncertain dynamical systems and have the ambition to methodologically unify these aspects through new representations and models with real-world validation.

Dr. Michael Wilkinson (m.h.f.wilkinson@rug.nl)
Keywords: Digital image analysis, segmentation, mathematical morphology, connected filters, biomedical imaging and visualization, remote sensing, astronomical image analysis, parallel and distributed computing for analysis of massive images and volumes.

2.6 Scientific Visualization and Computer Graphics

The group carries out research in the areas of scientific visualization, information visualization, software visualization, multiscale shape analysis, illustrative computer graphics, innovative interfaces using large displays, geometric modelling, vector graphics, visual perception and VR/AR. We apply our research to fundamental and practical problems from the life sciences (functional brain imaging, bioinformatics), astronomy, the medical domain, as well as the CAD industry. The group participates in the research school Behavioural and Cognitive Neuroscience (BCN) and the Neuroimaging Center (NIC) of the University of Groningen and the University Medical Center Groningen.

Chair: Prof. dr. Jiří Kosinka (j.kosinka@rug.nl)
Keywords: geometric modelling, computer aided (geometric) design, computer graphics, image processing

Dr. Steffen Frey (s.d.frey@rug.nl)

My research concerns the development of methods to gain insights from large quantities of scientific data (typically from experiments and simulations). Meaningful analysis requires addressing challenges both regarding presentation and performance, and involves diverse--but tightly connected--research directions, including machine learning /optimization for visualization, high performance computation (distributed/parallel approaches, in situ visualization), and multifield visualization. An overarching topic is the automatic, data-driven configuration of methods and systems.

Dr. Christian Kehl (c.kehl@rug.nl)

My main research interest is the design, implementation, extension and optimisation of algorithms that integrate observational data (e.g. from remote sensing or domain expert interpretation) in deterministic- and stochastic simulations of dynamic systems (such as fluid flow) as well as uncertain static systems (such reservoir architectures), and the visualisation of those systems on modern, easily-accessible platforms. Visual perception and interaction within those platforms are key aspects to make the visualizations effective.

Dr. Cara Tursun (cara.tursun@rug.nl)

Keywords: computational models of visual perception, perceptually inspired quality and visibility metrics, VR/AR display technologies, gaze-contingency paradigm and foveated rendering, high dynamic range imaging, generative deep learning for graphics.

2.7 Software Engineering and Architecture

Effective software engineering requires healthy software and teams. A healthy software is maintainable, well-performing, with low technical debt, and based on sound design decisions. A healthy team is productive, diverse and inclusive. And healthy software and team amplify each other. Our research enables the software industry to improve their software and team health.

Chair: Prof. dr. ir. Paris Avgeriou (p.avgeriou@rug.nl)

Keywords: software architecture, maintenance and evolution, technical debt, empirical software engineering

Large, complex, and long-lived systems are hard to design and maintain! We need evidence-based tools to make architecture decisions and manage technical debt.

Prof. dr. Vasilios Andrikopoulos (v.andrikopoulos@rug.nl)

Keywords: software architecture, cloud-based systems, distributed systems, sustainable software

To ensure system longevity, reduce environmental footprint, and maintain operational profitability, we need to connect design-time and run time.

Prof. dr. Andrea Capiluppi (a.capiluppi@rug.nl)

Keywords: open source, maintenance and evolution, mining software repositories, AI for software engineering

Building a software system is one thing, but maintaining it is much more expensive: this is the phase we need to prioritize!

Dr. Daniel Feitosa (d.feitosa@rug.nl)
Keywords: software architecture, technical debt, developer tools, mining software repositories, software analytics

If software development is to evolve, we need human-centered tooling to leverage cross-system knowledge sharing. Tools only enable productivity and velocity when they are designed and combined with the team's cognitive processes in mind. My research focuses on understanding and engineering of software systems to support developers in managing and improving the technical sustainability of software products.

Dr. Ayushi Rastogi (a.rastogi@rug.nl)
Keywords: AI for Software Engineering, Empirical Studies, Open Source, Software Analytics, Mining Software Repositories, Software Economics, Developer Productivity, Code Velocity, Fairness, Diversity and Inclusion. Software data empowers informed decision-making to make a better society (e.g., solving fairness problem) and the software industry (e.g., developer productivity).

Dr. Sushant Pandey (s.k.pandey@rug.nl)

I am working on various problems in the software engineering domain using AI tools, such as input prioritization, design pattern recognition, and software defect prediction. I am also working in a Data leak issue in computer vision.

Prof. dr. Tijs van der Storm (t.van.der.storm@rug.nl)
Keywords: developer tools, domain-specific languages

There’s too much code in the world! We should rethink the software stack with DSLs for better productivity, reliability, and stakeholder communication.

Artificial Intelligence Department

3.1 Cognitive Modelling

The Cognitive Modeling Group studies human cognition by creating cognitive models of complex behavior. Cognitive models are, essentially, theories of how people think, implemented in computer simulations. To test these models, their predictions are compared to human data from behavioral and neuroimaging studies. In particular, we are interested in model-based analyses of neural data, in which a model is used to guide the interpretation of the data.

Cognitive models can be applied in many domains: they can be used as the basis for designing education and training, or they can be used to implement intelligent agents in various applications. Many of the models we build are developed with the ACT-R language/modeling formalism or the PRIMs architecture which was originally developed by our group.

An overarching theme in our group is skill acquisition. We look at it in a variety of contexts, ranging from medical decision-making, to multitasking, and the transfer of skills across domains. We also investigate how people can reduce distraction and improve their mental abilities through meditation and how they acquire and interpret natural language. We also study cognition and learning in low-level spiking neural networks in the context of the Cognigron Center for Cognitive Systems and Materials.

Chair: Prof. dr. Niels Taatgen (n.a.taatgen@rug.nl)

My main specialty is cognitive modeling: using computer simulation to better understand human cognition. The topics I focus on are learning, multitasking, time perception and visual perception. To test the theories, I conduct experiments with human subjects.

Cognitive modeling has many applications in education, human-computer interaction and artificial intelligence. I am especially interested in multitasking in driving, and building cognitive tutors.

Prof. dr. Jelmer Borst (j.p.borst@rug.nl)

My main research interest is the development and improvement of analysis methods that connect computational (cognitive) models to neuroimaging data. Better methods will enable a more fine-grained analysis of the astounding amount of neuroimaging data that is collected worldwide. Ultimately, this should lead to a better understanding of the human mind, which should take the form of computational cognitive models at different levels of abstraction, from higher level process models in the cognitive architecture ACT-R to low-level spiking-neuron models developed in Nengo.

Prof. dr. Fokie Cnossen (f.cnossen@rug.nl)

Keywords: cognitive engineering, cognitive psychology and human factors applied to patient safety, human-machine interaction and usability, human-robot interaction, (medical) skill acquisition, driving behaviour

Prof. dr. Matthew Cook (m.cook@rug.nl)

Keywords: bio-inspired circuits and systems

Dr. Stephen Jones (s.m.jones@rug.nl)

My main area of research is the interface between theories of grammar and computational models of cognition. I am particularly interested in the link between grammar and on-line processing, including the syntax-prosody interface. I use language data from English, Dutch and Korean.

Dr. Jacolien van Rij-Tange (j.c.van.rij@rug.nl)

Keywords: language acquisition, sentence processing, context

I'm interested in the processing of (seemingly) ambiguous sentences. These are sentences that potentially have multiple potential interpretations, such as sentences with pronouns or idioms. For interpreting these sentences correctly, the listeners need to combine different sources of information in a relative short time (for example, world knowledge, visual context, and preceding linguistic information).

My research focuses on 1) how listeners combine different sources of information during sentence processing, and 2) how regularities in the linguistic input may facilitate this process. I combine computational simulations (error-driven learning), experimental studies, and advanced statistical methods to answer my research questions.

Dr. Andreea Sburlea (a.i.sburlea@rug.nl)

Keywords: human centered intelligence

My research interest is multidisciplinary covering neuroscience, brain-computer interfaces, and artificial intelligence (AI).

In the field of neuroscience, I am mostly interested in multimodal data, linking brain activity (mostly EEG), behavioral data (EMG, eye-tracking, kinematics), and computational models in (close to) real-life scenarios that investigate from a cognitive perspective the relation between human perception and action. In the field of brain-computer interfaces, my goals are to leverage signal processing and neuroimaging methods to understand the causal relationship between the perception of stimuli and the triggered action, through neural correlates of error-driven learning in motor behaviour. Furthermore, in artificial intelligence, I apply machine learning techniques and statistical approaches to optimize the design of human-centered closed-loop motor strategies for neuroprosthetic control.

Next to my research, I am very motivated by science education and dissemination at different levels. My focus is on developing methods that use AI to ensure inclusive and equitable quality education and learning opportunities for all. In my current position, I aim to promote learning about AI, learning with AI, and learning for human-AI collaboration.

Dr. Catherine Sibert (c.l.sibert@rug.nl)

I am interested in exploring the mechanisms of thought, with a particular focus on how the structure of the human brain gives rise to human intelligence. I believe that understanding this relationship is vital for informing and improving artificial systems that instruct, supplement, or collaborate with human users.

My work seeks to bridge the gap between neuroscience and AI by using brain imaging data to explore the high level frameworks of cognition proposed by computer science based architectural models and investigating how the constraints of the brain or tasks impact the behavior that results. By expanding on current theoretical accounts of human thought processes, like the Common Model of Cognition, I hope to incorporate insights from the human brain into platforms for general purpose artificial intelligence that more closely

resemble our own, and to use artificial intelligence tools to better understand and interpret human behavior.Keywords: human computer collaboration

Dr. Lisa-Marie Vortmann (l.vortmann@rug.nl)

I am fascinated by the role and effects of attentional mechanisms and states because I believe it has a fundamental influence on basically all other aspects of human cognition. Addressing different research questions and motivations regarding human attention, I have worked intensively with machine learning, biosignal data processing (mostly EEG and eye tracking), augmented reality, cognitive modeling, and brain-computer interfaces.

Prof. dr. Marieke van Vugt (m.k.van.vugt@rug.nl)

Keywords: artificial intelligence, computational psychiatry, decision making, EEG, cognitive modeling, mindfulness, attention, social neuroscience, brain decoding

In my lab, we try to understand when, how and why we mind-wander. When is it beneficial, when is it not? In this context, I am particularly interested in depressive rumination, as a specific example of where we get stuck in our thoughts. I examine in collaboration with Prof. Marie-José van Tol (UMCG) how interventions can reduce ruminative thinking. In addition, I am highly interested in biomarkers of mind-wandering and depressive rumination, based on behaviour, EEG, and speech (the latter in collaboration with Prof. Iris Sommer, UMCG). I also try to improve biomarkers of mind-wandering using generative artificial intelligence in a project in collaboration with Prof. Natasha Maurits (UMCG).

Apart from this, I am working on how we coordinate our behaviour using a tacit coordination task in combination with inter-brain synchrony measured with EEG. In a very unique project, I collaborate with Tibetan monks of Sera Jey monastic university (India) to see how a collaborative reasoning and meditation practice–monastic debate–affects cognition and emotion.

3.2 Human-Centered Robotics

The Human-Centered Robotics research group focuses on the foundational methodologies and cutting-edge technologies that enable intelligent robotic systems to seamlessly operate in complex, time-varying environments. Research within the group spans various domains including mechatronic design, perception, learning, and control, with the goal of addressing the diverse challenges inherent in human-robot cooperation and physical/social human-robot interaction. The group employs a diverse array of classical system-theory and machine-learning methodologies, such as model-based and data-driven control, as well as reinforcement learning and (deep) neural networks.

Beyond the commitment to advancing scientific knowledge, the group holds a deep appreciation for societal implications. As such, end-users, relevant industries, hospitals, and a wide spectrum of interdisciplinary stakeholders are actively engaged within the research domains. By fostering collaboration and understanding, the group aims to positively impact society at large.

Chair: Prof. dr. Raffaella Carloni (r.carloni@rug.nl)

The Robotics lab develops robotic systems that are intended to physically interact with uncertain dynamic environments and to cooperate with humans. The group’s main goal is the development of novel actuation systems, which are the key enabling components for motion generation. The work is accomplished by developing mechanical designs and

intelligent model-based or model-free control architectures. Current research projects focus on bio-inspired soft robots and lower-limb prosthetic devices.

Dr. Hamidreza Kasaei (hamidreza.kasaei@rug.nl)

The Interactive Robot Learning Laboratory (IRL-Lab) focuses on fundamental lifelong robot learning to make robots capable of learning in an open-ended fashion by interacting with non-expert users. In our research, apart from robot self-learning, non-expert human users could interactively guide the process of experience acquisition by teaching new concepts, or by correcting insufficient or erroneous concepts. This way, the robot will constantly learn how to operate effectively in complex environments, adapt to user preferences, and learn from user input without the need for re-programming.

We also work on challenging open problems at the intersection of robotics, computer vision, and machine learning. We develop algorithms and systems to understand the underlying principles of robust sensorimotor coordination in humans and animals with the aim of improving the skills and autonomy of complex robotic systems.

Dr. Paul Vogt (p.a.vogt@rug.nl)

Keywords: social robotics, human-robot interaction, developmental robotics, cognitive science, language development

My research focuses on how to design and develop social robots, and investigate how they can be used to achieve the goals they are designed for. Social robots are robots designed to interact with humans in a socially acceptable manner to support humans in a social, communicative way. My research particularly focuses on designing the communicative abilities of social robots to be applied in the domains of education and healthcare.

3.3 Machine Learning

The machine learning group is a team of scientists working to build the next generation of machines that can safely and responsibly learn to act through interactions with humans, infrastructures, and other machines. We explore scientific breakthroughs in modern machine-learning technologies and real-world applications that can transform industries, improve people's lives, and benefit humanity.

Chair: Prof. dr. Jilles Dibangoye (j.s.dibangoye@rug.nl)

Keywords: machine learning, reinforcement learning, game theory

Dr. Maruf Dhali (m.a.dhali@rug.nl)

Keywords: machine learning, computer vision, image processing, statistical image analysis, probabilistic robotics, document analysis, handwriting recognition, deep learning

Prof. Dr. Herbert Jaeger (h.jaeger@rug.nl)

Keywords: neural networks, energy-efficient computing, brain-like microchips, very complex systems

Jaeger's group ('Modeling Intelligent Dynamical Systems', MINDS) investigates how cognitive-level information processing can be realized in extremely energy-efficient, non-digital, 'brain-like', novel sorts of computing microchips. The MINDS group enjoys close collaborations with materials scientists, unconventional microchip designers, machine learners, and cognitive scientists. In this context, Jaeger's group contributes mathematical modeling methods and formal models of computing systems. Jaeger and his group are closely associated with the Groningen Cognitive Systems and Materials Center (CogniGron).

Dr. Matthia Sabatelli (m.sabatelli@rug.nl)
Keywords: (deep) reinforcement learning

Dr. Tsegaye Tashu (t.m.tashu@rug.nl)
Keywords: Natural language processing (NLP), Multilingual NLP, Sentiment Analysis, Machine Learning, Educational Text mining

Dr. Matias Valdenegro Toro (m.a.valdenegro.toro@rug.nl)
Keywords: machine learning, deep learning, uncertainty quantification, computer vision, Bayesian deep learning, neural networks

3.4 Multi-Agent Systems

The Multi-Agent Systems (MAS) Group carries out fundamental research on how to model and design intelligent systems that emerge from the interaction of different agents, human and/or artificial. Our research focuses on:

- Logical and computational models of higher-order social cognition to enhance the development of intelligent interaction between people and computer systems, by supporting their abilities to reason about one another. This has applications to among others systems that help to detect deception and understand the spread of fake news in social networks.
- Formal and computational models of argument and their application in AI and in law. An important aim is to investigate responsible hybrid systems that connect knowledge representation and reasoning techniques with the powers of machine learning.
- Computational models of group decision-making processes, such as voting and deliberation, to support the development of more effective decision-making mechanisms with applications to, among others, Blockchain and eDemocracy.

Chair: Prof. dr. Rineke Verbrugge (l.c.verbrugge@rug.nl)
Keywords: applications of logic in artificial intelligence, multi-agent systems, higher-order social cognition, hybrid intelligence

Dr. Zoé Christoff (z.l.christoff@rug.nl)
My research focuses on collective intelligence: how groups of agents can act smart together. I model collective decision making, opinion formation, social influence, and social network phenomena, using formal tools from logic, artificial intelligence, social network theory, social epistemology, and social choice theory. I am also interested in modal logics, graph theory, social psychology, formal learning theory, philosophy of science, self-reference problems, and limitative results in logic.

Prof. dr. Davide Grossi (d.grossi@rug.nl)
Keywords: collective decision-making, multi-agent systems, governance, game theory, social choice, digital democracy

We apply mathematical and computational methods to the analysis of collective decision-making problems and governance problems, and develop algorithmic solutions for them. We work on problems across a variety of fields: from artificial intelligence (cooperative AI), to blockchain (algorithmic governance), economics (social choice), and democracy (democratic innovations).

Prof. dr. Bart Verheij (bart.verheij@rug.nl)
Keywords: responsible AI, explainable AI, AI & law, computational argumentation

Dr. Harmen de Weerd (harmen.de.weerd@rug.nl)
Keywords: multi-agent systems, agent-based modeling, statistics