CONSTRUCTOR
UNIVERSITY

Research Report
2019–2022

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Constructor University

Research on Europe's most international campus
2019–2022

constructor.university/research

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Our Research Groups

School of Science

School of Computer Science & Engineering

School of Business, Social & Decision Sciences

Dr. Serg Bell, Chairman of the Board of Governors of Constructor University

Foreword

I have been involved in universities since I was a child and visited my parents in their physics laboratories. And since I began working and building companies, I have aspired to make enough money to create something like Constructor Group — an ecosystem that combines university research with technology and investment companies. With this configuration, I believe we can produce better science, offer a better education, and undertake better research.

There is no longer a wide divide between deeply fundamental science and science with immediate applications, and our system reduces the financial and practical barriers to innovation. That means we can do pure science, yet see the real-world impact of our research almost instantaneously.

We want to unlock the power of knowledge and harness science and education to solve the world's biggest challenges. We began in 2019 with the Schaffhausen Institute of Technology in Switzerland, but quickly realized that we needed to expand to achieve our goals. The university in Bremen offered a strong institution in a competitive location, a perfect fit.

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Constructor University is a top-ranked English-speaking university in Germany. Its location places its staff, students and alumni in the world’s largest trading bloc, with access to a wide variety of opportunities, stakeholders, and collaborators. Its success, like that of any university, is highly dependent on its ability to motivate and attract creative people. But unlike other sectors, money is not usually their main or only motivator: they want purpose, mastery, the ability to become better at, and learn more about, what they do, and — like brilliant people everywhere — to have autonomy.

As this research report shows, Constructor University is home to talented and inquisitive researchers whose work is expanding our knowledge and making the world a better place. Despite its relatively small size, the university offers a first-class education to its students, while continuing to punch above its weight in research output and impact.

Universities have three foundational pillars: professors, students, and the resources and facilities to support them. These resources allow universities to undertake relevant, cutting-edge research and learning, while their professors and students live and work in a place where they feel empowered and valued. At Constructor Group, we recognise the importance of these three pillars and that, without them, a university will not achieve its potential.

At the same time, technology is ubiquitous and universities need to keep up with its rapid march to remain relevant. At Constructor Group, which contains the expertise from the technology companies I have built, we will leverage computers, cyber security, artificial intelligence, software engineering, autonomous machines, physics, quantum technology, advanced functional intelligent materials, life engineering, as well as a number of areas in business. These fields are highly connected and support each other if we are to use the resulting knowledge to magnify our impact and address the manifold challenges facing the world.

While Constructor Group focuses on the power of technology, disciplines within the social sciences and arts both underpin and amplify our impact. The division of social and hard sciences is artificial, and within universities, people are motivated by mastery, autonomy and, of course, curiosity. Someone may want to start their career as a physicist and then pivot to the arts, or vice-versa, so any functional university must offer a broad set of subjects. This is very important.

But ultimately the direction of a university should not be up to the owner. We have a board of governors, a president, a provost and an entire management team. At its heart, a university is about smart academics and students, and they need the ability to decide for themselves what research and subjects are important. Constructor University is under construction. It’s a creative process, and a process of creating consensus.

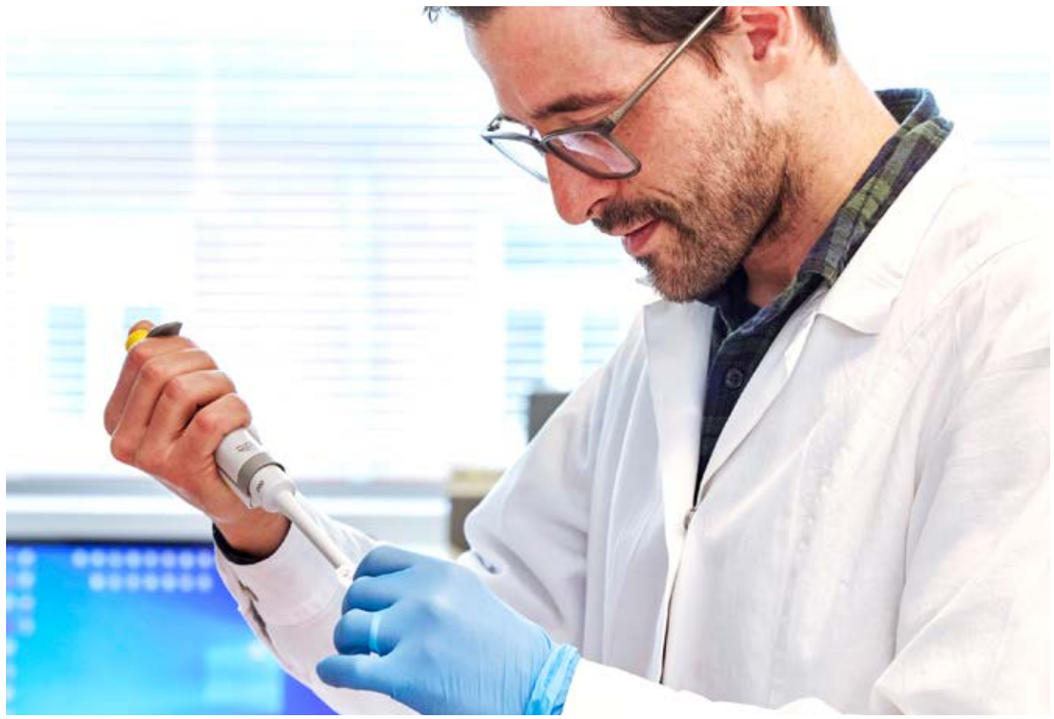
Constructor University has had uncertainty over the last few years, and over the next five years, we plan to focus on improving its research capabilities and continuing to attract excellent students and academics.

— Dr. Serg Bell

Constructing the future

Our research foci

During 2020, the university commissioned a bibliometric analysis of its research activities and performance over the previous five years. This analysis provided useful insight into areas of comparative research strength at the university and was intended to help shape a research strategy. Although the prospect of being part of Constructor Group was not yet on the horizon at the time, the need for the university's scientific activities to orient themselves around aspects of the digital economy and landscape was self-evident. As a result, we reviewed the outcomes of the bibliometric analysis in the context of identifying research strengths with a focus on digitization, thereby combining the backward-looking bibliometric analysis with a forward-looking strategic ambition.



The six research foci that emerged from this exercise in 2020 are remarkable for the prescient way in which they anticipated Constructor University's future academic, scientific and technological priorities within the Constructor Group:

Molecular Sciences:
- From Natural Products to Innovative Medicines

Emerging High-Tech Materials:
- Development, Resources, and Environmental Impacts

Complex Systems:
- From Data and Theory to Models

Digital Transformation Technologies:
- Digital Communication Systems, Digital Signal Processing, Machine Learning, Robotics, and Intelligent Systems

Emerging Economies and Global Supply Chains:
- Understanding Non-Western Societies and Businesses

Human-Centered Digitization:
- Digital Transformation, Digital Socio-Economic Models, Human-Machine Interaction, AI Methods for the Social Sciences

The overview presented below of Constructor University's research activities is organised around these six research foci and spans over the period 2019–2022.

Molecular sciences

Constructor University has a tradition of natural sciences research, and strong expertise in molecular sciences across several disciplines, from immunology and cell biology through to food safety. A major driver of the university's success is its strong interdisciplinary collaborations both within and outside of the institution. Its molecular science projects include a variety of topics, from developing new types of chocolate to understanding how Covid-19 affects neurons.

Marc-Thorsten Hütt, professor of computational systems biology, enjoys the "tremendous interdisciplinarity we achieve here". A physicist by training, the bioinformatician works at the interface of statistical physics, systems biology, and systems medicine. He collaborates with several colleagues at the university, and has students from all over the world, including Turkey, India, Greece, and Tunisia, among others. "The reason this works so well is probably due to the fact that this is an English-speaking campus, and has internationality in its DNA," he says. "And I have been perfectly free to design my own research questions and pursue ideas, and I've had a tremendous amount of support."

His group has pioneered the analysis of gene expression data via network coherences, and used network-based analyses of transcriptome data, to gain new insights into diseases such as chronic inflammatory bowel diseases and hepatocellular carcinoma. He is also part of Constructor University's large collaboration with chocolate giant Barry Callebaut, the Cocoa Metabolomics Initiative.

Chemist Nikolai Kuhnert uses mass spectroscopy and chromatography to identify the compounds in processed food. He began collaborating with Barry Callebaut more than a decade ago when the European Union banned certain additives from chocolate, and approached researchers at the university for assistance. Kuhnert and colleagues not only solved their problem, but also developed pink chocolate. "This is an applied outcome and you can go into any supermarket in the world and you can see a product that came out of my lab. It is very gratifying," Kuhnert says. Researchers from Constructor University have continued to work with the company.

Klaudia Brix, professor of cell biology and one of Kuhnert's collaborators at the university, has always been guided by her curiosity. Her research began with trying to understand how the thyroid works, and now incorporates a sprawling diversity of projects ranging from the safety of compounds for human consumption through to the effect of the coronavirus on neurons.

"We are good at taking beautiful microscopy images," says laboratory technician Maren Rehders, who works closely with Brix. "But it's also about the data: we need to extract numbers from those images that they can be used as evidence. That opens up lots of opportunities to collaborate with others." Brix collaborates with several other researchers at Constructor University, including Kuhnert, Hütt, and molecular plant microbiologist Matthias Ullrich.

The international diversity of students also enhances the scope of Brix's curiosity. "European students may be interested in Alzheimers or cancer," she says. "But when you have international students from countries in South America or Africa, they tend to be more interested in infectious diseases." The vast array of ideas creates a vibrant research environment, she says. "It's very rewarding to have these interactions. It's demanding and it's very different from what you would experience at another institution in Europe."

"A small place like this has big advantages when it comes to different people from different disciplines working together," says Sebastian Springer, professor of biochemistry and cell biology. His work focuses on immunology, molecular cell biology, and biochemistry, specifically on the intracellular transport of membrane proteins of the immune system, and its regulation.

The university's inclusion in the Constructor Group, with its expertise in software and computing, increases the horizons of collaborations and projects, he says. "The collaborative research effort in molecular science and in computation opens up a lot of possibilities."

Emerging high-tech materials

Interdisciplinary collaborations drive high-impact, relevant research at Constructor University. In today's changing climate, research needs to answer fundamental questions while offering sustainable solutions for the future.

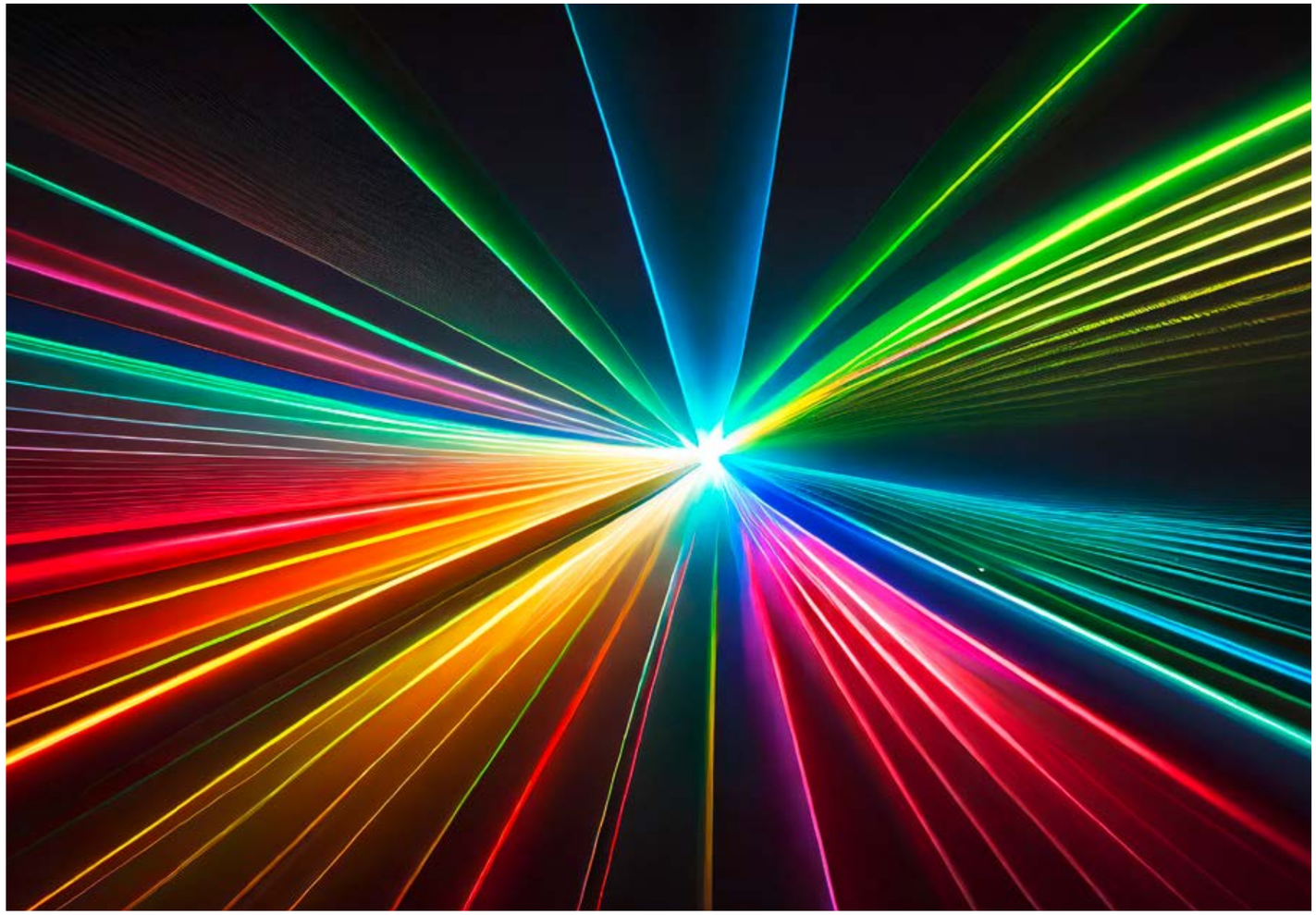
With increasing metal scarcity and new technologies, including mobile phones and renewable energy technology, there is a high demand for rare Earth metals. Unfortunately, many of these resources are in areas where there is political conflict or unethical labor practices, and so people are exploring deep sea mining. "There is a vast amount of metal-rich material lying on the seafloor in international waters," says Andrea Koschinsky, geosciences professor, who's research addresses pressing sustainability issues.

"'Constructing the future' actually means that we also need to take care of our resources, and the environmental consequences of our behavior, and what would be the most sustainable way forward in a holistic context," she says. "This is something we try to approach in both our teaching and research — what is the overall story, and what consequences do certain processes or technologies have?"

Koschinsky's group includes researchers from the Congo, the US, China, Argentina, and Europe. "This is part of the success of the group: we can work from all different kinds of aspects and experiences. These are global issues we need to solve, and we want to export the knowledge we create to make the world a better place," she says.

She has a joint laboratory with geoscientist Michael Bau, who focuses on the terrestrial aspect of resource extraction. "We cover a broad range of aspects of metal resources that we require to build our future and also to understand what the consequences of these uses are and how we could make it as sustainable as possible."

This interdisciplinarity informs research across the university. "Traditionally, you have chemists and biotechnologists, and they do not understand each other," says Elke Nevoigt, professor of molecular biotechnology. At Constructor University, researchers combine their expertise to undertake cutting-edge research. Nevoigt works with yeast, engineering the single-celled organism so that it can produce a variety of compounds, ranging from proteins through to pharmaceuticals. "I really want to use my knowledge to help protect our climate and contribute to the sustainable production of compounds we need to make for materials, food, and chemicals," she says. Nevoigt and her group are particularly interested in using carbon dioxide. This would both reduce atmospheric carbon levels and create valuable products.



Arnulf Materny, who joined the university more than 20 years ago, straddles the fields of physics and chemistry. He uses lasers to investigate molecular systems, mainly using Raman spectroscopy, in which researchers use light scattering to identify molecular fingerprints, and femtosecond spectroscopy.

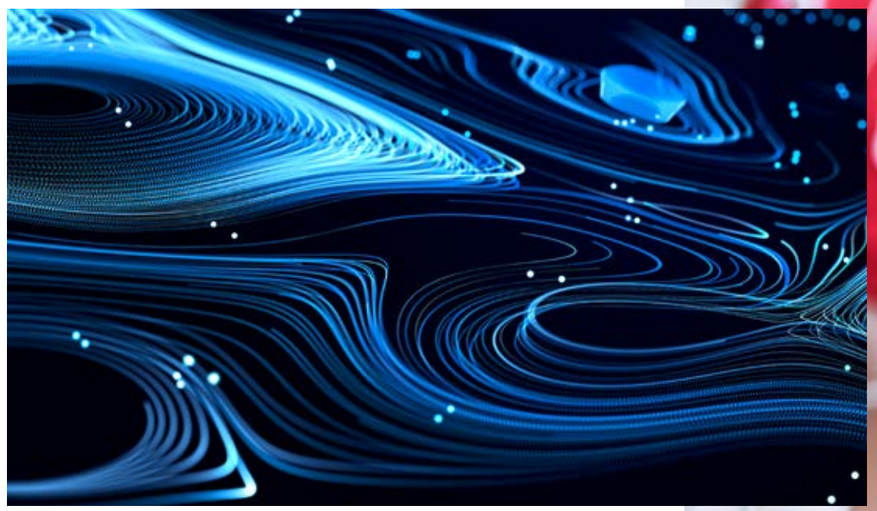
With Raman spectroscopy, he and his group can explore how molecules and substances interact with the environment. This has numerous applications and Materny and colleagues are investigating, among other things, how roofing materials degrade, how healthy cells transform into cancer cells, and the use of bacteria-killing viruses in food packaging. The group also uses femtosecond spectroscopy to investigate non-linear optical techniques and elementary processes. For example, Materny is collaborating with other university colleagues to improve the efficiency of their organic semiconductors. "We have small groups, we help each other, there is a lot of collaboration," Materny says. "This is a big advantage of being in a small university."

Complex systems

Our world is characterized by complex systems: whether it is how particles spin on a quantum level, the movement of vehicle traffic in a city, or even how creatures behave in ecosystems. Understanding complex systems requires a mixture of first-principles research and data-driven techniques. Researchers at Constructor University combine expertise in physics, mathematics, statistics and computer science to model how complex systems work, and apply that knowledge to real-world problems.

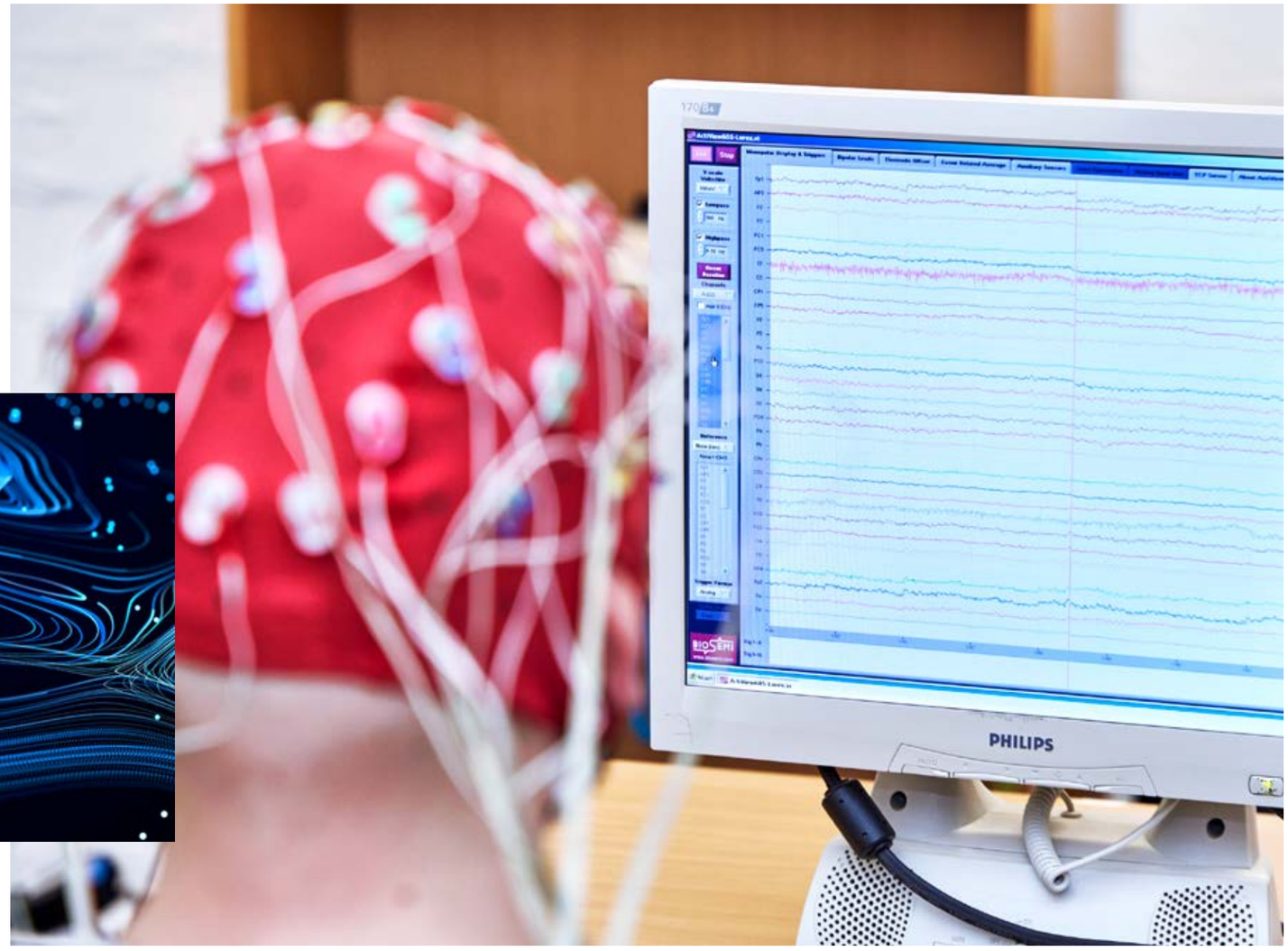
“Complex systems have many parts which interact with each other, and when they interact, they give rise to new phenomena, which have very different properties to their individual components,” explains Stefan Ketteman, professor of complex systems. He uses networks to model complex systems, which include quantum spin systems, semiconductors, power transmission, and distribution grids.

Some of his research is theoretical, but other projects have real-world applications. For example, one of his PhD students modeled and conducted a disturbance analysis of power transmission grids in African countries, including Ghana, Nigeria, and Rwanda. “He was also able to involve students from other African countries here at Constructor University, and I think it was valuable for them to be able to contribute something to their respective countries,” says Ketteman.



Meanwhile theoretical physicist Ulrich Kleinekathöfer investigates computation physics and biophysics. He looks to describe dynamic processes in molecular systems both theoretically and numerically. Complex systems range from small molecules to large bio-molecular complexes and thousands, even millions of atoms. His group has a special focus on membrane pores, and in collaboration with other researchers at Constructor University, they are exploring how antibiotics enter bacteria to destroy them. He also looks at light-harvesting mechanisms during photosynthesis in plants. “I’m a physicist, but here at Constructor University I work with a lot of chemists and biologists. For me, it’s important to have connections to all these different people,” he says.

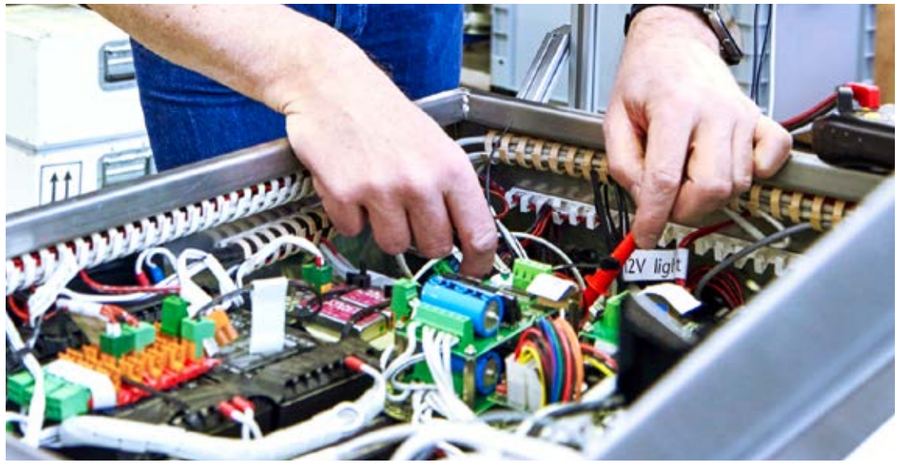
Complex systems, whether they are biological or artificial, have some characteristics in common, explains Hildegard Meyer-Ortmanns. These characteristics, which include feedback reactions and intrinsic uncer-



tainties, make these systems difficult to model. Her group uses tools from statistical physics, nonlinear dynamics and network science to analyze their behavior. She looks at aging systems, particularly in manufacturing processes, to determine the balance between the costs to fix systems and the precision required to ensure product quality.

Her group also investigates power grids. As renewable energy technology becomes more ubiquitous, researchers need to model how their contribution affects power supply. Wind and solar energy are inherently uncertain, as the wind does not always blow and the sun does not always shine. This uncertainty translates into variability of power supply. Her group has developed algorithms to estimate the state of a given power grid, even large ones. With these algorithms, they can estimate the frequency of blackout events. In recent research, her group's research has enabled them to propose statutory and economic interventions to stabilize power grids in the face of uncertainty and fluctuations.

Meanwhile, Hendro Wicaksono, professor of industrial engineering, applies data-driven decision-making tools to complex industrial systems. Technology has become pervasive, and there are also many vendors and products on the market. Often, these technologies, with different structures and vocabularies, are present in the same cyber-physical system. "We aim to provide decision makers in complex industrial systems with useful descriptive and diagnostic information, prediction and simulations," he says. His group is particularly practical and has collaborated with large and small organizations throughout Germany to support industry and government to streamline and improve their processes, and simplify their systems.



Digital transformation technology

With the digital revolution, data and information have become a new currency, not only in science, but also in industry, the economy, and society in general. Since its inception, Constructor University has dedicated itself to developing new digital methods, products, and services.

When Andreas Birk joined the International University Bremen, as it was then called, the university already had robotics and AI in its crosshairs. “The idea of intelligent systems was already there when the university was founded,” says Birk, who specializes in autonomous systems. Since then, the university has been building up a critical mass of researchers and students.

Birk investigates both the fundamental and applied sides of intelligent systems. “I think it’s important to have this applied side because it gives you feedback on your fundamental ideas. This coupling between theoretical concepts and reality, especially for AI and intelligent machinery, is essential,” he says. “There also can’t be any real intelligence without interaction with the real world. Intelligence is always a continuous process.” His group aims to understand machine perception, which allows robots to regognize objects and locate them in space. They also undertake automated real-world modeling, such as generating maps underwater in poor visibility.

Francesco Maurelli applies robotics, artificial intelligence and automation to autonomous robots that operate in, under and around water. His group concentrates on how robots navigate and operate underwater, including being able to self-diagnose faults and identify features underwater. However, such technology can be used in other places, such as space or even the city of Bremen. Maurelli’s group worked with the European Space Agency to design a system to explore tunnels on the moon. At the same time, he has been working with the city of Bremen to contribute to its autonomous driving policy, an engagement which could have a long-term impact on the local community.

Meanwhile, Giuseppe Abreu is looking at technologies that are currently disrupting the way that we live. His wireless communication and signal processing group works across a range of technologies. For example, they are developing advanced variations on 5G and the upcoming 6G systems, as well as technology to manage vehicle rental fleets. With a rental industry partner, Abreu is integrating various systems, such as booking, optimal vehicle location, and license requirements for drivers. His group is also researching integrated communications and sensing, in which users can determine device location based on conventional mobile services, rather than relying on GPS. “We want to use the same hardware that we use for communications to do radio functions and vice versa,” he says.

Being at a small and agile university like Constructor University allows him the freedom to follow his research interests and take on interesting projects. “There’s a difference between large, established and rigid universities and what we have here,” says Abreu, who has lived in Brazil, Japan, Finland, and Germany. “I enjoy the freedom of what we can research — in other, larger places, you feel like you are stepping on someone else’s toes.”

However, as technology becomes more omnipresent, so do the threats that it poses. Computer scientist Jürgen Schönwälder researches computer networks and distributed systems. “Our overall goal is to develop technologies that help provide resilient and secure services over the Internet, even in the face of failures and attacks,” he says. “Increasingly, our research focuses on device, network, and system security.”

Emerging economies

Supply chains now criss-cross the world and there is increased trade between developed and emerging economies. Historically, this interaction created the possibility of exploitation. “I want to understand how the exchange between foreign and domestic companies can be a win-win,” says Tilo Halaszovich, professor of global markets and firms.

Halaszovich’s research focuses on entrepreneurship within emerging markets and the competitiveness of firms within these markets. “My research projects revolve around two main themes: ‘Which strategies enable firms from developed and developing countries to cooperate and mutually benefit from the cooperation?’ and ‘What role can entrepreneurship and entrepreneurial ecosystems play within the context of developing countries?’” he says. Much of his research has focused on interactions in sub-Saharan Africa, with his work cited by the former chancellor Angela Merkel in Germany’s 2021 Compact with Africa summit. His group has analyzed the involvement of medium-sized German firms in sub-Saharan Africa, as well as the impact of Covid-19 on the German-African business networks.

Emerging economies, such as China, India, and Brazil, have established themselves as large global players, and their interaction with developed economies and amongst themselves is driving international trade and economic growth. Tobias ten Brink, professor of Chinese economy and society, uses theories from political science, global political economy, innovation and business studies to analyze China and other emerging economies such as Brazil and India, and to understand the international repercussions of their rise. In one of his projects, ten Brink provides evidence for the kinds of collaboration taking place between European firms and Chinese research institutions in order to better understand industry-university collaboration in China and the risks and benefits for international entities.

Ten Brink also heads the Center for the Study of China and Globalization at Constructor University. The center focuses on the political, cultural, social, economic, and managerial implications of China’s growing roles in Germany and Europe, as well as the challenges China faces in its ambition to create a sustainable and balanced innovation-led growth.

The international character of Constructor University organically promotes an interest in emerging countries across all schools. For example, Nikolai Kuhnert's group aims to understand the composition and chemistry of processed food, but his diverse student cohort means that the research they undertake often has an international flavor.

"We are interested in food and medicinal plants, and so this kind of international community then brings along their home-grown diet and medicinal plants," Kuhnert explains. Once these students graduate, they often return to their home countries, which has given rise to a sprawling network of international collaboration. "I've made many contacts in the developing world," he says. "They often lack certain scientific infrastructure, which we have, but then they have great biological resources." He regularly has visiting scholars in his laboratory, and they collaborate on projects and jointly publish their findings.

Human-centered digitization

The digital revolution is changing the way that we live. From human-machine interactions to digital innovation, researchers at Constructor University recognize the impact digital transformation is having on our societies. By exploring the risks and opportunities of such developments, they look at how human-centered digitization could create more peaceful human-machine interactions and a better future for all.

When the Covid-19 pandemic closed the doors of learning, it reinforced the importance of e-learning and increased demand for computer-supported learning formats. Christian Stamov Roßnagel, professor of organizational behavior, has collaborated with the likes of aerospace giant Airbus, automation company Festo, and the German Research Center for Artificial Intelligence to enhance contemporary learning design and boost the drivers of learning engagement.

His group — known as DAISy, which stands for Digital Assistants for Individualized Learning Systems — has developed digital assistants to enhance learning, and is working to develop guidelines for a comprehensive instructional design which supports course authors in virtually any domain. “Through our individualized learning research, we see increases in the effectiveness and efficiency of learning, empowering learners to assume more responsibility for their learning process,” he says.

Christoph Latteman, professor of business administration and information management, investigates how advanced information technologies and innovation management approaches are empowering companies to develop new services. His I3 group, which stands for international business, innovation, and information management, aims to design state-of-the-art ICT applications for innovation management, service provision, and education, particularly in the creative sector. In the BMBF-funded project StudyBuddy, a team of four businesses and research organizations, including Latteman’s group, developed an AI-based learning companion for professional development. His group also used AI and machine-learning algorithms to determine the prices of non-standardized products in complex markets.

Meanwhile, Yilmaz Uygun, professor of logistics engineering, technologies, and processes, is turning to digital methods and emerging technologies to increase the efficiency in logistics and production systems. Uygun and his group worked with a large automotive supplier on a simulation-based supplier network so that they could detect anomalies in their vast logistics network. In addition to this, they investigated material substitution in the automotive accessories industry to boost the industry’s sustainability. Ultimately, “we have developed a simulation-based decision support tool for outsourcing, which shows all the effects of such a strategic decision”, Uygun says.

Digital connectivity extends beyond the individual into country-wide infrastructure. Energy economist Gert Brunekreeft headed a working group at the National Academy of Science and Engineering called ‘Resilience of Digitised Energy Systems’. In the working group, they are investigating the opportunities and challenges that digitization is causing in the electricity system.

Brunekreeft’s group has also scientifically evaluated different blockchain-based solutions to manage energy, including smart meters. The project was conducted in collaboration with more than 20 partners, including companies like SAP and Deutsche Telekom and digital start-ups and blockchain experts. “Our core competence is on “competitiveness as part of the sustainability goal, namely delivering energy in a cost-effective and economically efficient way,” he says.

Constructors of the future

Newly appointed young faculty

Prof. Dr. Felix Jonas

“I wanted to be in as international a place as possible,” says molecular geneticist Felix Jonas. Constructor University international character was a major drawcard. “If everyone comes from the same place, you can get stuck in a certain worldview. I wanted to get exposed to people who don’t think the way I do,” says Jonas, an assistant professor of biochemistry who already has students from Georgia, China, and Nepal, as well as Germany.

His research focuses on transcription factors. All cells in the body contain the same genetic material, but “they read the same genetic material differently”, Jonas explains. “Transcription factors are like bookmarks that tell the cell whether it should read the genetic material and, if so, open to the right page.” If the transcription factor is not working properly, the cell behaves incorrectly, which can lead to problems, such as disease. “I want to understand transcription factors on a molecular level,” Jonas says.

Constructor University has a range of molecular expertise, which is another factor that attracted him to the institution. These expertises range from investigating the structure of molecules themselves through to understanding how whole organisms behave. “My research sits in the middle, and so there is a lot of opportunity for collaboration,” he says.

Similarly, there are several opportunities for cooperation within the Constructor Group as a whole. “I’m excited because we now have very strong computational resources, and there are so many artificial intelligence researchers under the Constructor umbrella,” he says.

“One of the reasons I came here is because the faculty is very motivated to do new things. They have energy and drive, and this is a very encouraging environment. It gives me the impetus to try something new and I think that’s important.”

Prof. Dr. Katrin Rosenthal

Constructor University's small campus and intimate character offers many opportunities for collaboration, says Katrin Rosenthal, an assistant professor of biotechnology.

"There are many different facilities and laboratories in a small location, and there are many research topics connected to my research, so that I can collaborate with other researchers."

Rosenthal researches biocatalysis, and uses enzymes to produce compounds for pharmaceuticals. Biocatalysis has been heralded as a 'greener' way to produce chemicals. "Enzymes are everywhere in nature, and we can use things which are already available in nature to produce valuable compounds," she explains. Enzyme cascades allow researchers to transform a simple material into high-value compounds.

However, identifying new compounds can be very labor-intensive and expensive, so Rosenthal incorporates bioinformatics to screen for promising candidates. Constructor University already has computational engineering expertise, and the university's incorporation into the Constructor Group increases the possible avenues to augment her research with digitization. "We are producing data and we would like to use our data not just for the next experiment, but also for modeling, for prediction, and for machine learning," Rosenthal says.

"This is a direction I'd really like to focus on — if we combine wet lab experiments with modeling and prediction, we can reduce the number of experiments in the lab," she says. Rosenthal is eager to promote environmental sustainability, and believes that biocatalysis has an important role to play in reducing humanity's impact on the environment. "I always include calculations about how sustainable our reactions are. In our biocatalysis research, we try to replace chemistry, but I also include whether it is economically viable and, importantly, is our reaction better for the environment?"

In a recent paper, published in Trends in Biotechnology, Rosenthal and colleagues recommend how to estimate the environmental impacts of early-stage bioprocesses. "You have to calculate if your reaction really is working, if it reduces carbon emissions, if it actually is less harmful," she says. "We really have to prove that we are greener" than traditional processes.

Prof. Dr. Andreas Seebeck

Andreas Seebeck is passionate about the ways in which data affects people, society and business. It's not just talking about coding and numbers, he says. It's really talking about issues and topics, and showing students how you can really apply them to real-world questions.

Seebeck, an assistant professor of global economics and management, harnesses the power of big data to investigate the future performance of companies. When companies file their annual reports, they include text to describe their performance and plans. This text is a treasure trove of information, says Seebeck. "And it's not just one report — there are thousands of reports uploaded" to the likes of the US Securities Exchange Commission.

"I cannot read them manually, and this is how I leverage the power of big data," he says. By identifying topics covered, phrasing, and words used, it is possible to pick up patterns. "For example, whenever a firm reported about a specific issue, it becomes likely that they file for bankruptcy in the next five to 10 years," Seebeck says. "I find patterns in the written part of the qualitative parts of financial reporting, which tells me about the future performance of the firm."

"It's totally unique that you have people from over 100 nations living together and studying together. These students challenge thoughts that you've never challenged on your own" talking about situations in which most people do not own cars, do not own their own homes, and where trade is not based solely on money in the bank."

"It is really enriching when you have so many people from different fields and different backgrounds coming together."

Push the frontiers
of knowledge
through research

Our research groups

School of Science

Geochemistry — Geosciences

Prof. Dr. Michael Bau

Research in the CritMET (Critical Metals for Enabling Technologies) group focuses on the distribution of elements, in particular of critical metals, in the environment, how this distribution evolved throughout the Earth's 4.5 billion-year history, and how critical metals accumulate to form ore deposits. Investigated are the processes that govern the behavior of critical metals in rivers, estuaries and oceans, in groundwater and in drinking water, and how they transfer from rocks, soils, sediments and water into organisms. In close cooperation with the research group of Prof. Andrea Koschinsky, the interdisciplinary projects not only combine basic and applied research, but also cover the interface between the geosciences (such as geology and oceanography), chemistry, and the life sciences.

Specific themes and goals

Research projects revolve around a group of high-technology metals such as the rare earth elements, niobium, germanium, gallium and scandium, that are integral to modern enabling technologies such as telecommunications, renewable energy, fuel cells, electromobility, and medical diagnostics.. Due to significant supply risks in Germany, the European Union, and abroad they are considered "Critical Raw Materials" worldwide.

However, supply of these elements will not keep up with future demand, given the characteristics of the major deposits and the geopolitical situation in the countries where they are located. Moreover, the rising use of these metals means that they are increasingly released into the environment, exposing plants, animals and humans to these once-exotic metals. In spite of their manifold new applications and their recognition as (micro)contaminants in soil, dust, water (including drinking water), and in the food chain, only little is known about their distribution and behavior in the environment and about their (eco)toxicity.

Group composition & projects / funding

- In 2019-2022, the CritMET group included four Post-Docs and six doctoral candidates, all of whom were externally funded by third-party research grants. The group also has a part-time laboratory technician.
- The group hosted a visiting professor, as well as a visiting PhD student.
- The group received about €400.000 annually from a variety of sources:
  - The European Union for two projects on environmental geochemistry and one project on geothermal resources);
  - The Research Council of Norway for one project on environmental geochemistry;
  - Deutsche Forschungsgemeinschaft for two projects on environmental and resource geochemistry and on Early Earth studies; and
  - Bundesanstalt für Geowissenschaften und Rohstoffe for four projects on critical metals and their resources and recycling.

Selected publications

D Kraemer, M Bau, 2022. Siderophores and the formation of cerium anomalies in anoxic environments. Geochemical Perspectives Letters 22, 50–55.

M Bau, R Frei, D Garbe-Schönberg, S Viehmann, 2022. High-resolution Ge-Si-Fe, Cr isotope and Th-U data for the Neoarchean Temagami BIF, Canada, suggest primary origin of BIF bands and oxidative terrestrial weathering 2.7 Ga ago. Earth and Planetary Science Letters 589, 117579

A Mundl-Petermeier, S Viehmann, J Tusch, M Bau, F Kurzweil, C Münker, 2022. Earth's geodynamic evolution constrained by 182W in Archean seawater. Nature Communications 13 (1), 1–8

AL Zocher, F Klimpel, D Kraemer, M Bau, 2022. Naturally grown duckweeds as quasihyperaccumulators of rare earth elements and yttrium in aquatic systems and the biounavailability of gadolinium-based MRI contrast agents. Science of The Total Environment, 155909

DM Ernst, K Schier, D Garbe-Schönberg, M Bau, 2022. Fractionation of germanium and silicon during scavenging from seawater by marine Fe (oxy) hydroxides: Evidence from hydrogenetic ferromanganese crusts and nodules. Chemical Geology 595, 120791

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Biomedicine of Proteolysis — Quantitative Cell Biology

Prof. Klaudia Brix

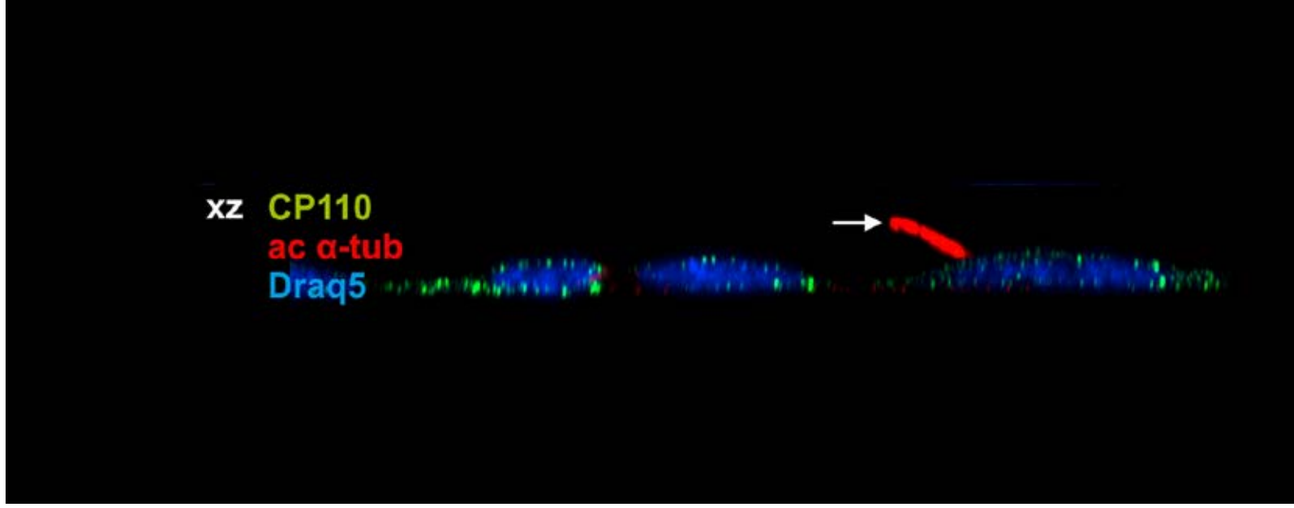
The thyroid gland generates and releases hormones, which are the master regulators of most cells and tissues in mammals. Thyroid hormones guide vertebrates' development and growth, and are crucial for metabolic homeostasis, regular organ function and tissue repair. Thyroid disorders are among the most common diseases in the world with higher prevalence in women than in men, and they manifest differently at different ages.

Specific themes and goals

There are numerous regulatory mechanisms that ensure that thyroid hormones are produced in sufficient amounts to direct the cells in the body. Deciphering thyroid-gland regulation is vital to understand healthy thyroid states and how to maintain them. Thyroid gland function depends upon a highly interwoven network of special enzymes, transporter molecules, and receptor signaling. To decipher the various contributions that ensure healthy thyroid function, we have used thyroid tissue phenotyping by quantitative cell biology.

Highlights and impact

- **Thyroid Gland Auto-Regulation** — As a continuation of our previous studies on thyroid gland self-regulation by non-classical mechanisms, we conducted a series of studies. It became obvious that two different G protein-coupled receptors — the trace amine-associated receptor 1 (Taar1) and the thyroid stimulating hormone (TSH) receptor — co-regulate thyroid function. In the absence of a specific thyroid hormone transporter, Mct8, thyroid hormone thyroxine cannot be released into circulation. Mct8 also affects the localization and signaling of the TSH receptor. We achieved these results on non-classical and classical thyroid regulation using mouse models. It is important to note that patients with a rare disease, known as Allan Herndon Dudley Syndrome, partly exhibit similar phenotypes.
- **Aging** — We investigated the link between thyroid dysfunctions and the effects of thyroid hormones on target organs upon aging. In particular, we characterized proteases (a special type of enzyme) in the central nervous system and the thyroid gland itself, and found a range of changes to them upon aging. Moreover, we studied anti-oxidant response regulators and thyroid gland functionality in aging.
- **Cancer and Protease Trafficking** — In specific cell lines, we observed alternative transport pathways for proteases such as the cysteine cathepsins B and V in human thyroid epithelial cell lines. Carcinoma cells featured additional mis-sorting and altered protease trafficking
- **Cross-talk of GPCRs and Proteases at Primary Cilia** — One of our most astonishing findings of recent years was the observation that proteolytically active cysteine cathepsins are essential to keep primary cilia intact and extended from the apical surface of polarized epithelial cells. Because cilia serve as signaling platforms, such as via Taar1 of thyroid epithelial cells, we developed a cellular model to allow detailed future investigations on the underlying molecular mechanisms.



Immunostaining of thyroid tissue from control and Klk7-/- mice and thyroid phenotyping parameters derived by Cell Profiler-based image analysis in a quantitative cell biology approach

Group composition & projects / funding

In 2019–2022, the research group headed by Klaudia Brix consisted of two PhD students, a coordination team assistant, and a lab technician supervising the research projects of 18 BSc students. DAAD and DFG funded some of the group's research activities. In addition, we received funding from the European Thyroid Association, the DFG, and the HAORI Foundation for COVID-19 related projects, which are ongoing. We cooperated with international groups such as at ETH Zürich in Switzerland and Stanford University in the United States, as well as local groups at University of Bremen and Constructor University. Klaudia Brix was the main responsible principal investigator for the recent acquisition of a high-end laser scanning microscopy system for Constructor University.

Selected publications

Szumska, J., Batool, Z., Al-Hashimi, A., Venugopalan, V., Skripnik, V., Schaschke, N., Bogyo, M., and Brix, K. (2019) Treatment of rat thyrocytes in vitro with cathepsin B and L inhibitors results in disruption of primary cilia leading to redistribution of the trace amine associated receptor 1 to the endoplasmic reticulum. Biochimie 166, 270–285.

Al-Hashimi, A., Venugopalan, V., Sereesongsaeng, N., Tedelind, S., Pinzaru, A.M., Hein, Z., Springer, S., Weber, E., Führer, D., Scott, C.J., Burden, R.E., and Brix, K. (2020) Significance of nuclear cathepsin V in normal thyroid epithelial and carcinoma cells. BBA — Molecular Cell Research 1867, 118846.

Venugopalan, V., Al-Hashimi, A., Rehders, M., Golchert, J., Reinecke, V., Homuth, G., Völker, U., Manirajah, M., Touzani, A., Weber, J., Bogyo, M.S., Verrey, F., Wirth, E.K., Schweizer, U., Heuer, H., Kirstein, J., and Brix, K. (2021) The Thyroid Hormone Transporter Mct8 Restricts Cathepsin-Mediated Thyroglobulin Processing in Male Mice through Thyroid Auto-Regulatory Mechanisms that Encompass Autophagy. Int. J. Mol. Sci. 22, 462.

Qatato, M., Venugopalan, V., Al-Hashimi, A., Rehders, M. Valentine, A.D., Hein, Z., Dallto, U., Springer, S., and Brix, K. (2021) Trace Amine-Associated Receptor 1 Trafficking to Cilia of Thyroid Epithelial Cells. Cells 10, 1518.

Yu, D.M.T., Dauth, S., Margineanu, M.B., Snetkova, V., Rehders, M., Jordans, S., and Brix, K. (2022) Characterization of cysteine cathepsin expression in the central nervous system of aged wild-type and cathepsin-deficient mice. Appl. Sci. 12, 2608.

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Geophysical Fluid Dynamics

Prof. Sergey Danilov and Dr. Stephan Juricke

Geophysical fluid dynamics deals with the motion of different media such as air or water on a rotating sphere such as our planet Earth. More specifically, in our group we describe and analyze the movement of the global oceans and atmosphere using mathematical equations of physical laws. We then aim to either analyze these equations by classical mathematical techniques or solve them numerically using, in particular, high performance computing on dozens to thousands of parallel processors.

Specific themes and goals

The main research goal of our group is to improve our understanding and prediction of the ocean and atmospheric circulation as part of the climate system. We use complex climate models to simulate the oceans as well as advanced diagnostic methods to analyze the data from simulations and observations.

Ocean and climate models

Our research tools range from idealized to comprehensive state-of-the art ocean and climate models, partly developed at the Alfred Wegener Institute in Bremerhaven. We run and continuously improve these models using numerical methods and classical mathematical and physical analysis.

Biases and errors

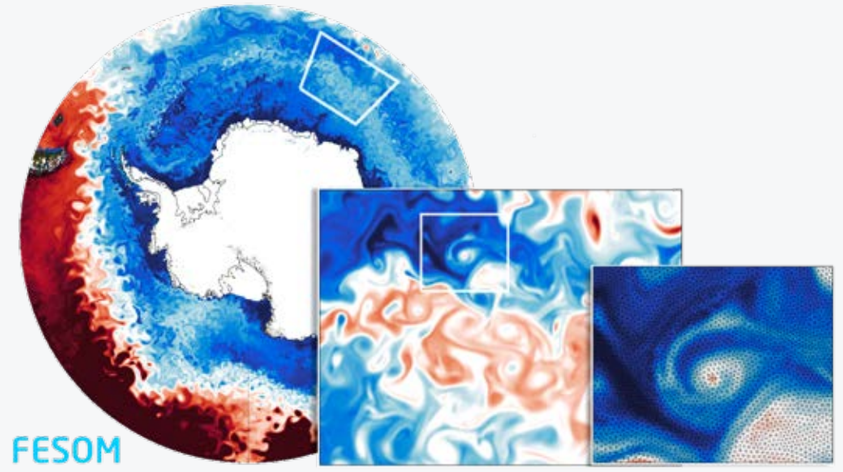
We diagnose the models' biases and strive to reduce these systematic errors as well as understand how they come about and how they are related to physical properties of complex dynamical systems.

Energy transfers

A specific focus of our group is understanding the kinetic energy contained in the motion of the world's oceans. In this context, we also investigate the interaction and energy exchanges between the atmosphere and the oceans at the air-sea interface and at various spatial and temporal scales.

Highlights and impact

- We developed and implemented a numerical scheme that improves the representation of organized ocean turbulence — so-called mesoscale ocean eddies — in ocean simulations. Eddies carry heat, salt, and other tracers and are therefore an important ingredient in the dynamics. Their seamless simulation requires very fine computational grids, which is prohibitively expensive in climate studies. The new scheme helps to re-energise eddies in locations where the grid is insufficiently fine and leads to large improvements of ocean models especially in very turbulent regions such as western boundary currents, such as the Gulf Stream, and the Southern Ocean.
- We developed new diagnostic tools to separate different types of motion in the ocean, namely balanced and unbalanced motions, which allows a better understanding of the general dynamics and interpretation of observations. These tools ultimately help to improve the representation of these motions in ocean and climate models.
- We created new diagnostics to analyze the scaling of turbulent motions, which is how motions of different spatial extents contribute to the overall energy content in the flow.
- We developed a new coupled Earth-climate model by coupling the OpenIFS model of the atmosphere and the FESOM ocean model. This model will be used for climate projections and to contribute to future Intergovernmental Panel on Climate Change reports. Its distinctive feature is good numerical efficiency, which allows researchers to resolve the circulation of the atmosphere and ocean with a high level of detail.



Southern Ocean temperature at 100m as simulated by the ocean model FESOM on a grid with 4.5 km horizontal resolution. From www.fesom.de

Group composition & projects / funding

The group consists of the three principal investigators, one Postdoc, and five doctoral candidates. Funding sources include the DFG (Deutsche Forschungsgemeinschaft, German Research Foundation) via the collaborative SFB (Sonderforschungsbereich, Collaborative Research Centre) TRR181 project, and the Helmholtz School for Marine Data Science (MarDATA) in collaboration with the Alfred Wegener Institute in Bremerhaven and Prof. Zaspel (Constructor University, Computer Science).

Selected publications

Streffing, J., D. Sidorenko, T. Semmler, L. Zampieri, P. Scholz, M. AndrésMartínez, N. Koldunov, T. Rackow, J. Kjellsson, H. Goessling, M. Athanase, Q. Wang, J. Hegewald, D. V. Sein, L. Mu, U. Fladrich, D. Barbi, P. Gierz, S. Danilov, S. Juricke, G. Lohmann, and T. Jung, 2022: AWI-CM3 coupled climate model: Description and evaluation experiments for a prototype post-CMIP6 model. Geosci. Model Dev., 15, 6399–6427.

Strommen, K., S. Juricke, and F. Cooper, 2022: Improved teleconnection between Arctic sea ice and the North Atlantic Oscillation through stochastic process representation. Weather Clim. Dynam., 3, 951–975.

Franzke, C. L. E., F. Gugole, and S. Juricke, 2022: Systematic multi-scale decomposition of ocean variability using machine learning. Chaos, 32, 073122.

Juricke, S., S. Danilov, N. Koldunov, M. Oliver, D. V. Sein, D. Sidorenko, and Q. Wang, 2020: A kinematic kinetic energy backscatter parametrization: From implementation to global ocean simulations. Journal of Advances in Modeling Earth Systems, 12, e2020MS002175.

Juricke, S., S. Danilov, N. V. Koldunov, M. Oliver, and D. Sidorenko, 2020: Ocean kinetic energy backscatter parametrization on unstructured grids: Impact on global eddy-permitting simulations. Journal of Advances in Modeling Earth Systems, 12, e2019MS001855. https://doi.org/10.1029/2019MS001855

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https://www.mardata.de/ (MarDATA graduate school website)

Biophysics and Didactics of Physics

Prof. Jürgen Fritz

Our group investigates the structure and interaction of single biomolecules by atomic force microscopy (AFM), and we work on detecting the presence and activity of biomolecules with nanomechanical biosensors. Both approaches aim for a better understanding of biomolecular systems on a fundamental level, in order to develop new bioanalytical tools and explore the application of biomolecules in nanotechnology.

Specific themes and goals

In previous projects, we investigated the lipid bilayer-peptide interactions, measured forces between single chromatographic beads and biomass, and developed sensors for directly measuring mechanical properties of cellular membranes. However, our research focus recently switched from experimental biophysics to didactics in physics, especially investigating the impact of weekly homework on the performance of first-year physics students

The didactics research addresses the diversity of first-year university students' prior knowledge in physics, which regularly leaves subgroups of students either bored or overburdened. We aimed to support student performance by adapting the weekly physics homework problems to students' knowledge levels and self-regulated learning profiles.

Highlights and impact

The most interesting outcome of our research was the clear importance of homework performance on final exam grades in physics classes. Homework grades across the semester can be early indicators of student failure. Such information enables instructors to implement countermeasures. Student groups which got tailor-made homework adapted to their skills performed better than groups which got standard homework.

Physics classes can also serve as a model case for other science or math-based university courses with weekly homework. We plan to further investigate whether the improved attractiveness of homework including right level, interesting tasks, and suitable support can also improve overall performance of students in physics classes.

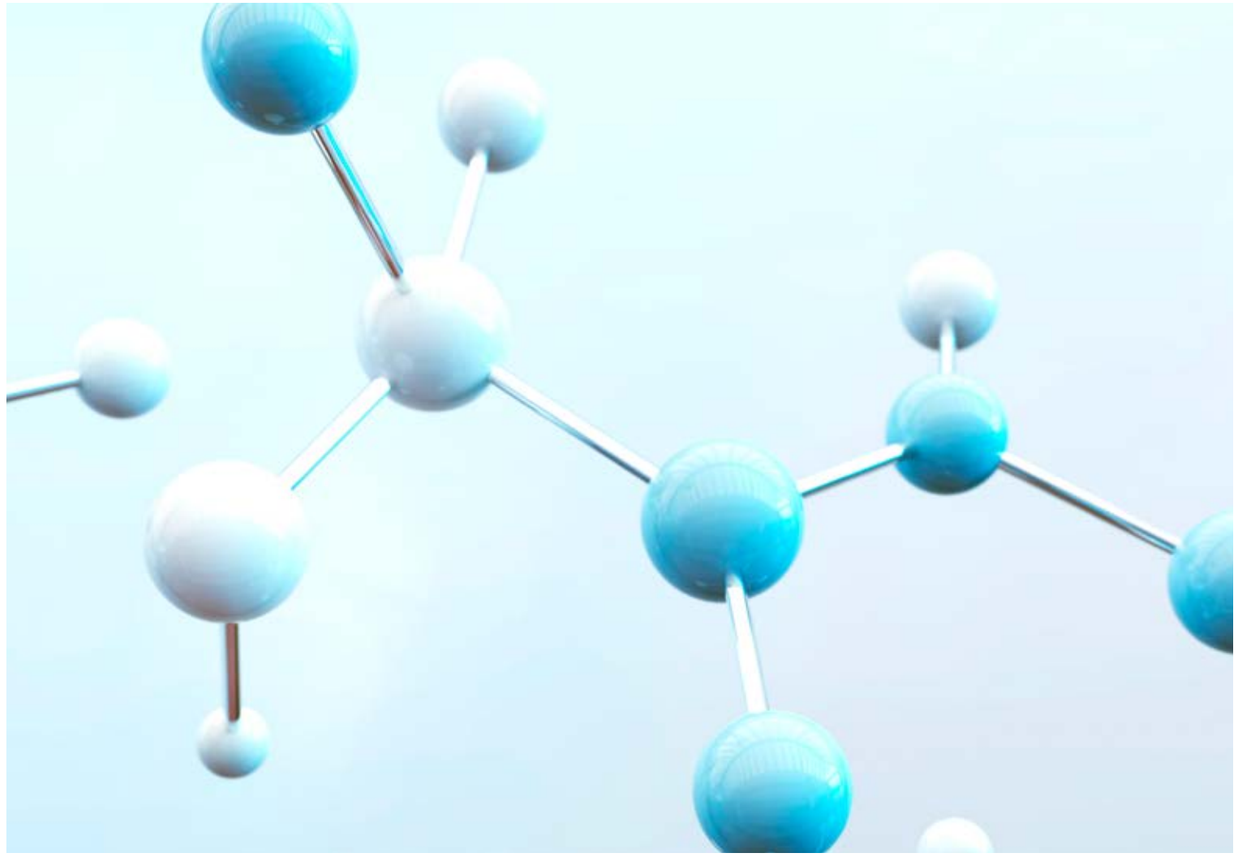
Group composition & projects / funding

Our group currently consists of one professor and a postdoctoral researcher.

Selected publications

J. Direnga, C. Stamov-Roßnagel, V. Wagner, J. Fritz: Elektronisches Adaptives Hausaufgabenkonzept für Erstjahres Physikvorlesungen, DPG Spring Meeting, Bonn, 29.03.-03.04.2020 (DD16.56).

J. Direnga, M. Kupresak, C. Stamov-Roßnagel, V. Wagner, J. Fritz: Einführung eines einfachen adaptiven Hausaufgabenkonzeptes für Erstjahres-Physikvorlesungen, DPG Spring Online Meeting, 22.-24.03.2021 (DD14.23).



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Chemistry

Prof. Dr. Detlef Gabel

The group works on two different projects.
Project 1: Development of a new dye preparation for eye surgery
Project 2: Chemistry and supramolecular properties of boron clusters

Specific themes and goals

Project 1: We have developed a new dye preparation for eye surgery, which consists of a new dye, recently developed by us, for staining and a new excipient for proper application. The preparation has been tested extensively for absence of unwanted side effects and has very recently been introduced on the market.

Project 2: Boron clusters have unexpected properties of coordination with water, and with hosts in supramolecular chemistry. We want to understand this behavior and have therefore systematically investigated the effect of substituents on such clusters with respect to their binding to supramolecular hosts. In this endeavor, we have found greatly improved methods to attach organic moieties to the dodecaborate cluster.

Highlights and impact

- A dye preparation for eye surgery with better clinical performance has been developed and introduced in the market
- New methods to functionalize the dodecaborate cluster have been developed
- Binding of functionalized dodecaborates to cyclodextrins has been investigated

Group composition & projects / funding

Project 1 was carried out together with a local ophthalmologist and a company

Project 2 was carried out with post-doctoral and doctoral fellows and third-year bachelor students

Selected publications

Marei, T., M. K. Al-Joumhawy, M. A. Alnajjar, W. M. Nau, K. I. Assaf and D. Gabel (2022). “Binding affinity of aniline-substituted dodecaborates to cyclodextrins.” Chem. Commun. 58: 2363-2366.

Mohr, A., P. Cendoya, J. Wilinska, M. Apostu, E. Apostu, J. Janku, T. Wilfling, G. Ramos, M. Al-Joumhawy and D. Gabel (2022). “New dual dye for vitreoretinal surgery with increased transparency.” BMJ Open Ophthalmology 7: e001116.

Shmal’ko, A. V., P. Cendoya, S. A. Anufriev, K. Y. Suponitsky, D. Gabel and I. B. Sivaev (2022). “New approaches to the functionalization of the 1-carba-closo-decaborate anion.” Chem. Commun. 58: 3775-3778.

Al-Joumhawy, M., P. Cendoya, A. Shmalko, T. Marei and D. Gabel (2021). “Improved synthesis of halo- and oxonium derivatives of dodecahydrido-closo-dodecaborate(2-).” J. Organomet. Chem. 949: 121967.

Al-Joumhawy, M. K., T. Marei, A. Shmalko, P. Cendoya, J. La Borde and D. Gabel (2021). “B–N bond formation through palladium-catalyzed, microwave-assisted cross-coupling of nitrogen compounds with iodo-dodecaborate.” Chem. Commun. 57: 10007-10010.

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Complex Dynamical Systems

Prof. Igors Gorbovickis

Dynamical systems are mathematical models of real-life evolutionary processes. They appear in various applications, from weather forecasts to the study of planetary motions to the evolution of species population numbers. The aim of the theory of dynamical systems is to understand the mechanisms behind certain fundamental phenomena that can be shared by various seemingly quite different dynamical systems. Such phenomena may include questions of stability (Is our solar system stable?) or the onset of chaos in completely deterministic systems (Why can't we always give an accurate weather forecast?). One approach is to consider simplified versions of the real-life systems in the hope of "extracting" certain phenomena and then examining them without unnecessary obstructions. Nevertheless, it turns out that even very simple-looking dynamical systems can behave in mysterious ways that are yet to be understood.

Specific themes and goals

We can think of a dynamical system as a function f(x), with which, given an initial state x0, one can compute x1=f(x0), x2=f(x1), x3=f(x2), and so on. Each of the inputs (x0, x1, x2) can be a number or a vector of numbers.

One of the recurring themes in Igors Gorbovickis' research is the application of methods from complex analysis to the study of dynamical systems. This means that the inputs can be complex numbers, containing both real and imaginary parts. Even though this makes the dynamical system more complicated, it allows for the introduction of various powerful methods of complex analysis.

Prof. Gorbovickis is also studying the mechanisms behind the Feigenbaum-Coullet-Tresser type (FCT-type) universalities. In the late 1970s mathematical physicist Mitchell Feigenbaum (and independently Pierre Coullet and Charles Tresser) empirically observed that the transition from regular to chaotic dynamics through cascades of period doubling bifurcations happens according to a certain "universal scaling law". More specifically, they discovered that the small scale structure of the bifurcation loci in a certain large class of one-parameter families of real one-dimensional dynamical systems with a critical point is independent of the specific family.

A large number of experiments highlighted the importance of their discovery, and showed that the period-doubling scenario occurs in many natural systems, such as the onset of turbulence in fluid flow, oscillations in chemical reactions, and electrical networks, to name a few.

Although a lot of progress has been made by mathematicians in understanding the reasons behind the FCT-type universality phenomena, there are cases in which we still lack a complete picture. Igors Gorbovickis' research aims to explain the FCT-type universalities in these cases by adopting appropriate complex analytic methods.

In other ongoing research projects, Igors Gorbovickis studies the distribution of critical points of the multiplier maps in the space of rational maps on the complex plane; renormalization and related rigidity and universality phenomena for Lorenz mappings; and the study of the Hausdorff dimension of some Julia sets.

Highlights and impact

- Five refereed articles published or accepted for publication in 2019–2022. Two articles are under review for journal publications.
- Co-organized the Hanseatic Dynamical Systems Day IV at Constructor University in December 2019.
- In joint work with Michael Yampolsky at the University of Toronto, Prof. Gorbovickis obtained the first C1+α-rigidity result for multicritical circle maps with an arbitrary number of critical points.
- In joint work with Artem Dudko (Institute of Mathematics of the Polish Academy of Sciences) and Warwick Tucker (Monash University, Australia), Prof. Gorbovickis significantly improved the known lower bounds on the Hausdorff dimension of some real-symmetric Julia sets.

Group composition & projects / funding

Igors Gorbovickis' research is supported by the DFG, which provides funding for one postdoctoral position. Prof. Gorbovickis collaborates with mathematicians from the United States, Canada, Sweden, Australia and Poland.

Selected publications

(with A. Dudko and W. Tucker) Lower bounds on the Hausdorff dimension of some Julia sets, (submitted) 2022.

(with M. Yampolsky) Rigidity of analytic and smooth bi-cubic multicritical circle maps with bounded type rotation numbers, (submitted) 2021.

(with T. Firsova) Accumulation set of critical points of the multipliers in the quadratic family, (to appear in Ergodic Theory Dynam. Systems) 2020.

(with D. Gaidashev) Complex a priori bounds for Lorenz maps, (to appear in Nonlinearity) 2020.

(with T. Firsova) Equidistribution of critical points of the multipliers in the quadratic family, (to appear in Adv. Math.) 2019.

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Computational Systems Biology

Prof. Marc-Thorsten Hütt

Computational Systems Biology unites approaches from mathematics, physics and computer science, in the search for basic principles and universal laws in biology. We contextualize data from high-throughput technologies using mathematical models and computational techniques, to understand the functioning of signal transduction pathways, gene regulatory networks and genome-scale metabolic systems.

Specific themes and goals

The Computational Systems Biology group at Constructor University works at the interface of statistical physics, systems biology and systems medicine. Our investigations simultaneously cover 'omics' data interpretation in biology and medicine and theoretical studies of dynamics on graphs.

We have pioneered the analysis of gene expression data via network coherences (small quantifiers of the match between a network and an expression profile), which has allowed us to better understand the interplay of chromosomal organization and transcriptional regulatory networks in bacterial gene regulation.

Our work on network-based analyses of transcriptome data from clinical cohorts has led to new insight into various diseases, such as primary hyperaldosteronism, chronic inflammatory bowel diseases, and hepatocellular carcinoma.

We have discovered self-organized excitation waves around hubs in complex networks and explored the implications of this finding for neuroscience.

Furthermore, we used the notion of multilayer networks to identify a simple fundamental principle, how a biological system can balance the conflicting requirements of sensitivity and robustness.

A large body of our work across the years focuses on interdisciplinary applications of concepts from the theory of complex systems and from network science (including, for example, long-distance train connections, industrial production, co-authorship networks, psychotherapy dynamics, and networks of scientific hypotheses).

Highlights and impact

Starting from the foundation of dynamical processes on graphs, the Computational Systems Biology group has become a prominent research unit at the interface of statistical physics, data science and biology. The group's achievements between 2019 and 2022 include:

- In the EU-funded project i-CONN, we have studied how network architecture shapes dynamics across a wide range of network architectures and dynamical processes. We found two distinct types of structure-function relationships (Voutsa et al., 2021) and discussed their relevance in various disciplines.
- In a joint work with Paolo Moretti at the University Erlangen-Nürnberg, we achieved a theoretical understanding of self-organized waves on graphs (Moretti and Hütt, 2020).
- In collaboration with researchers from France, we have found that genetic point mutations (single nucleotide polymorphisms) in cancers follow different statistical distributions with respect to chromosomal domains compared to non-cancer diseases (Jablonski et al., 2022).
- In an ongoing industry-funded project on cocoa metabolomics COMETA (which is a joint project with the research groups of Matthias Ullrich and Nikolai Kuhnert at Constructor University), we have studied how the chemical composition of cocoa beans allows prediction of origin countries and fermentation status (Kumar et al., 2021).
- The BMBF-funded project sysINFLAME brought together clinical researchers with systems biologists, as well as researchers from medical informatics and medical statistics. The Computational Systems Biology group has designed a generator of transcriptomics data for disease cohorts based on concepts from statistical physics.
- In collaboration with colleagues from Universitätsklinikum Eppendorf (UKE), we have discovered via simulated evolution a potential origin of the modularity of neuronal structures (Damicelli et al., 2019).

Group composition & projects / funding

Between 2019 and 2022, the Computational Systems Biology group consisted of seven to 10 PhD students and two postdocs. We obtained funding from the German Ministry of Education and Research (BMBF), the German Research Foundation (DFG), the Volkswagen Foundation, the European Union within the framework of an Innovative Training Network (ITN), and several partners from industry.

Selected publications

Jablonski, K.P., Carron, L., Mozziconacci, J., Forné, T., Hütt, M.-Th. and Lesne, A. (2022) Contribution of 3D genome topological domains to genetic risk of cancers: a genome-wide computational study. Human Genomics 16(1), 1–15.

Kumar, S., D'Souza, R. N., Corno, M., Ullrich, M. S., Kuhnert, N., and Hütt, M.-Th. (2022). Cocoa bean fingerprinting via correlation networks. npj Science of Food 6(1), 1–9.

Voutsa, V., Battaglia, D., Bracken, L.J., Brovelli, A., Costescu, J., Diaz Munoz, M. Fath, B.D., Funk, A., Guirro, M., Hein, T., Kerschner, C., Kimmich, C., Lima. V., Messé, A., Parsons, A.J., Perez, J., Pöppl, R., Prell, C., Recinos, S., Shi, Y., Tiwari, S., Turnbull, L., Wainwright, J., Waxenecker, H. and Hütt, M.-Th. (2021) Two classes of functional connectivity in dynamical processes in networks. Roy. Soc. Interface 18(183), 20210486.

Moretti, P. and Hütt, M.-Th. (2020) Link-usage asymmetry and collective patterns emerging from rich-club organization of complex networks. PNAS 117,18332–18340.

Damicelli, F., Hilgetag, C.C., Hütt, M.-Th. and Messé, A. (2019) Topological reinforcement as a principle of modularity emergence in brain networks. Network Neuroscience, 3, 589–605.

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Microbiology

Prof. Dr. Boran Kartal

Life on earth is fueled by elemental cycles, which are controlled by the activity of tiny, unicellular life forms called microorganisms. These microbes convert elements from one redox state to another while gaining energy. Their activity has an immense impact on our planet. For example, photosynthetic microorganisms produce oxygen for the planet and nitrogen-cycling microorganisms control the bioavailability of nitrogen, which is integral to the production of crucial biological compounds such as proteins. In the field of environmental microbiology, we focus on characterizing environmentally-relevant microorganisms in molecular detail, and determine their function in the global ecosystem, their interactions, and how human activities impact them. This information is essential to understand how our planet functions and the evolution of life on it, to model its future, and to get inspiration for biotechnological applications.

Specific themes and goals

In the Microbial Physiology Group, which is based at the Max Planck Institute for Marine Microbiology, we discover new biochemical pathways, and aim to fundamentally understand the physiology and interactions of microorganisms that govern global carbon and nitrogen cycles.

In bioreactor systems that we design and optimize, we cultivate and perform experiments on microorganisms under controlled conditions, which closely mimic their natural environment. We analyze the resulting cultures using omics, biochemical and physiological approaches. The information we acquire is vital to understand carbon and nitrogen cycling on present-day earth and the impact of human activities on these cycles. Moreover, through our results we gain insights into the evolution of carbon- and nitrogen-transforming pathways.

The natural environment can be mimicked very closely in a laboratory-scale bioreactor. In the bioreactor depicted here, microorganisms extract energy from nitric oxide, and thus essentially breathe poison.

Highlights and impact

- Between 2019 and 2022, we published 17 peer-reviewed scientific papers.
- National and international media reported on our papers on nitric-oxide-dependent anaerobic ammonium oxidation and on the discovery of a new nitric-oxide-producing enzyme. The press included German, Italian and American news organizations. Furthermore, American Chemical Society, Dutch Chemical Society, Le Scienze, Phys.org and Focus Magazine highlighted our work.
- Two group members won the prizes for best oral and poster presentations at the 25th European Nitrogen Cycle Meeting in Rome.

The natural environment can be mimicked very closely in a laboratory-scale bioreactor. In the bioreactor depicted here, microorganisms extract energy from nitric oxide, and thus essentially breathe poison.

Group composition & projects / funding

Currently, the Microbial Physiology Group at the Max Planck Institute for Marine Microbiology comprises two postdoctoral fellows, three PhD students, and one technical assistant. The group has been funded by Max Planck Society, Netherlands Organisation for Scientific Research, China Scholarship Council, and European Research Council Starting Grant.

Selected publications

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Computational Physics and Biophysics

Prof. Ulrich Kleinekathöfer

The Computational Physics and Biophysics Group mainly focuses on the theoretical and numerical description of dynamical processes in molecular systems. The systems can range from small molecules to large bio-molecular complexes of thousands and even millions of atoms. Some of the processes like the transport of ions can be described using classical dynamics while others like the transport of electrons and excitation energies heavily rely on quantum mechanics. To be able to understand quantum effects in larger molecular complexes, we use multi-scale approaches.

Specific themes and goals

Concerning the quantum dynamics in molecular systems, the group develops and applies a variety of approaches. These schemes range from purely quantum mechanical approaches on model systems to multi-scale approaches in which we derive the parameters for the model systems from atomistic simulations. Examples in this direction, on which the Kleinekathöfer group has focused, are the excitation energy transfer in biological light-harvesting systems and the charge transfer through molecular junctions, i.e., molecules between two leads.

Over the last few years, the group has also performed various molecular dynamics simulations on proteins in bacterial membranes. We had a special focus on the membrane pores through which antibiotics need to enter bacteria to destroy them. The poor understanding of these permeation processes leads to serious problems in the development of new antibiotics. In close collaboration with the group of Prof. Mathias Winterhalter at Constructor University, we are studying these and other topics in the area of nanopore permeation. Other areas include substrate transport, the electroosmotic flow which pushes neutral substrate through pores, the identification of chiral isomers, and the assembly of transmembrane pores from mirror-image peptides.

Highlights and impact

- **Photosynthesis** — Due to the size of light-harvesting complexes and the involvement of electronic degrees of freedom, computationally these systems need to be treated in a combined quantum-classical description. We used Born-Oppenheimer molecular dynamics simulations in a quantum mechanics/molecular mechanics fashion for the ground state followed by excitation energy calculations. By now, this scheme has been tested for several light-harvesting complexes. The spectral densities, in particular, show an excellent agreement with experimental findings. In addition, we showed that the obtained results for the fluctuating site energies and couplings can be used to estimate the excitation energy transfer dynamics.
- **Transport through nanopores** — Researchers are using the voltage-dependent transport through biological and artificial nanopores in many applications such as DNA or protein sequencing and sensing. The primary approach to determine the transport has been to measure the temporal ion current fluctuations caused by solutes when applying external voltages. The electroosmotic flow is a voltage-dependent ion-associated flow of water molecules. In a joint study with the Winterhalter group, we have investigated the electroosmotic flow by probing the transport of cyclodextrin molecules through the ΔCymA channel.
- Nanopore sensing — Chirality is essential in nearly all biological organization and chemical reactions but is rarely considered due to technical limitations. Using OmpF, a membrane channel from the bacterium E. coli with an electrostatically asymmetric constriction zone, we were able to determine chiral amino acids in a single peptide. Using a statistical analysis of the respective ion current variations, we were able to distinguish the presence and position of each chiral amino acid.

Group composition & projects / funding

In 2022, the Computational Physics and Biophysics Group consisted of six PhD students and two postdocs, funded through the German Science Foundation, DFG, the German Academic Exchange Service, DAAD, and the Federal Office for Radiation Protection, BfS. The group is part of the DFG Research Training Group “Quantum Mechanical Materials Modeling” and of the DFG Priority Programme “Molecular Machine Learning”.

Selected publications

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Functional Inorganic Materials: Synthesis, Characterization, and Catalysis

Prof. Ulrich Kortz

Discrete, anionic metal-oxo clusters (known as polyoxometalates, or POMs) are a class of inorganic compounds. POMs are usually water-soluble with a tunable shape, size, and structure and a large range of physicochemical properties. Their versatility makes them particularly interesting to several industries, from energy through to biomedical sciences. For example, the chemical industry uses them as heterogeneous or homogeneous redox catalysts. In fact, POMs contributed to the 2009 Nobel Prize in Chemistry for the structure determination of ribosomes as co-crystallising agents.

Specific themes and goals

Metal-oxo clusters

Prof. Ulrich Kortz's group is active in the synthesis, structural characterisation and study of the physicochemical properties of discrete metal-oxo clusters. The group has experience in the design and screening of reactions aimed at the discovery of novel compounds, including upscaling for commercial applications. We use a large range of analytical instrumentation including nuclear magnetic resonance (NMR) and single-crystal x-ray diffraction (XRD), as well as catalytic reactors (batch and flow) to perform industrially-relevant catalyst screening.

Polyoxopalladates

In 2008, the Kortz group discovered a novel class of anionic metal-oxo clusters comprising exclusively the noble metal palladium. Polyoxopalladates (POPs) are discrete, molecular palladium-oxo nanoclusters. Palladium and platinum are of much interest for industrial catalysis and we are exploring the use of POPs as (pre)-catalysts for industrially-relevant hydrogenation reactions and other petrochemical transformations. The group has been working in this area with a large chemical company, and has contributed to more than 10 patents.

Noble-metal-free POMs

The Kortz group has also been active in the synthesis of noble-metal-free POMs in a number of industrially-relevant applications. Areas include renewable energy and battery research. We are also active in researching POMS as active components of self-cleaning surfaces.

Highlights and impact

Ulrich Kortz is a global leader in the area of POM chemistry, ranging from synthesis and structural characterization of metal-oxo clusters to the study of properties and applications of these materials in various sectors, which is supported by a large network of academic and industrial collaborators. With a portfolio of 319 publications, 14791 citations, and H-index 67 the work of the Kortz group has significant impact on the global development of the research field.

- Between 2019 and 2022, the Kortz group has published 49 articles in international, peer-reviewed journals.
- In 2021 and 2020, respectively, the Kortz group published reviews in Comprehensive Coordination Chemistry III (Quo vadis, Polyoxometalate Chemistry?) and Current Medicinal Chemistry (Polyoxometalates in Biomedicine: Update and Overview).
- The Kortz group has a large and constantly expanding international network of collaborators.
- The prominent standing of the Kortz group in the POM community keeps attracting young scientists from all over the world to join the research group.
- The Kortz group engages Constructor University undergraduates in research, from as early as their first year of study. To date, this approach has resulted in 36 publications with Constructor University undergrads as coauthors.

Group composition & projects / funding

Currently the Kortz group comprises seven PhD students and two postdoctoral researchers. The group received financial support from different third-party projects (from, for example, the chemical industry), the German Science Foundation (DFG, KO-2288/29-1, KO-2288/31-1), and international funding agencies (DAAD, CSC etc.).

Selected publications

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Geochemistry of Trace Metals in the Ocean

Prof. Dr. Andrea Koschinsky

We aim to better understand the role of trace metals in the oceans under changing environmental and climatic conditions, both as elements important for life, as potential toxins, or as critical resources for new technologies. Trace metals such as iron, copper, cobalt and nickel play an important role in the ocean. Some of them are important micronutrients (or toxins) for plankton and other marine organisms, while others accumulate at the seafloor and form valuable mineral deposits such as ferromanganese nodules and crusts. Natural sources of these trace metals include land-derived weathered rock material introduced by rivers or atmospheric deposition, and hydrothermal systems discharging hot metal-rich fluids at the seafloor. Increasingly, anthropogenic metal input related to the use of metals in traditional and modern technologies increases concentrations of potentially toxic metals, especially in coastal regions. We study trace metal geochemistry in the oceans by collecting data and samples on sea-going expeditions with modern research vessels.

Specific themes and goals

Hydrothermal research

Submarine hydrothermal activity is the principal mechanism that controls the transfer of heat and chemicals at the ocean/crust interface. At the seafloor, this process manifests as spectacular black smokers, where high-temperature, metal-rich, anoxic and acidic fluids are emitted into the cold, oxygen-rich bottom waters of the oceans. The strong physico-chemical gradients lead to the precipitation of metals that form the black smoke as well as the chimney structures from which the fluids are venting. However, the hydrothermal plume can transport trace-metals over large distances and contribute to the elemental budget of the ocean.

The GEOTRACES programme

For more than 40 years, scientists around that world have participated in a joint effort to study the distribution, sources, and sinks of trace metals and their isotopes in different oceanic settings. Koschinsky's group has been part of this programme for more than 10 years and provided the first data set of rare metals such as niobium (Nb), a trace metal of which very little is known, to this database.

Estuary research

The large Amazon and Pará Rivers converge in the Amazon-Pará River estuary. As a result of their enormous water volumes, these rivers are a major source of trace metals, nutrients and organic matter. We determined, for the first time, the fluxes and distributions of transition metals such as iron, cobalt, nickel and lead in the Amazon-Pará River estuary. We also conducted cruise M169 in the North Sea, and specifically investigated the estuaries of three German rivers (the Weser, Ems, and Elbe). We focused on the input of critical metals used in new technologies and medicine into coastal waters.

Environmental impact of deep-sea mining

The MiningImpact 2 project, part of the EU programme JPI Oceans, studies the environmental impacts and risks of mining ferromanganese nodules in the deep-ocean basins. We assessed the release of potentially toxic metals during mining operations. After the test mining of a nodule collector prototype, the upcoming cruise SO295 will revisit the disturbed area after more than a year to investigate the environmental impact and recovery processes.

Highlights and impact

- The Northeast Lau Basin is an area affected by widespread hydrothermal activity, but little was known about the geochemistry of high-temperature hydrothermal fluids venting in a number of places. Based on research cruise SO263, we reported the first vent fluid data for Maka volcano and Niuatahi volcano, describing the processes that affect the vent fluid composition.

Overview of cruises with research vessels Sonne, Meteor, and others with participation of the marine geochemistry group at Jacobs University. Numbers in red shows research cruises scheduled for 2023 and 2024

- Our recent Amazon estuary workshop highlighted the global relevance of this large land-ocean interface in times of climate change and participants started planning an upcoming followup cruise in the Amazon estuary during the dry season.
- The team looks forward to four exciting research cruises taking place in 2023 in the Central Pacific (SO298), northern Atlantic (M190), Mediterranean (M192) and Indian Ocean (SO301) in collaboration with partners from GEOMAR, MARUM, and others. The focus will be on hydrothermal systems and GEOTRACES-related topics.

Group composition & projects / funding

The marine geochemistry group with a focus on trace metals consists of a diverse team, which currently includes four PhD students, three postdoctoral researchers, and a lab technician as well as two visiting scholars. Many former group members are still affiliated with our team as guest scientists or collaboration partners. Personnel and research projects are funded through several grants from the German Science Foundation (DFG) and the Federal Ministry for Education and Research (BMBF), as well as some scholarships.

Selected publications

R. S. Krishnan, K. Jana, A. H. Shaji, K. S. Nair, A. D. Das, D. Vikraman, H. Bajaj, U. Kleinekathöfer and K. R. Mahendran, Assembly of Transmembrane Pores from Mirror-Image Peptides, Nat. Commun. 13, 5377 (2022).

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Analytical Chemistry

Prof. Dr. Nikolai Kuhnert

The Kuhnert group aims to understand the composition and chemistry of processed food. Whenever people heat, treat, or ferment food, its chemical composition changes dramatically. We aim to elucidate chemical structures of food constituents formed during processing, understand how they are formed, and use this information to improve food quality for industrial partners and consumers. Ultimately, our research tries to understand our diet to improve human health. From 2019-2022 the Kuhnert group contributed 34 peer-reviewed publications to these topics with a current h-index of 52 of the group leader.

Specific themes and goals

Processed food is our main focus, and over the last decade, we have focused on a selection of popular products including black tea, roasted coffee, red wine, cocoa and plants from the Fabaceae (beans and pulses) and Ericaceae (Rhododendrons) families. In processed food, typically a few hundred plant primary and secondary metabolites are converted to thousands, at times tens of thousands of new chemical compounds. By harnessing the resolution and sensitivity of modern mass spectrometry, we can gain detailed insight into the structures formed. After we eat food, our bodies — through the gut, liver and other organs — change the chemical composition of the food constituents, producing a myriad of diverse compounds in human body fluids. Each step increases the chemical complexity and diversity of compounds, creating a considerable challenge to the analytical sciences.

To understand beneficial or adverse health effects of specific diets, we require a complete chemical understanding of the raw material, processed material, and metabolites following consumption. To achieve this goal, our group is developing novel mass spectrometric methods and strategies, mainly based on modern computational tools, artificial intelligence, and computer learning algorithms on big data sets.

Highlights and impact

- We identified antiviral compounds in coffee, which inhibit the SARS CoV-2 Spike protein ACE-2 receptor interaction (offering a plausible agent to prevent Corona infections)
- We identified antiviral compounds from figs to act against human Papilloma Virus
- We developed novel data-science-based strategies to identify and detail human dietary metabolites in body fluids after cocoa and coffee consumption
- We contributed to a better understanding of tea, coffee and cocoa composition and metabolome
- We help to develop new products and improve processes in the cocoa industry (with Barry Callebaut Group)
- We developed aerosols produced from food waste extracts to disinfect public spaces.
- We organized the Fifth International Conference on Cocoa, Coffee and Tea (Cocotea 2019) on Constructor University campus, with more than 200 international participants.
- We collaborated and jointly published with international research partners from 14 countries, namely Spain, Sri Lanka, Canada, the United States, United Kingdom, Brazil, South Korea, China, Belgium, Switzerland, Italy, Egypt, France, and South Africa.
- Our publications show a strong contribution from undergraduate students' research with nine publications listing 12 undergraduate students as co-authors.

Group composition & projects / funding

The Kuhnert group currently comprises one postdoctoral fellow, three technicians, and six PhD students, as well as about 10 undergraduate students. Major funding sources included industrial funding from Barry Callebaut Group and public funding by the Bremer Aufbaubank as well as collaborative funding, for example, through the DAAD, Humboldt foundation, and Sri Lankan government.

Selected publications

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Biological Effects of Artificial Magnetic and Electromagnetic Fields

Prof. Alexander Lerchl

People often fear the introduction of new technology, particularly the introduction and the use of artificial magnetic and magnetic fields. For example, while the new 5G standard for wireless communication is necessary to transport ever-increasing amounts of data, many people think it is a new, untested technology. Similarly, the public is concerned about new technologies for wirelessly charging automobiles. Our group is investigating potential biological effects of both technologies, using cell and animal models.

Specific themes and goals

5G effects on human skin cells

We have tested the effects of high frequency (27 GHz and 40.5 GHz) electromagnetic field exposures on two types of human skin cells, using sophisticated exposure units. We took special care to control for undesired temperature effects of exposure. To prevent any influence by the investigators, these were blind experiments, and only after we had conducted all the experiments did our technical cooperation partner, Seibersdorf Laboratories, Austria, reveal the results.

Intermediate frequency effects on animals and unicellular organisms

We also tested the potential biological effects of magnetic fields in the so-called intermediate frequency range (20 and 85 kHz) in female mice, thus exposing the animals to the same type of magnetic fields which are used to wirelessly charge buses. It was a technical challenge to expose a large number of animals (80 per group) to magnetic fields of the required strength, but our technical collaboration partner, the ifak Institute for Automation and Communication in Magdeburg, helped to solve this problem. We took special care to avoid differences between the exposed and the control animals.

Highlights and impact

- We could not find any tumor-inducing effects linked to exposure to high-frequency electromagnetic fields, and also no such effects by intermediate-frequency magnetic fields.
- We did detect some behavioral effects in mice as a result of exposure to intermediate-frequency magnetic fields, but were not a cause for concern. The exposed mice performed somewhat better than the controls.
- Our results confirm and extend the majority of research that shows that there are no detrimental or damaging effects from exposure to magnetic or electromagnetic fields at levels below or even above the current legal exposure limits.

Group composition & projects / funding

Our research group consists of two Postdocs, two PhD students, and one technician. Our research is supported by the Federal Ministry of the Environment, Nature Conservation, Nuclear Safety, and Consumer Production, as well as by the Federal Office for Radiation Protection.

Selected publications

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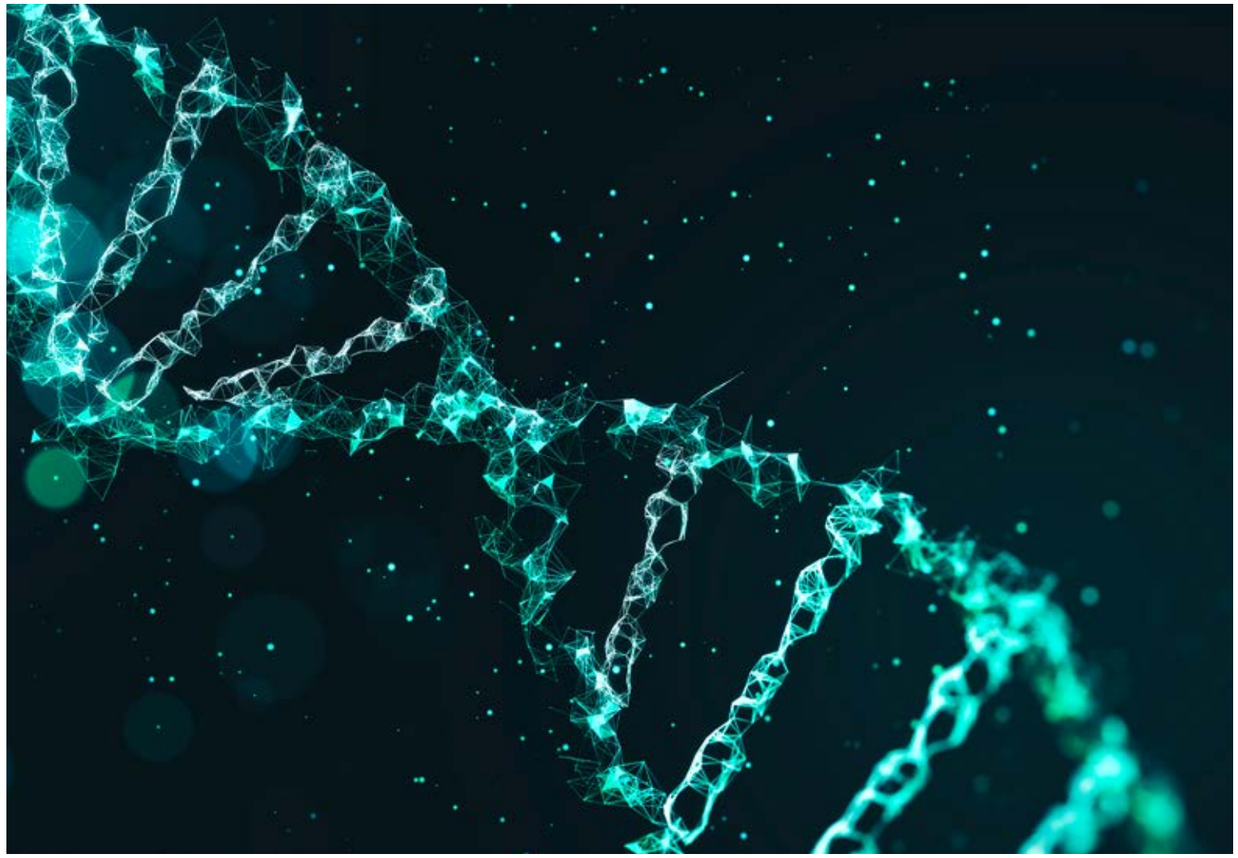
Computational Life Sciences and Synthetic Biology

Dr. Andreas Martin Lisewski

Synthetic biology is the disruptive technology of the 2020s. It is historically unprecedented for a single technology to have such an impact on not only medicine, food, livestock, defense sector, but also on the entire human society and the global biosphere. Our research focuses on computational approaches to synthetic biology, from understanding basic concepts through to developing specific medicinal applications such as thermostability of proteins. Following this research, basic elements of molecular biology (such as DNA replication, transcription, translation, structural stability) are analyzed from a modern information engineering perspective that incorporates the transmission of genetic information from a sender to a receiver (see Figure below). This application of (Shannon-Weaver) communication theory at a molecular biology level allows a representation of the basic elements of synthetic biology using a hierarchy of abstraction through parts, modules, devices, and sender-receiver systems. A focus is additionally placed on the technological risks and societal impacts that come from recent breakthroughs in synthetic biology.



Specific themes and goals

The application of modern communication theory to predict thermostability of enzymes, and the rational redesign of therapeutically important biologics. For example, the design of a thermostable human interleukin 1 receptor antagonist.

The analysis of infectious diseases emergence and epidemiology from a synthetic biology standpoint. For example, the investigation of the original outbreak and of superspreader events of COVID-19

Highlights and impact

- Discussed how the historically unprecedented COVID-19 mass vaccination campaign could be epidemiologically, pharmacologically and biologically understood and evaluated. This contribution reviewed the first mass vaccination campaign with the new type of synthetic nucleic acid and virus vector-based vaccines that took place in Europe (initially, the United Kingdom), beginning in December 2020 (see, reference 1 below).
- Analyzed how short-term vaccine effectiveness (the potential to reduce disease outcome in the vaccinated population relative to the unvaccinated) could be measured for COVID-19 vaccines given that SARS-CoV-2 transmission is highly volatile and dominated by superspreader events (see, reference 2 below).
- Asked how we can even begin to understand the risks and consequences of digitalization and automation that are both advancing and challenging our civilization (see also, Weser Kurier, Fortschritt braucht mehr als Technik (Progress is more than technological progress), 16 February 2021: Featured documentary and interview newspaper about my own research and teaching (global existential risks)).
- Explored what type of global existential risks there are, and whether we have a sufficient level of understanding and control over the risks, such as genetic engineering, that lie before us in the 2020s (see, Le Monde, Origin of SARS-CoV-2: The search continues, 28 December 2022); and Weser Kurier, Menschheit am Scheideweg (Humanity at the crossroads), 7 June 2019: documentary and interview about my own research and teaching (synthetic biology, genetic engineering, pandemic risks, global existential risks)).

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Chemical Physics — Laser Spectroscopy

Prof. Dr. Arnulf Materny

When laser light interacts with matter, it can yield information about its molecular building blocks, thus also about materials made up of different molecules. The Materny group applies and develops different types of linear and nonlinear laser spectroscopy in the frequency and time domains. The researchers apply Raman spectroscopy, which yields vibrational energies of molecules. The spectra can be considered to be molecular fingerprints and help to detect chemical changes, such as those caused by the environment. Ultrashort laser pulses are used to take snapshots of ultrafast processes occurring inside molecular systems after optical excitation. Using complex nonlinear spectroscopy techniques, the group is able to access fundamental material properties, but also to obtain data important for applications.

Specific themes and goals

Frequency-domain spectroscopy

Here, the group mainly concentrates on Raman spectroscopy to investigate material properties. The technique allows for the analysis of practically all substances in gas, liquid and solid phases. The vibrational spectrum of the molecules helps to determine materials' compositions and their interactions with the environment. This research is performed in an extensive collaboration with other researchers and with companies in diverse fields such as food analysis, investigation of cancer development, and quality control for different kinds of polymer-based materials.

Time-domain spectroscopy

Investigations with an extremely high temporal resolution in the femtosecond range (10-15 seconds) are very demanding. The Materny group has developed a variety of techniques to access elementary dynamics in molecular systems. Presently, the group is studying the dynamics in organic semiconductors and ionic liquids, which are salts that remain in a liquid state even when at room temperature. For this, electronic and vibrational dynamics are accessed, for example using "femtosecond coherent anti-Stokes Raman scattering" excited and probe with up to four ultrashort laser pulses. The ionic liquids have potential applications in fields such as pharmaceuticals and green chemistry.

Highlights and impact

- To make Raman spectroscopy even more useful, the group has developed techniques, which increase the sensitivity by enhancing the signal in the so-called surface-enhanced Raman scattering (SERS) process and at the same time suppressing unwanted background signals.
- Organic semiconductors are highly attractive due to their variability and relatively simple and cheap production. However, stability and efficiency of electronic devices, such as solar cells, still needs to be improved. For this, a better understanding of the generation dynamics of charges has been reached in close collaboration with the research group of Prof. Veit Wagner.
- Using femtosecond time-resolved coherent anti-Stokes Raman scattering, the dynamics of inter-ion energy transfer in ionic liquids has been studied. The results helped to design ionic liquids with specific properties. Together with partners from India, the experimental results have been supplemented by "Density Functional Theory" (DFT) calculations.
- In a project involving several companies and research institutes, biofilms, which form on microplastic particles in water, have been investigated. These biofilms consist of, for example, algae and bacteria, and might influence the lifetime of the particles, but could also pose a threat to animals and human health if ingested through food.

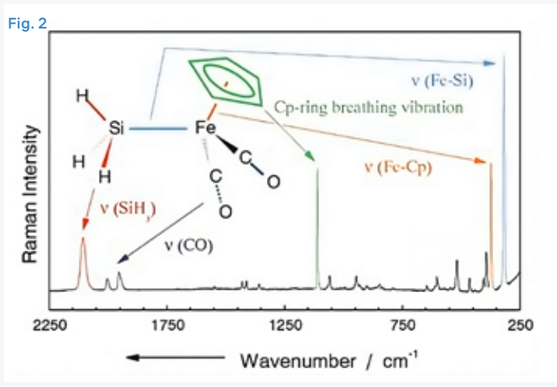

Fig. 1: Fs-laser setup

Fig. 2: Raman fingerprint of molecule

- Together with an industry partner from Bremen, ethylene tetrafluoroethylene (ETFE) plastic foils used in roof construction have been studied using Micro-Raman spectroscopy. The results helped to improve the chemical stability and resistance of coatings against the environment. Similar experiments have been performed with Russian research partners, with whom there is a long-standing cooperation.

Group composition & projects / funding

Three PhD students and four postdoctoral fellows carried out most of the group's research. Funding came from the German Research Foundation (DFG; Individual Grants Program), the Federal Ministry for Economic Affairs and Climate Action (BMWi; ZIM Program), the Alexander von Humboldt Foundation (postdoc fellowships), and industry.

Selected publications

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Group representations, complexity, and randomness

Dr. Keivan Mallahi-Karai

Today's modern world hinges on waves, such as in telecommunications, national power grids, or even aerospace. Developing new tools and deepening our mathematical understanding of waves can broaden their applications. Harmonic analysis is a branch of mathematics dealing with representing wave-like objects as a combination of simpler waves with different frequencies. This powerful tool has its roots in the concept of Fourier series discovered in the groundbreaking work of Joseph Fourier in 1822. Fourier suggested that a periodic wave can be decomposed into pure harmonic waves. Ever since this discovery, this idea has been applied to a large variety of problems in analysis and geometry. Keivan Mallahi-Karai investigates harmonic analysis in a number of settings.

Specific themes and goals

Local randomness of compact groups

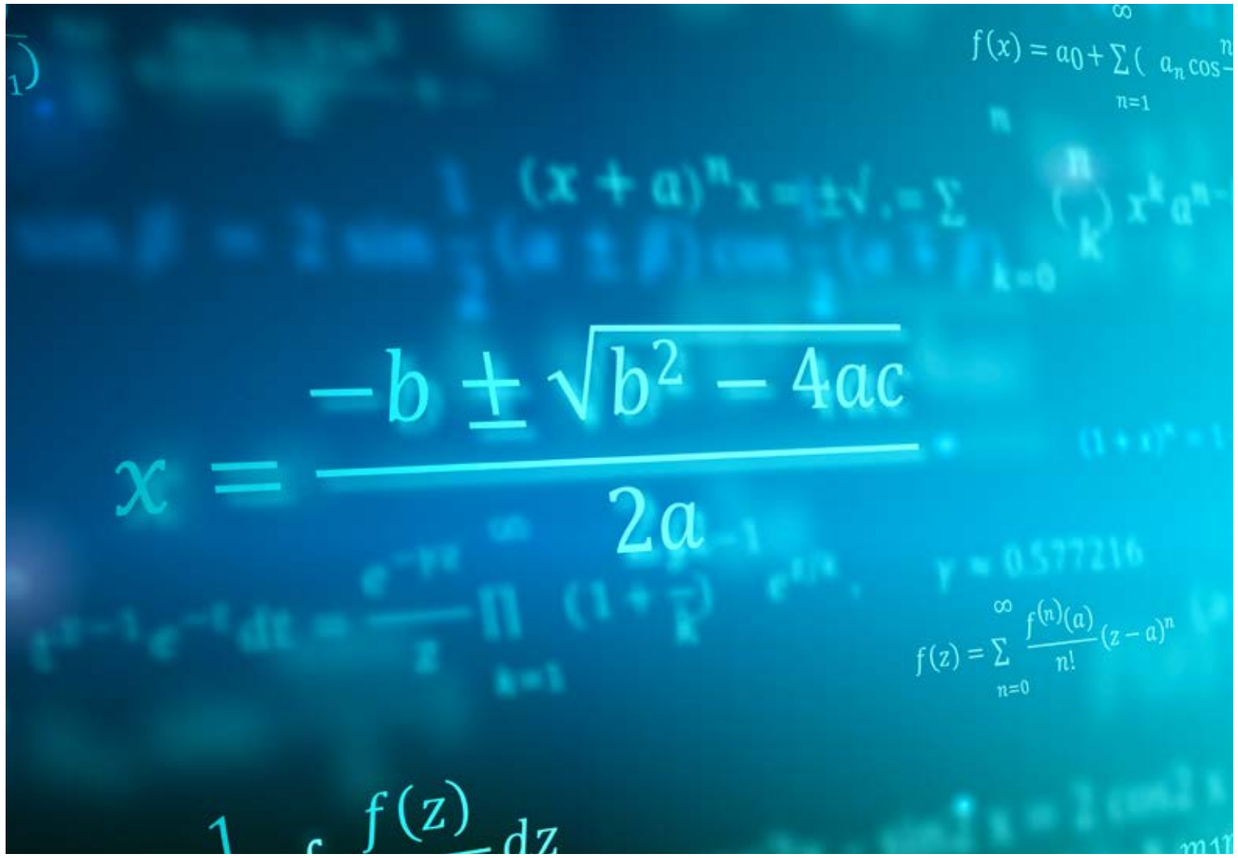
A compact group is a group of motions in a homogenous space. The simplest example is the group of rotations in space. These groups often appear in applied areas such as quantum mechanics. Mallahi-Karai and colleagues are applying the tools of harmonic analysis to study questions with a probabilistic flavor on such groups. For example, in their recent work, they have proven that if X and Y are two random rotations then their composition XY is more random than what is predicated by the well known Caught inequality.

Mathematical models of decision-making

Mallahi-Karai and colleagues propose a model of decision-making based on the Weiner process (also called 'Brownian motion', which is the random motion of particles). Previous scholars had applied this process to simple yes-or-no decisions, however Mallahi-Karai and colleagues broadened its scope to multiple-option decision-making. An example is if a person were trying to choose between three different mobiles phones. Such a decision-making process can be represented by a cube, which has six sides and each side corresponds to a choice. With the Weiner process, a point and direction are chosen randomly within the cube. The first wall that the moving 'dot' hits will be the choice (if 'yes', the decision has been made; if 'no', that wall disappears and the shape of the decision-making container changes into a four-sided object). The starting point is the 'initial bias', and with this model of decision-making, it is possible to predict the choice probabilities and mean response time of a given decision.

Group composition & projects / funding

Some of Mallahi-Karai's research was funded through a DFG grant, acquired jointly with Adele Diederich. During the 2019-2022 period, he supervised one master's and nine bachelor's theses.



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Supramolecular Chemistry

Prof. Werner Nau

Supramolecular chemistry deals with interactions between molecules, and is known as the “chemistry beyond the molecule”. Prof. Werner Nau’s group focuses on the principles of supramolecular chemistry, which govern the formation of membranes and cells, the structure and function of proteins, the binding of drug molecules to enzymes and biological receptors, adhesion to material surfaces, and the function of molecular machines and catalysts.

Specific themes and goals

Our research team at Constructor University studies the fundamental driving forces that bring molecules together. We also develop new applications in supramolecular chemistry, generally focusing on water as the most important solvent. In many cases, our research builds on international collaborations.

For more than a decade, we have been at the forefront of supramolecular chemistry. In 2011, we proposed high-energy water as an important driving force in supramolecular chemistry. In 2013, we designed systems that allowed us to observe chemical reactions inside molecular containers in the gas phase. In 2015, we discovered the special properties of superchaotropic ions and described the chaotropic effect as a complementary driving force to the hydrophobic effect. Furthermore, we have designed fluorescent probes and a new line of enzyme (in 2007) and membrane (in 2014) assays, so-called supramolecular tandem assays.

Our work on fluorescent sensors; macrocycles, particularly cucurbiturils; high-affinity binders (including most recently boron clusters); and complexation-induced pKa shifts has found applications in pharmaceutical drug discovery and drug delivery. Our contribution is exemplified by the recent discovery of a new class of membrane carrier, with Javier Montenegro at Santiago de Compostela University in Spain.

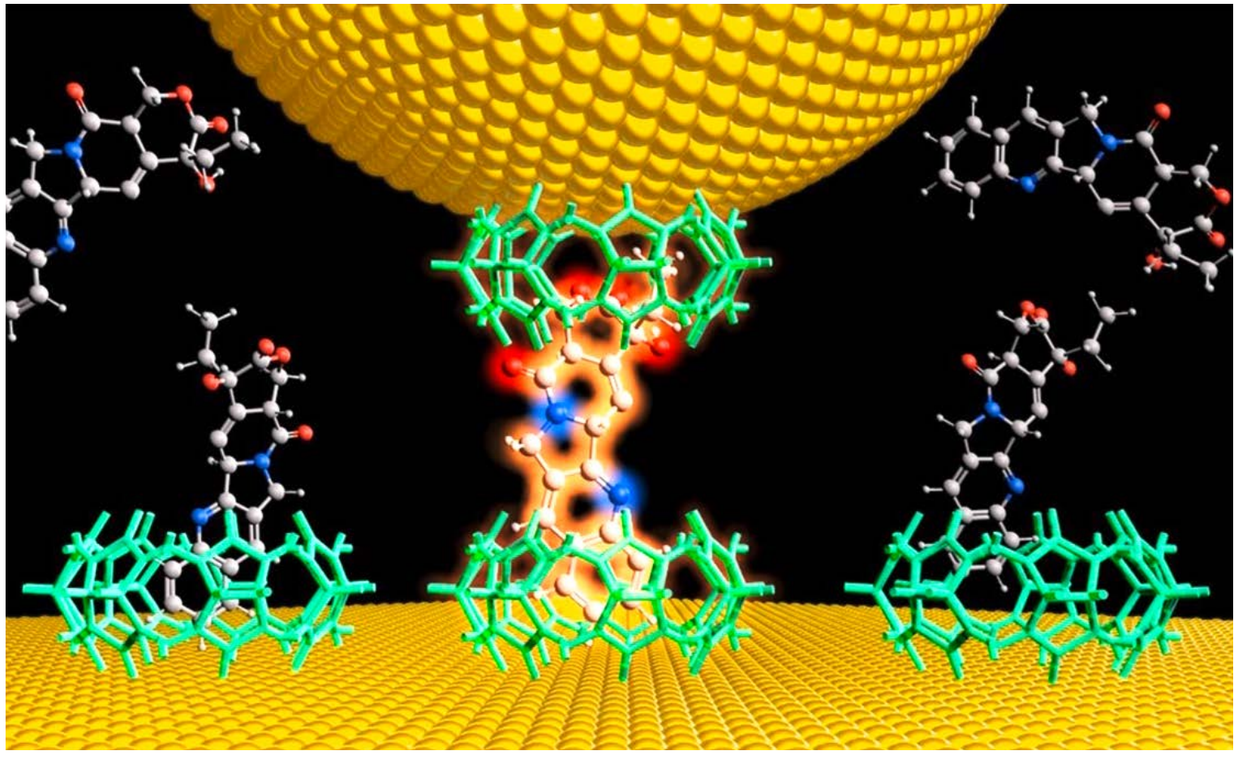
Regarding young researcher support, the group has graduated 25 PhD students and hosted 20 postdoctoral fellows as well as two habilitation candidates, in addition to 10 visiting scientists/professors (sabbaticals). Twenty of the overall 45 supervised PhD students and postdocs have entered academic careers in universities and research institutes around the world. Most of them are now in permanent professor positions, and many of them have returned to their home countries, ranging from Spain, Lebanon, China, Germany, India, Iran, and Jordan.

Highlights and impact

- Jury Member for the academics (Die Zeit) prize “Young Researcher of the Year”
- Honorary Faculty Member at Indian Institute of Technology IIT Guwahati, India
- Appointment as Concurrent Professor of Hubei Province at Wuhan Textile Industry
- Re-elected Executive Committee Member of the European Photochemistry Association
- Co-organizer of the “Superchaotropic properties of nano-ions” two-day session at the European Colloid and Interface Society Conference 2019, Leuven, Belgium
- The research work has been highlighted in major scientific media, including Chemical & Engineering News, Angewandte Chemie, and Nachrichten für Chemie und Technik.
- Selection of two articles in Angewandte Chemie as “Hot Paper”, another one as frontispiece.

Group composition & projects / funding

Currently, the group consists of two postdoctoral researchers, six PhD students, and typically two to three undergraduate research assistants. During 2019-2022, several co-workers have been awarded with fellowships (Humboldt, China Scholarship Council). The research has been largely funded through three projects of the German Science Foundation (DFG).



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Molecular Biotechnology

Prof. Elke Nevoigt

Molecular biotechnology uses molecular biology techniques to modify nucleic acids and proteins for multiple applications. It is an exciting interdisciplinary research field fueled by the ability to transfer genetic information between organisms, and the goal is to create useful products and processes. The completion of numerous genome-sequencing projects as well as the development of highly efficient methods for genome engineering have opened a myriad of opportunities and novel applications.

Specific themes and goals

The group of Elke Nevoigt uses cutting-edge techniques of molecular biology and genetics to engineer yeasts and optimize their characteristics for industrial applications. Baker's yeast (Saccharomyces cerevisiae) has traditionally been used in the industrial production of food and beverages (such as bread, beer and wine). Another well-known application of this yeast is the production of proteins such as human protein insulin. Nowadays, S. cerevisiae and several other yeast species have also been exploited in the area of industrial biotechnology (also known as "white biotechnology") for the sustainable production of chemicals, fuels and materials from renewable resources. In this way, the research field helps to address the urgent environmental problems caused by the use of fossil resources in the chemical industry. In the past, our group has mainly focused on broadening the spectrum of raw materials that can be used to feed the yeast S. cerevisiae such as glycerol (inevitable residue from biodiesel production) and D-galacturonic acid (a major component of residues from sugar beet processing). We have also been working on the production of the platform chemical succinic acid from glycerol and CO_2. Future work will focus on the utilization of carbon sources that can be obtained from CO_2. By producing valuable products from these compounds, we seek to contribute to the reduction in CO_2 emission as well as CO_2 capture.

Highlights and impact

The Nevoigt Laboratory is an international leader in the field of glycerol utilization by baker's yeast for the production of chemicals, particularly succinic acid. Our lab developed the first S. cerevisiae strains able to efficiently utilize glycerol and they formed the basis of interesting novel applications such as the production of various chemicals, yeast biomass and proteins. We have successfully established the CRISPR/Cas9 system as a tool for yeast engineering.

- **Glycerol** — A DFG project has focused on engineering the central metabolism of baker's yeast for more efficient growth on glycerol. Glycerol is an attractive source of carbon and energy since its electron density is higher than that of sugars. Apart from yeast biomass, the target chemical is succinic acid, an important precursor for the chemical industry. An attractive aspect of the project is the fact that CO2 can be incorporated into the target product. So far, we achieved a product yield per glycerol consumed that corresponds to 47% of the theoretical maximum (Malubhoy et al, 2022). A recently secured extension project focuses on fundamental research to improve succinic acid production by the yeast S. cerevisiae.
- YEASTDOC — This European Joint Doctoral programme (Marie Skłodowska-Curie Innovative Training Network) trains early-stage researchers in the field of yeast biotechnology. Six academic institutions worked with seven industry and two training partner organizations to offer an international training programme leading to the award of joint PhD degrees. The interdisciplinary, trans-sectoral research topic takes advantage of recent technological developments to link fundamental research in yeasts with new applications in the beverage and white biotechnology sectors.
- YEASTPEC — In this European collaborative project, Constructor University co-ordinated research with partners from VTT Finland, TU Munich, University of Lisbon, and the industrial partner GlobalYeast in Belgium. This project addresses the optimized utilization of sugar beet pulp, an agricultural pectin-rich waste stream, for bioethanol production by engineered baker's yeast. Our group focused on the co-utilisation of pulp and glycerol.
- Eco2Phy — Funded by BIS Bremerhaven in collaboration with the company Kaesler Nutrition GmbH (Cuxhaven), this project aimed to establish a more eco-friendly approach to produce the industrial enzyme phytase using yeast as the production organism. Phytase is commonly added to animal feed in order to release inorganic phosphate from an organic phosphate source (phytic acid) which is present in the feed. The current processes for phytase production rely on yeast as a production host and use methanol. One goal of the project was to replace methanol with glycerol.
- The group leader is author on 56 peer-reviewed publications, two book chapters, seven patent applications, and co-editor of one book and two special issues.

Group composition & projects / funding

In 2021, the Nevoigt Laboratory consisted of five PhD students, one postdoc, and one technician. The current funding in 2022 originates from the extension of the above-mentioned DFG project.

Selected publications

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Organic Chemistry

Prof. Thomas Nugent

The synthesis of natural products or pharmaceutical drugs have an immediate societal impact. They allow the suppression of new illnesses or the next generation of disease-fighting compounds for diseases such as cancer and Alzheimers. These molecules require many chemical operations to synthesize them and sometimes require years of research to do so. The Nugent group focuses on the concise design of pharmaceutical drugs and natural products.

Specific themes and goals

The challenging architectures pharmaceuticals and natural products require insightful strategies to efficiently synthesize them. More often than not, scientists can only realize leaps in efficient synthesis by developing or incorporating new methods. We develop strategies to synthesize pharmaceutical drugs which incorporate enantioselective catalysis. Development of these reaction sequences is important because they transform inexpensive prochiral organic starting materials into high-value chiral advanced building blocks.

New methods of synthesis

Without this, drug developers will not investigate these medicines because they would cost too much to synthesize. We have identified new ways to synthesize (R)-Pristiq, ( )-O-desmethylvenlafaxine, an antidepressant, in the highest yield known to date. Furthermore, we achieved the first enantioselective synthesis of a leading Alzheimer's research drug, a d-secretase modulator (GSM).

Morphine

We are currently focusing on the efficient synthesis of morphine, with the goal of developing new morphine family-based analgesics. We rely on a critical enantioselective intermolecular cascade reaction, among others, to achieve synthesis. The cascade reaction partners are diverse in nature and this flexibility provides several synthetic pathways to complete a morphine synthesis. A successful outcome would involve synthesizing morphine using the shortest enantiopure route to date (thirteen steps).

Cascade reactions

While not new to chemical thinking, cascade reactions have not been sufficiently exploited for pharmaceutical drug synthesis. We are investigating cascade reactions based on Michael-Henry and Michael-Henry-third reactions. These enantioselective cascades have historically been catalyzed via enamine intermediates or partial deprotonation of Michael pronucleophiles. Our ultimate goal is to trigger an intermolecular cascade reaction which installs the entire carbon framework of morphine and simultaneously sets the absolute and relative stereochemistry at most stereocenters of morphine.

Highlights and impact

- We synthesized (R)-Pristiq, a commercial antidepressant.
- We also synthesized an Alzheimer's research drug, a d-secretase modulator (GSM-1).
- We focused our medicinal chemistry efforts on identifying morphine-family analgesics.

Group composition & projects / funding

Prof. Nugent's group comprised one postdoctoral researcher, one doctoral candidate, and six undergraduate researchers. The research was funded through a German Research Foundation grant.

Selected publications

Invited contribution to a Special Collection on Organocatalysis: T. C. Nugent, A. E. de Vos, I. Hussain, H. A. E. D. Hussein, A 2000 to 2020 Practitioners Guide to Chiral Amine Based Enantioselective Aldol Reactions: Ketone Substrates, Best Methods, in Water Reaction Environments, and Defining Nuances, Eur. J. Org. Chem. 2022, 7, eLocator: e202100529.

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Algebra, Lie Theory and Geometry

Prof. Ivan Penkov

In our group, we research three interconnected core areas in pure mathematics. For the last three decades, Prof. Ivan Penkov has had a broad research programme in Lie theory, algebra, and geometry. He and his research group are working in close collaboration with research groups in the United States at Yale University; the University of California, Berkeley; the University of Texas in Arlington; and the University of Buffalo. Penkov's research group maintains close working contacts with the Max Planck Institute of Mathematics in Bonn, as well as with the University of Hamburg, the University of Cologne, and the Ruhr University in Bochum. His research has been funded continuously by multiple DFG projects for the last 15 years.

Specific themes and goals

Structure and representations of infinite-dimensional locally finite Lie algebras

The structure and representation theory of semi-simple Lie algebras is a jewel of mathematics and has been developed by mathematical giants of the 20th century such as Hermann Weyl, Andre Weil, Bourbaki, Israel Gelfand, Harish-Chandra and others. A theory of infinite-dimensional locally semi-simple Lie algebras emerged in the late 1980s. By the mid-1990s, Prof. Penkov had developed a broad programme to understand these Lie algebras and their representations at the level of depth already acquired for finite dimensional semisimple Lie algebras. Since then, this programme has achieved several milestones, and the theory of locally finite Lie algebras has become a mainstream research area in algebraic representation theory.

Tensor categories and representations of non-locally-finite infinite-dimensional Lie algebras

This research direction arose in the last several years, driven by the possibility of describing universal non-rigid tensor categories as representation categories for "large" Lie algebras.

Geometry of homogeneous infinite-dimensional spaces, more specifically geometry of homogeneous ind-varieties

Some of the deepest results in mathematics arise from the interaction of algebra and geometry. In the early 2000s, Penkov and colleagues started to build a geometric counterpart to the algebraic theory of locally finite Lie algebras. This brought the theory of ind-varieties of generalized flags to life.

Highlights and impact

- In 2022, we published the joint monograph "Classical Lie Algebras at Infinity", describing key results from our research during the last 20 years.
- We completed a series of joint works with Aleksey Petukhov on primitive ideals of infinite-dimensional Lie algebras. One result is an algorithm which computes the annihilator in U(sl(∞)) of any simple highest weight sl(∞)-module Lb(λ). This algorithm is based on an infinite version of the Robinson-Schensted algorithm. Other papers were devoted to various aspects of the theory of highest-weight sl(∞)-modules. We discovered a new category of integrable sl(∞)-modules.
- In one of our greatest research efforts, we provided a classification of all simple bounded weight modules over basic classical Lie superalgebras, and studied the categories of such modules.
- We are also particularly proud of a publication in which we resolve a challenge which emerged a few years ago in our earlier work. Namely, when one builds general tensor categories over Mackey Lie algebras, the trivial representation is no longer injective as an object of those categories. In this research, we constructed an infinite-length injective hull of the trivial representation, which allowed us to understand general infinite-length injective hulls of tensor modules over Mackey Lie algebras.
- We also developed a general theory of linear flag ind-varieties and showed that every such variety is GL(∞)-homogeneous, and is hence isomorphic to an ind-variety of generalized flags. This gives a purely algebraic-geometric construction of ind-varieties of generalized flags.

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Mathematical Physics

Prof. Sören Petrat

The laws of physics are formulated in the language of mathematics. In the field of mathematical physics we use rigorous mathematics to understand problems from physics better, or to solve problems in physics that require a lot of mathematics. The general goal of my research is to understand how effective macroscopic equations arise from the microscopic laws of quantum theory, which describes the microscopic world of elementary particles, atoms and molecules.

Throughout the sciences, exact solutions to interacting equations are difficult to obtain, either analytically or numerically. Instead, we rely on effective descriptions, which arise by coarse graining and neglecting certain microscopic degrees of freedom. This allows us to make macroscopic predictions and we can analyze the corresponding equations analytically as well as with efficient numerical techniques. In my research, I work to derive effective equations in a mathematically rigorous sense. The main applications are cold atomic gases such as Bose-Einstein condensates.

Specific themes and goals

The focus of my research is on non-equilibrium quantum systems, using mathematical tools from the fields of analysis and partial differential equations. There are two types of systems that need to be differentiated:

Fermi gases

Fermions are one of the two fundamental types of particles in nature. They have a tendency to repel each other.

Bose gases

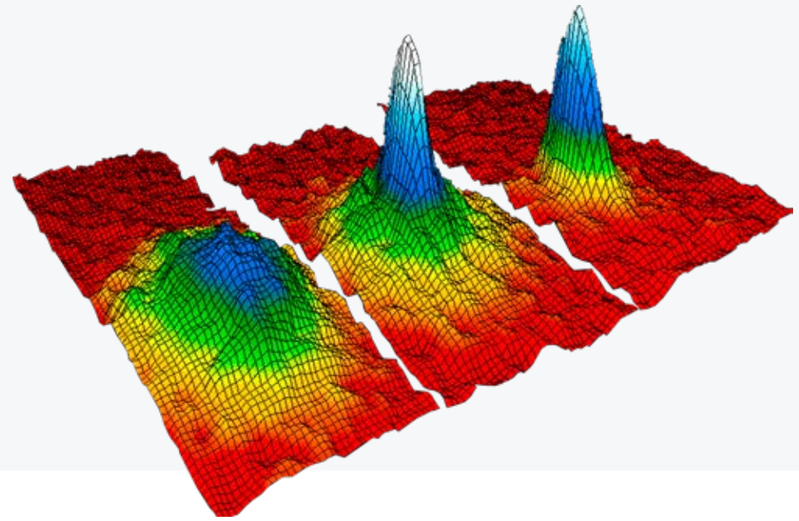
Bosons are the other type of fundamental particle, and tend to cluster, which leads to the effect of Bose-Einstein condensation.

From the perspective of a microscopic derivation of effective dynamics, there is still much to explore for these types of systems. The high relevance for modern-day experiments makes this area of research particularly compelling. For example, Bose-Einstein condensates are now regularly created in laboratories, after their first experimental realization in 1995. This research also promotes a fundamental understanding of the transition between micro and macro phenomena.

Highlights and impact

For both Bose and Fermi gases, we consider systems where the particles are so close together that we can effectively describe the whole cloud of particles collectively. Some of the results obtained for such systems are:

- **Asymptotic Expansions for Bose Gases** — For mean-field Bose gases, most of the particles are condensed and they occupy the same quantum state. This means they collectively show quantum behavior, and can be described by a nonlinear Schrödinger equation. But often this condensate is very homogeneous, so we are more interested in the deviations from the condensate. Such deviations form quasiparticles, which are objects that are collective excitations of many particles, but can also effectively be described as a separate particle. In a series of recent works, we have shown exactly how the quasi-particles interact. This is described with a so-called asymptotic expansion. We have applied these ideas to particles with pair interaction, and to particles interacting with a radiation field. In terms of applications, we have computed binding energies and corrections to a central limit theorem. This was joint work with collaborators from IST Austria, LMU Munich in Germany, Politecnico di Milano in Italy, Rutgers University in the United States, and University of Basel in Switzerland.
- Fermi Gases — In this area, we have been trying to prove the Hartree-Fock equations in a mean-field limit. This corresponds to the idea that each electron has its own "orbital". We have obtained results for bounded interactions, but how to do this for Coulomb interaction remains an open question. We will investigate this within a joint French-German collaboration project together with researchers in Braunschweig, Lorraine, and Rennes.



Bose-Einstein condensation.

(Source: wikipedia, public domain.)

Group composition & projects / funding

Currently, the research group consists of several Bachelor students. Two postdocs are expected to join the group soon. We are about to start two DFG-funded projects on "Effective Approximation and Dynamics of Many-Body Quantum Systems" and "Asymptotic Expansions for the Weakly Interacting Bose Gas".

Selected publications

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D. Mitrouskas, S. Petrat, and P. Pickl. Bogoliubov Corrections and Trace Norm Convergence for the Hartree Dynamics. Rev. Math. Phys., 31(8): 1950024 (2019).

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Fluorine Chemistry

Prof. Gerd-Volker Röschenthaler

Fluorine and fluorinated products, mostly human made, are integral to our daily lives. Fluorinated materials are indispensable for modern technologies, pharmaceuticals, photonics, batteries, high-performance polymers, and medicinal imaging, amongst other areas. They have many benefits, but also several environmental drawbacks. The unique properties of the fluorine atom and carbon-fluorine bonds are the reason that fluorinated organic chemicals are a major, dynamically developing research topic in both academia and industry laboratories. New synthetic methods and methodologies are the driving advancements in organofluorine chemistry. Our research group combines basic research with industrial research and development. We also collaborate with numerous institutions in China, Israel, Japan, Poland, Czech Republic and Spain.

Specific themes and goals

We synthesize and develop:

- Fluorinating and polyfluoroalkylating as well as fluorinated building blocks to modify biological and pharmacological active compounds
- modern fluorinated liquid crystal molecules for LCD-displays
- high-performance lithium-ion battery electrolyte components
- novel bisphosphonates, active agents against osteoporosis and bone cancer
- new perfluorinated monomers for co-polymerization

Highlights and impact

- We synthesized and investigated fluorine- and phosphorus-containing compounds for their application in material science and medicinal chemistry.
- We design and developed lithium battery electrolytes
- We synthesized and used fluorinated monomers in high-performance polymers
- We used new small molecules containing phosphorus and fluorine as bioactive compounds
- The group contributed to two books, and filed five patents.

Group composition & projects / funding

Between 2019 and 2022, the group consisted of six postdoctoral research associates and two PhD candidates working on basic research projects concerning organofluorine chemistry. They were supported by the German Research Foundation (DFG) jointly with the National Natural Science Foundation of China (NSFC) and the Czech Science Foundation (GACR). Further projects deal with lithium battery component development supported by the Federal Ministry of Economy and Energy (BMWi), together with the Münster Electrochemical Energy Technology (MEET) research center and companies like Bosch and BASF. In industrially oriented projects, we designed and developed fluorinated high-performance materials.

Selected publications

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Planetary Geology

Prof. Angelo Pio Rossi

Planetary geology is largely about remote mapping, and geologic mapping is a key element of planetary exploration for mission planning, orbital and rover reconnaissance, and target selection for in-situ analysis and sample return. It is also vital to further our understanding of the formation and evolution of planetary surfaces.

We can now analyze the growing amount of data collected by planetary missions to the Moon, Mars, Mercury using more integrated, data-driven approaches than scientists did in the 1970s, when they had to interpret photos. In particular, new datasets allow us to analyze planets' subsurfaces, which is a relatively new mapping method. Present and future landing sites for robotic and human missions on both the Moon and Mars are primary targets, as planetary analogues are one of the ways, together with remote sensing, to tackle their exploration.

Specific themes and goals

Our group focuses on planetary data analysis and mapping to understand planetary evolution, complemented by analogue studies and activities.

- Funded projects in the last two years cover planetary data analysis and specifically planetary data analysis and geologic mapping.
- Prof. Angelo Pio Rossi serves as the coordinator of the Virtual Access for the H2020 Europlanet Research Infrastructure, specifically its planetary geologic mapping activity GMAP.
- Prof. Rossi is also leading the Lunar data exploitation efforts within H2020 Explore.
- Additionally, ESA Human Space flight- related planetary analogue activities are being funded, supporting future robotic and human exploration.

Highlights and impact

Planetary geosciences efforts at Constructor University in the last decade have been visible in leading international venues, such as the Europlanet H2020 Research Infrastructure.

- In our contribution, we have pioneered efforts to bridge the geospatial and Virtual Observatory communities in terms of data and tools.
- We have led planetary data services across FP7/H2020.
- We have led planetary geologic mapping efforts across the European Union and beyond with countries such as the United States and China.
- We have also supported the European Space Agency human exploration and technical directorates for current human spaceflight and future robotic exploration.

Group composition & projects / funding

In 2019-2022, the planetary geoscience group included one postdoctoral fellow and three to four PhD candidates, funded through four European H2020 projects (Planmap H2020 #776276, EuroPlanet-RI-H2020 # 654208, NEANIAS H2020 #863448, EXPLORE H2020 # 101004214), as well as the ESA Miracles Geology and Science Support. In 2019-2022, the entire group was entirely third-party funded.

Figure top left: Broad view of Mars' southern pole, hiding clues of subsurface water(ESA/MEX/HRSC/DLR/FU Berlin). Top right: Mars hyperspectral exemplary data (NASA/MRO/CRISM). Center left: ESA Miracles 2022 campaign. Bottom left: Marius Hills pit on the Moon, with its floor littered by boulders, so far unexplored further. Bottom center: Design of a Lunar subsurface robotic explorer. Bottom right: artistic view (credit J. Schiavo) of planetary 3D mapping based on remote sensing and 3D geo-modelling.

Selected publications

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Mathematical / Theoretical Physics: Classical and Quantum Gravity, Quantum Information

Prof. Dr. Peter Schupp

Research at the interface of mathematics and physics involves the development of physical theories and new mathematical approaches as well as occasional serious theorem proving. Mathematical models can be used as virtual microscopes or telescopes that go well beyond the reach of the most powerful instruments. Our current research focuses on theories of gravity and quantum geometry, with applications to physics of the early universe and other regimes where quantum gravitational effects play a role. We also investigate quantum information and quantum systems. The two fields of research may have very different applications and motivation, but they are fundamentally related by their mathematics and physics.

Specific themes and goals

Cosmology

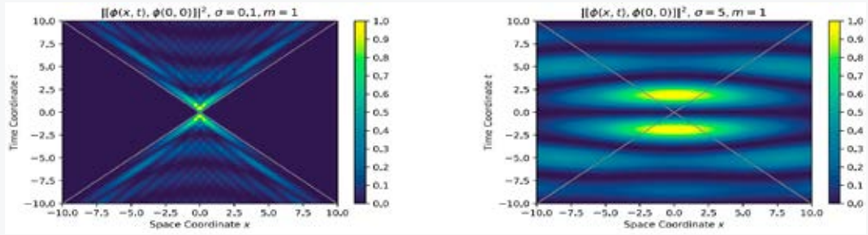
We revisited the flatness and horizon problem of classical Friedmann-Lemaître cosmology (that are often used to support cosmological inflation) in the light of modern ideas on quantum geometry. Classical cosmology assumes the validity of General Relativity with its smooth Riemannian spacetime geometry at all scales — even below the Planck scale, where researchers expect quantum-gravitational effects to dominate. We have found that models that take quantum-gravitational effects and the resulting quantum geometry of spacetime below the Planck scale into account are quite generically not affected by the horizon problem of classical cosmology. A slight adjustment of the quantisation prescription of quantum field theory leads to models with the required symmetries and expected effects of quantum geometry including fuzzy light cones and non-locality. Preliminary computations show that in these models not only the horizon problem but also the flatness problem may be resolved.

Generalized geometry

Generalized geometry provides a powerful mathematical setting for the formulation of gravity theories. Since it naturally incorporates stringy symmetries, it is useful in deriving the low-energy effective gravity actions of string theory, where it allows us to bypass complicated computations in a target space approach. We have contributed to the development of differential geometric methods in this field and have computed effective actions in general backgrounds. In this effort, we have pioneered an approach based on graded super geometry, out of which the objects and relations of generalized geometry arise as derived structures.

Particle physics and gravity

In related work, we have found a systematic way to formulate actions for bosonic (tensor) particles in a unified fashion. This includes the well-known Lovelock and Horndeski classifications of gravity theories. As an application, we have investigated the gravitational analog of axion electrodynamics with a parity-violating gravito-electromagnetic theta term. We have shown that this term leads to potentially observable effects, namely corrections to the Lense-Thirring effect and to the propagation of gravitational waves that are more than 80 orders of magnitude stronger than that of the much more familiar gravitational Chern-Simons term quadratic in curvature.



Highlights and impact

- We constructed a non-local quantum field theory toy model that can describe important aspects of quantum geometry in the context of cosmology.
- We discovered a unified description of bosonic field theories including gravity in the framework of graded super geometry.
- We predicted a new strong topological gravitational effect with potential for astrophysical observation.
- We developed new coherent state entropy-based methods to analyze the cosmic microwave background (CMB) that are particularly sensitive to non-Gaussianities in the data, are very efficient in computing resources, and have their origin in our research on quantum information theory.

Group composition & projects / funding

DFGResearch Training Group “Models of Gravity”, with PhD students, BSc students, visitors.

Selected publications

A. Chatzistavrakidis, G. Karagiannis, G. Manolakos, P. Schupp. Axion gravitodynamics, Lense-Thirring effect, and gravitational waves. Physical Review D. 2022.

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Molecular Mechanisms of the Immune Response and Immuno-Biotechnology

Prof. Sebastian Springer

Major histocompatibility (MHC) class I molecules are protein complexes with a pivotal role in the adaptive immune system of all vertebrates. These molecules present fragments of viruses and tumors to specialized immune cells, which induce the killing of these cells. This in turn controls viral spread and tumor progression. In Prof. Sebastian Springer's group, we investigate these proteins to understand pathological and immunological processes, and this basic research offers insight into how to manipulate MHC molecules to prevent and treat viral and tumor diseases.

Specific themes and goals

We have worked on the structure and biochemistry of MHC class I molecules for more than two decades. One main research focus is to describe class I intracellular quality control and trafficking. Class I molecules, like every protein, are generated inside the cell, where they also bind the peptide. But they fulfill their role at the cell surface, where the bound virus or tumor fragment (antigen) is presented to specialized immune cells called cytotoxic T cells (CTL). Quality control and trafficking of class I molecules are tightly regulated processes, strictly dependent on the presence of the peptide. We investigate the mechanisms that move class I molecules to the cell surface and then back inside (endocytosis) and their manipulation by viruses. Recently, we discovered novel dimeric forms of class I on the cell surface.

MHC class I molecules are also tools in practical applications. When bound to a specific peptide, they can be used to stain, isolate, and activate specific CTL from patients. These activated immune cells can then, for example, be re-infused into the patient to clear an infection or stop tumor growth. We develop MHC class I-based reagents for that purpose.

In the last 20 years, we have contributed substantially to both basic and applied MHC class I research. We are especially interested in synergies between the two, and use state-of-the-art techniques from cell biology, biochemistry, biophysics, biotechnology, and computational biology.

Highlights and impact

- **MHC clusters** — We have discovered that MHC class I molecules form clusters at the cell surface, with each other and with other proteins. We have investigated these clusters at a level of detail unprecedented in the literature. We are currently engaged in describing these clusters and their cellular role.
- **Viral immune escape** — Viruses often try to block antigen presentation using proteins called immunoevasins. We have described the mechanism of action of an immunoevasin by a herpes virus, and are currently working on another one. The results will help to further elucidate the everlasting battle between viruses and the immune system. They will allow us to better understand how herpes viruses can persist in people's bodies throughout their lives as a result of immunoevasion.
- Novel reagents for tumor immunotherapy — We have invented a stabilized form of an MHC class I molecule that can be rapidly loaded with peptide. This allows the rapid generation of so-called MHC tetramers, which are important reagents for the detection of tumor-specific T cells in patients. We have licensed this patented technology to several companies, and we set up our own company, Tetramer Shop, to market it.

Group composition & projects / funding

Our group has two postdocs, two PhD students, one technician, and several undergraduates. We are funded by the Deutsche Forschungsgemeinschaft and the Tönjes Vagt Foundation of Bremen.

Selected publications

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Medicinal Chemistry

Dr. Anna Tevyashova

Antibiotic resistance is a growing global problem. Increasingly current antibiotics are unable to kill certain strains of bacteria and fungi, and the World Health Organization estimates that millions of people die annually as a result of antibiotic-resistant pathogens. Invasive fungal mycoses may affect more than 300 million people each year and are responsible for the death of 1.5 million individuals globally. Skin and nail mycoses affect up to one in four people globally, which makes them one of the most frequent forms of infection.

Specific themes and goals

Dr Anna Tevyashova's research relates to the search for and development of a new generation of antibiotics and antitumor agents. In addition to the widespread resistance of microorganisms, researchers have linked the complexity of chemotherapy for several infectious diseases to a lack of efficacy and adverse reactions.

During the last few years, her research has focused on finding antifungal drug candidates. The most common fungal nosocomial infections are caused by external pathogens. This makes them difficult to avoid, because opportunistically pathogenic fungi are part of the human microflora. Current methods of preventing fungal infections remain unsatisfactory.

Doctors use antifungals used to treat invasive fungal infections, and they can be split into four classes of drugs, two of which — polyene macrolide antibiotics and synthetic azole derivatives — target ergosterol, a component of the fungal cell membrane. Some established antifungal drugs have other targets. There is an urgent need to develop novel, highly selective drug candidates with a different mechanism of action for antifungal chemotherapy or for agricultural applications.

Tevyashova's future projects will focus on designing and chemically synthesizing inhibitors of enzyme pathways unique for fungal cells, such as the one involved in amino acids biosynthesis pathways and protein biosynthesis. She will evaluate the biological activity of the obtained compounds on different models including their antimicrobial activity. The obtained results will provide guides for the next high-affinity generation of inhibitors of the fungal specific enzymes, which may serve as targets for new drugs.

Additionally, Tevyashova will develop attractive antimicrobial candidates against Gram-negative bacteria, such as Escherichia coli and Pseudomonas aeruginosa.

Highlights and impact

In her previous position as a principal investigator at the Gause Institute of New Antibiotics in Russia, Tevyashova headed up interdisciplinary projects involving the design, synthesis, and evaluation of antimicrobial and antitumor compounds. This research included coordinating preclinical studies of selected drug candidates. Her team developed two candidate compounds suitable for further clinical development — antifungal Amphamide for the treatment of systemic mycoses and antitumor drug candidate Olivamide.

As a part of Constructor University, she plans to continue her research, focusing on the discovery and development of new potent and safe antimicrobials.

Group composition & projects / funding

Tevyashova is currently setting up a laboratory of medicinal chemistry at Constructor University, with a focus on anti-infective drug discovery and development.

Selected publications

Tevyashova A.N., Efimova S.S., Alexandrov A.I., Omelchuk O.A., Ghazy E., Bychkova E.N., Zatonsky G.B., Grammatikova N.E., Dezhenkova L.G., Solovieva S.E., Ostroumova O.S., Shchekotikhin A.E. Semisynthetic amides of Amphotericin B and Nystatin A1: A comparative study of in vitro activity/toxicity ratio in relation to selectivity to ergosterol membranes, Antibiotics, 2023, 12, 151

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Molecular Plant Microbiology

Prof. Dr. Matthias S. Ullrich

Molecular plant microbiology investigates the molecular and metabolic changes in plants, algae, fungi, and bacteria occurring during their diverse natural interactions. Understanding these interactions at a cellular and biochemical level is fundamental for improving microbial food processing, identifying novel bioactive compounds such as antibiotics, and dissecting ecologically relevant processes in nature. These improvements will ultimately help us make agriculture, the food industry, and the use of bioactive substances in medicine more sustainable and more effective.

Specific themes and goals

Plants, plant products, or photosynthetic processes dominate our nutrition, most of our health, and a significant part of our biosphere in one or the other way. The tiniest lifeforms, microbes, are not only ubiquitously distributed on Earth but they also frequently interact with plants or algae, influencing their repertoire of primary and secondary metabolites. We focus on four major research goals:

Cocoa

In cooperation with a big industrial cocoa producer, analytical chemists, and systems biologists, we analyzed microbe-induced metabolic changes during the processing of cocoa beans from bush to bar. We also identified factors, which contribute to cocoa quality or specific characteristics such as fine taste, desirable aroma, best-practice texture, or a particular color of the resulting chocolate. Additionally, we have started working with a spin-off company of the cocoa producer to investigate bioactive compounds from this important crop plant.

Antimicrobial substances

In cooperation with analytical chemists, cell biologists, hygiene experts, and bioinformaticians, we identified and characterized safe-to-use antimicrobial substances from food production waste products or crop plants other than cocoa. This project included hands-on cooperation with small companies from the food hygiene sector in Bremen, such as Just-in-Air GmbH and ProPure Protect GmbH, and was funded by the Bremer Aufbaubank. Our ultimate goal is to find one or several novel antibiotics, which may be used in hospitals or veterinary medicine to treat or prevent infectious diseases.

Phosphorous

We tested in vitro cultures of marine and freshwater algae from self-grown photo-bioreactors for the accumulation of particulate phosphorus. Ultimately, it will be used as a fire protectant in biopolymers in cooperation with the Oceanlab at Constructor University; the Federal Institute of Material Research, Berlin; and the Biopolymer company, Technaro GmbH.

Carbon-dioxide fixation

In cooperation with marine scientists at the Max Planck Institute Bremen and the Alfred Wegner Institute in Bremerhaven, we analyzed global processes which lead to carbon-dioxide fixation and vertical organic matter sinking in the oceans. We used a genetically accessible in vitro model system consisting of a diatom and a marine bacterium. Here, our major aim is to dissect the signal exchange between the interacting organisms and to see how such signals affect differential gene expression. Ultimately, this will lead to a much more detailed picture of marine processes impacted by global climate change and ocean acidification.

Highlights and impact

Prof. Ullrich's laboratory has played a key coordinating role in and has contributed to large and small interdisciplinary research projects, such as the COMETA project and the project on identification of food production waste products applicable as disinfecting agents (PhytActBio). We have successfully finished the Vibrio in Seawater and Oysters project termed ENVICOPAS, and we have started the new project µFirephyte with new industry partners. In addition, we have initiated a new collaboration with scientists from Ghana to work on a sustainable intensification of sub-Saharan agriculture supported by the DFG. In most of these projects, the microbiologists from the Ullrich team cooperated with chemists (Nikolai Kuhnert), bioinformaticians (Marc-Thorsten Hütt), and cell biologists (Klaudia Brix).

- We successfully continued the Cocoa Metabolomics cooperation projects with major funding, resulting in numerous research papers and innovations for the industry partner.
- In 2019, we completed a marine project on temperature increases affecting pathogenic bacteria in seawater and oyster tissue demonstrating a negative correlation with temperature increase and abundance of pathogens.
- Since 2020, we have conducted a project on use of food production waste products as a fumigated disinfectant for room cleaning, resulting in the preliminary formulation of an ingredient.
- We established a firm scientific basis for novel bioactive compounds from plants resulting in EU patent applications.

Group composition & projects / funding

During 2019-2022, the Ullrich team consisted of two postdoctoral fellows, two technicians, three Masters' students, and six doctoral candidates. Additionally, two other postdoctoral fellows and two additional technicians are part of the COMETA team, supervised jointly with Nikolai Kuhnert and Marc Thorsten Hütt. All research projects were funded via third-party funding from industry partners, the DFG, the BMBF, and the Bremer Aufbaubank.

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Physics of Near-Earth Space

Prof. Joachim Vogt

The near-Earth space environment or geospace is a complex physical system, connecting the Sun, interplanetary space, and the Earth's upper atmosphere. Geospace dynamics affect technological infrastructure such as Earth-orbiting spacecraft and electrical power grids at high latitudes. We study these dynamics using satellite measurements and ground-based observations. We are particularly interested in constellation missions consisting of several satellites; they operate as a multi-point array in space, allowing us to investigate changes in geospace structures in both space and time.

Specific themes and goals

At Constructor University, Prof. Joachim Vogt and his space physics research group investigate the structure and the dynamics of the near-Earth space environment. In the past, they did this through plasma theory and magnetohydrodynamic simulations of the magnetosphere, but more recently they began using in-situ data from multi-spacecraft missions such as Cluster, Themis, and Swarm.

Electric currents in the auroral zone

One of our thematic foci is the electric currents in the auroral zone that flow along magnetic field lines. They are called field-aligned currents (FACs), and these auroral FACs control the exchange of momentum and energy between the ionized upper atmosphere at high latitudes and distant magnetospheric regions. These currents are thus an important element in space weather prediction models. We are working on developing robust multi-point estimators for FAC density, constructing multi-scale analysis methods for the magnetic field, and validating data products such as Level-2 FAC density derived from measurements of the European Space Agency's three-satellite mission Swarm.

Lower thermosphere and ionosphere

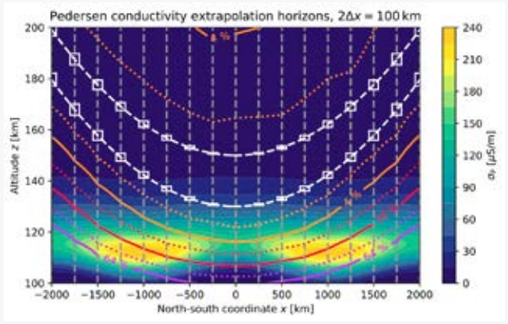
In support of new satellite missions to study the lower thermosphere and ionosphere (LTI), we developed and implemented the Monte Carlo simulation framework DIPCont for constructing extrapolation horizons of key LTI observables in Python.

Spacecraft missions

Our other activities revolved around magnetic field measurements of planetary spacecraft missions such as BepiColombo, with Joachim Vogt as co-Investigator of the magnetic field instrument, and Venus Express.

Highlights and impact

- **Multi-scale spacecraft data analysis methodology** — We extended a multi-scale single-satellite FAC analysis method, which was previously developed as part of a doctoral project at the university, and applied it to Swarm magnetic-field data. Combining time series from several spacecraft, we developed and tested another novel scale-sensitive vectorial correlation technique for studying auroral FACs.
- **Validation of ESA Level-2 FAC data products** — We evaluated the properties of different FAC estimators, giving special consideration of spatial scales, and compared them to reciprocal vector estimators based on a local least-squares approach.
- Multi-point estimation of electric currents and magnetic gradients — We developed and implemented a unified gradient estimation framework for general arrays consisting of arbitrary numbers of spacecraft, the rasada algorithm (Robust Adaptive Spacecraft Array Derivative Analysis). We tested and validated the novel algorithm using Cluster and Swarm measurements, and proved it to be statistically robust and suitable for very general array geometries.



Two-dimensional section of Pedersen conductivity in the LTI with extrapolation horizons as modeled by the DIPCont Monte Carlo simulation framework. Synthetic measurements are produced along two satellite orbits (white dashed lines). The parameters of vertical profiles are estimated using measurements within a window (white solid rectangle) around the nodes of a horizontal grid (gray dashed lines). Extrapolation horizons (solid and dotted colored lines) for a set of relative error levels are displayed as contours of a relative deviation measure, here the root- mean-square deviation of the ensemble of extrapolated profiles from the model prediction.

- **Empirical modeling of planetary magnetic fields and current systems** — We constructed a high-resolution statistical model of the solar wind-induced magnetic configuration at Venus and refined it using about 3000 orbits of Venus Express magnetic observations.
- **DFG Special Programme SPP 1788 DynamicEarth** — We contributed to the DFG Special Programme SPP 1788, and presented our findings in June 2022 at the final SPP colloquium in Kühlungsborn.

Space physics research at Constructor University is embedded in national and international programmes and networks. The Swarm satellite mission is central to the DFG Special Programme SPP 1788 DynamicEarth, and Joachim Vogt is co-initiator and topic speaker for Ionospheric Current Systems. The FAC analysis methodology developed at Constructor University contributed to an international team effort dedicated to ionospheric analysis tools, hosted at and funded by the International Space Science Institute (ISSI) in Bern, Switzerland. Our Swarm Level-2 calibration activities are carried out in collaboration with the ISS Bucharest, Romania, and are regularly reported at Swarm Data Quality Workshops organized by the European Space Agency.

Group composition & projects / funding

In 2019-2022, space physics research at Jacobs University was supported by a DFG project, which provided financial support for a post-doctoral researcher. The project SIFACIT offers financial support for a guest scientist, is carried out in collaboration with the ISS Bucharest, and funded by the European Space Agency.

Selected publications

J. Vogt, A. Blagau, C. Bunescu, and M. He (2019). Local least squares analysis of auroral currents, Multi Satellite Analysis Tools - Ionosphere. ISSI/Springer.

C. Bunescu, J. Vogt, O. Marghitu, and A. Blagau (2019). Multi-scale estimation of the field-aligned current density. Annales Geophysicae 37.

A. Blagau and J. Vogt (2019). Multi-point field-aligned current estimates with Swarm. Journal of Geophysical Research 124.

J. Vogt, A. Blagau, and L. Pick (2020). Robust adaptive spacecraft array derivative analysis. Earth and Space Science 6.

M. He, J. Vogt, E. Dubinin, T. Zhang, and Z. Rhong (2021). Spatially Highly Resolved Solarwind-induced Magnetic Field on Venus. Astrophysical Journal 923.

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Organic and Nanoelectronics

Prof. Veit Wagner

Most electronics are based on silicon, but the element is brittle and there is a burgeoning need for novel materials with smart functionality and low production costs. Applications include windows, facades, large TV screens, and wearable or foldable electronics.

Specific themes and goals

The group of Prof. Veit Wagner develops new materials for electronic applications. Through tailored chemical synthesis, we manipulate the basic building blocks of matter or use nano-structuring methods and proper combination of different functional layer to develop materials with new functionalities. For example, we develop are organic solar cells with a nanoscale materials mixture (bulk heterostructure) for improved performance; metal-oxide transistors with potential for flat-panel display applications; and two-dimensional materials such as MoS_2 for hydrogen evolution reaction or for low-power transistors. Through nanoscale materials manufacturing, we can build improved barrier layers to hinder water diffusion or build flexible transparent electrical contacts via carbon nanotube (CNT) or silver nanowire (Ag-nw) networks.

Typically, we wet-chemically deposit the materials, which is a low-cost process and is scalable to large areas. Specifically, we apply spin-coating, doctor-blading or spray pyrolysis. These lab-scale approaches are a stepping stone towards high-volume printing machine manufacturing. For example, we can use a newspaper printing machine with “electronic inks” can to produce large area or large volume electronics.

Highlights and impact

- Organic and Nanoelectronics group activities and results include
- two-dimensional material growth on liquid surfaces
- the development of optimized water-splitting electrodes
- a spray deposition process, which we monitored-clarified with high-speed cameras monitoring and the development developed of a three-dimension scenario analysis that uses automated recognition and machine learning.
- flexible organic electronics

Group composition & projects / funding

The organic and nanoelectronics group consisted of four PhD students and two postdoctoral researchers, and was funded through DFG, private foundations, and industrial cooperation projects.

Selected publications

Rutkowska, C.J. Schürmann, V. Wagner, N. Kuhnert, P.J. Kulesza, W.M. Nau, U. Kortz U. Discrete, Cationic Palladium(II)-Oxo Clusters via f-Metal Ion Incorporation and their Macrocyclic Host-Guest Interactions with Sulfonatocalixarenes. Angewandte Chemie - International Edition 61(25). 2022.

Nisar, T. Balster, A. Haider, U. Kortz, V. Wagner. Growth of ultra-thin large sized 2D flakes at air-liquid interface to obtain 2D-WS2 monolayers. Journal of Physics D: Applied Physics 54(6). 2021.

J. Köhling, V. Wagner. High speed picoliter droplet top-view analysis for advancing and receding contact angles, boiling regimes and droplet-droplet interaction. International Journal of Heat and Mass Transfer 169. 2021.

J. Köhling, V. Jovanov, N. Kalinovich, G.V. Röschenthaler, V. Wagner. Tailored -diketones as effective surface passivation for solution processed zinc oxide thin film transistors. Organic Electronics 86. 2020.

A. Tamang, R. Parsons, U. Palanchoke, H. Stiebig, V. Wagner, A. Salleo, D. Knipp. Color Sensing by Optical Antennas: Approaching the Quantum Efficiency Limit. ACS Photonics 6(8). 2019.

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Biophysics

Prof. Dr. Mathias Winterhalter

Selective permeability is a key feature of biological membranes, and is controlled by the lipid membrane and membrane proteins, which form channels that allow specific molecules to pass through. Our team develops methods to quantify transport across membranes and membrane channels. In particular, we are trying to understand the pathway of antibiotics on a molecular level. At Constructor University, we collaborate closely with the teams lead by Prof. Ullrich Kleinekathöfer, Prof. Werner Nau, and Prof R. Wagner, as well as with our collaboration partner at the Fraunhofer Institute IME in Hamburg.

Specific themes and goals

Nanopore as sensing elements

Biological mesoscopic channels selectively allow small molecules like nutrients to membranes. We characterize the movement of small molecules across a biological channel at the level of a single molecule. This principle can also be used for detection and discriminating between single D- and L- amino acid substitution. Here, our ultimate goal is to sequence peptides or proteins.

Antibiotic uptake in Gram-negative bacteria

Within the Innovative Medicine Initiative, the European Union set up a larger platform called New Drugs for Bad Bugs (www.ND4BB.eu) to support the development of new antibiotics. The Constructor University team was academic leader of the Translocation, a subgroup which involved up to 150 researchers from 28 institutions in Europe and overseas. The project was a private-public partnership with five major pharmaceutical companies bringing in a number of basic questions concerning the current bottlenecks in antibiotic development. In a joint effort, we investigated how to overcome the poor permeability of antibiotics acting against Gram-negative bacteria. Outer membranes are often a rate-limiting step for antibiotics. Chemical optimisation, informed by the permeability properties of lead molecules, can help an antibiotic enter a specific area, and may enhance its antimicrobial activity. In the Translocation group, we developed experimental methods to quantify permeability parameters. Using a toolbox of experimental and in-silico methods, we investigated a wide range of mechanisms that allow antibiotics to pass through membranes, and in future researchers can systematically apply these findings to create optimized compounds. The Translocation consortium provided technologies which address multiple transport mechanisms, such as porins, siderophore uptake systems, and efflux systems. Its results will help to expose targets located in all cellular compartments to antibiotic compounds.

Highlights and impact

- We quantified cephalosporin uptake in vivo vs. in model system
- We discriminated between a single D-L conversation in a small peptide
- We published a review of our antibiotic uptake investigation
- We investigated the influence of LPS on transport and enhanced detection by chemical modification
- We had a weekly webinar — nanoporemeeting2020 — which had between 60 and 120 participants.

Group composition & projects / funding

The group currently comprises nine researchers, and projects are funded by BMBF-JPIAMR (Reset-Me and Translocation-Transfer a Virtual Institute), BMBF (TSenArEO).

Selected publications

M Masi, J Vergalli, I Ghai, A Barba-Bon, T Schembri, WM Nau, D Lafitte, M Winterhalter, JM Pagès. Cephalosporin translocation across enterobacterial OmpF and OmpC channels, a filter across the outer membrane. Comm. Biology 5 (2022) 1059.

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JD Prajapati, U Kleinekathöfer, M Winterhalter. How to enter a bacterium: bacterial porins and the permeation of antibiotics. Chemical Reviews 121 (2021), 5158-5192.

J Wang, R Terrasse, JA Bafna, L Benier, M Winterhalter. Electrophysiological Characterization of Transport Across Outer-Membrane Channels from Gram-Negative Bacteria in Presence of Lipopolysaccharides. Angewandte Chemie International Edition 59 (2020), 8517-8521.

J Wang, JA Bafna, SP Bhamidimarri, M Winterhalter. Small-Molecule Permeation across Membrane Channels: Chemical Modification to Quantify Transport across OmpF. Angewandte Chemie International Edition 58 (2019), 4737-4741.

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School of Computer Science & Engineering

Communication and Signal Processing

Prof. Giuseppe Abreu

Prof Giuseppe Abreu's Wireless Communications and Signal Processing group develops theory and algorithms for advanced wireless communications, wireless localisation, and signal processing for wireless systems, focusing on physical and multi-access layers. Wireless Communications and Signal Processing are integral to our modern society. These fields of electrical engineering allow people to communicate quickly over large distances, and form the basis of GPS navigation, the internet, cloud-based digital storage, and mobile phones, to name a few. Rapid technological developments and new applications, such as the Internet of Things (IoT), Automated Connected Electric Vehicles (ACES), Unmanned Airborne Vehicles (UAVs), Artificial and Augmented Reality (AR/VR) and Artificial Intelligence (AI), are now driving demands for wireless systems and signal processing technologies capable of delivering and processing huge volumes of data at extremely high speeds to a large number of devices.

Specific themes and goals

Beyond 5G and 6G Systems

The first generation (1G) cellular systems was a public extension of cordless telephony, based on an adaptation of analog trunk radios. The second generation (2G) introduced digitalisation and data compression, while the third (3G) was the first to feature purpose-built PHY and MAC technologies to support large numbers of users and provide voice and data services over cellular infrastructures at affordable cost to the general population. The fourth generation (4G) "long-term evolution" (LTE) system surpassed the full range of data services previously offered by cable networks. The most recent, fifth generation (5G) system was designed to provide a larger degree of flexibility in terms of data rate, latency, penetration, user capacity and link quality, enabling high-speed wireless internet, among other things. We are developing advanced variations of 5G and the upcoming 6G systems, which will incorporate several advanced solutions such as full-duplex radio, non-orthogonal multiple access, rate-splitting multiple access, and sub-THz transmission.

V2X Communications

Current wireless-based systems serve people primarily through their smartphones. A large portion, if not the majority, of future wireless traffic will comprise vehicles, due to autonomous connected driving and/or communications being routed by vehicles, as there is a trend towards small and moving cell architectures. This paradigm of vehicle-to-anything (V2X) communications requires training advanced technologies such as full-duplex radio, non-orthogonal multiple access, and rate-splitting multiple access, to fast time-varying channels. Our research group is actively investigating this topic.

Wireless Localization and Awareness

The recent expansion of wireless localization services, initially possible only via (GPS), to mobile (cellular) and even personal (WiFi, Bluetooth and UWB) systems, has greatly enriched the experience of users and made wireless connectivity an essential tool of modern life. Still, the accuracy of current navigation systems is too poor to enable autonomous driving; 3D tracking in industrial environments is still unreliable; and consumer-friendly indoor localization services are not adequate. With a long track-record in the area, which includes a successful start-up (see https://zigpos.com), our research group continues to push the boundaries of wireless localization technologies towards the more general concept of wireless awareness systems.

Physical-layer Wireless Security

As the world becomes more connected and automated, we are increasingly exposed to cybersecurity threats. While a person today may interact daily with a few wireless devices (a laptop, a mobile phone, perhaps a smart watch), in the future people will use dozens of devices (wearables, ambient sensors, vehicles), sometimes unknowingly. All of these devices will be autonomous and wirelessly discoverable. This scenario renders current high-layer security protocols impractical, requiring new mechanisms that rely on physical-layer features to provide data security. Our group develops algorithms and hardware that provide seamless end-to-end security.

Highlights and impact

- Two PhD candidates graduated, both Summa Cum Laude: Dr. Stoica (now with Lenovo Research, Germany) and Dr. Iimori (now with Ericsson Research, Japan);
- In 2022, Prof. Abreu became an Associated Editor of the journals IEEE Signal Processing Letters and the IEEE Wireless Communication Letters, after serving a five-year term as Executive Editor of IEEE Transactions on Wireless Communications (2017 to 2021);
- Led a large industrial project, with the group producing 14 patents.

Group composition & projects / funding

During the period 2019-2022, the Wireless Communications and Signal Processing group included six PhD students, supported by an industrial project sponsored by Continental AG and the EU-Japan project ORACLE, which was sponsored jointly by the BMBF and the JSP.

Selected publications

Hyeon Seok Rou, Hiroki Iimori, Giuseppe Abreu, David González G., and Osvaldo Gonsa: "Scalable Quadrature Spatial Modulation," IEEE Transactions on Wireless Communications, Aug. 2022.

Omid Taghizadeh, Tianyu Yang, Hiroki Iimori, Giuseppe Abreu, Ali Cirik, and Rudolf Mathar: "Quantization-Aided Secrecy: FD C-RAN Communications with Untrusted Radios," IEEE Trans. on Wireless Communications, Apr. 2022.

Liming Hou, Feng Lian, Shuncheng Tan, Cong'an Xu and Giuseppe Abreu: "Robust Generalized Labeled Multi-Bernoulli Filter for Multitarget Tracking with Unknown Non-stationary Heavy-tailed Measurement Noise," IEEE Access, vol 9, Jul. 2021.

Naoya Hirosawa, Hiroki Iimori, Koji Ishibashi and Giuseppe Abreu: "Minimizing Age of Information in Energy Harvesting Wireless Sensor Networks", IEEE Access, Nov. 2020.

Razvan-Andrei Stoica, Giuseppe Abreu, Takanori Hara and Koji Ishibashi: "Massively Concurrent Non-orthogonal Multiple Access for 5G Networks and Beyond", IEEE Access, Jun. 2019

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Robotics

Prof. Andreas Birk

Prof. Andreas Birk's group investigates the Artificial Intelligence (AI) side of robotics, especially with respect to machine perception and world-modeling for intelligent autonomous systems. It also researches fundamental methods, such as robust registration in 2D and 3D, and real-world applications in unstructured environments, such as in marine systems, search and rescue operations, and logistics.

Specific themes and goals

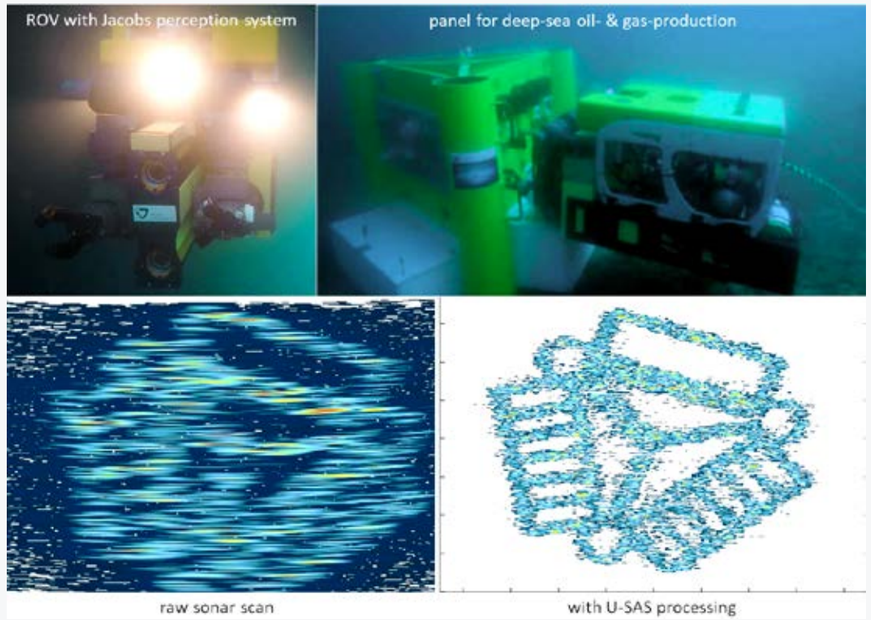
Machine perception is essential for the operation of intelligent systems. It allows robots to recognise objects and locate them in space, as well as undertake automated world-modeling, such as generating maps. But many state-of-the-art methods are designed to operate in benign conditions. This makes them ill-suited to applications in which, for example, sensors can only deliver poor quality, noisy data or in environments with few or ambiguous structures. There are many possible reasons for these limitations, ranging from the quality of the sensors through to the environment the robot is operating in. Our group investigates and develops robust methods to cope with these limitations.

Highlights and impact

- The group developed and improved methods to represent, recognize, and localize objects. Among others, we derived a numerically stable formulation for superquadrics, which are a special family of 3D shapes. They are particularly important when training machines to perceive curved surfaces. Our results were published in the highest-ranking journal in the field of Artificial Intelligence, IEEE Transactions on Pattern Analysis and Machine Intelligence.
- In ongoing research, we are developing a novel way to process sonar data. Sonar is an essential sensor for underwater applications as it provides data under bad or even no visibility conditions and over longer distances. But its spatial resolution depends on a combination of factors. The current state-of-the-art synthetic aperture sonar (SAS) has a number of constraints on the way it can be used. We developed an unconstrained version for the processing of synthetic aperture sonar (U-SAS), which can be computed on arbitrary trajectories and without navigation sensor data. The U-SAS leads to higher quality sonar images without the constraints of the current systems. The innovation could render very costly additional navigation sensors redundant and enable sonar-carrying vehicles to conduct more complex missions.
- An international survey showed that during the COVID pandemic, robotics and automation instructors switched to online education even for lab courses and other hands-on activities. While this method had its drawbacks, instructors felt that several aspects of online education boosted learning, and should be retained going forward. The results are published in Robotics and Automation.

Group composition & projects / funding

- Our U-SAS project was financed by the Deutsche Forschungsgemeinschaft (DFG).
- The Bundesministerium für Bildung und Forschung (BMBF) within the eHeritage program funded a project which created a 3D digitization of the memorial Submarine Bunker Valentin with air-, ground-, and underwater-robots. On the technological side, the project was interesting due to the size of the object and its complex structures, including among others flooded basement areas that are completely inaccessible — even for professional human divers.
- The group undertook three research projects related to education in the context of the B3 program of the Jacobs Foundation. An important goal was to explore the prospects and limits of online education, especially in the context of laboratory and other hands-on education.
- In the time covered in this report, the group had two postdocs and six PhD students.



Remotely Operated Vehicles (ROV) are essential for daily operations in oil- and gas-production (top). The effects of U-SAS to improve sonar data are illustrated here with a top-view onto the infrastructure with which the ROV interacts (bottom)

Selected publications

Andreas Birk. Seeing through the forest and the trees with drones: Signal-processing of thermal images that are autonomously collected by a drone detects people in densely occluded forests. Science Robotics, 6(55)

Arturo Gomez Chavez, Andrea Ranieri, Davide Chiarella, Andreas Birk. Underwater Vision-Based Gesture Recognition - A Robustness Validation for Safe Human-Robot Interaction. IEEE Robotics and Automation Magazine (RAM), 28 (3), pp. 67- 78, DOI: 10.1109/MRA.2021.3075560, 2021

Madhura Thosar, Christian A. Mueller, Georg Jäger, Johannes Schleiss, Narender Pulugu, Ravi Mallikarjun, Sai Vivek Rao Jeevangekar, Andreas Birk, Max Pfingsthorn, Sebastian Zug. From a Multimodal Property Dataset to Robot-centric Conceptual Knowledge About Household Objects. Frontiers in Robotics and AI, 2021

Andreas Birk and Dora Simunovic. Robotics Labs and Other Hands-On Teaching During COVID-19: Change Is Here to Stay? IEEE Robotics and Automation Magazine (RAM), 28 (4), pp. 92-102, 2021

Narunas Vaskevicius, Andreas Birk. Revisiting Superquadric Fitting: A numerically stable formulation. IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI), 41(1), pp.220-233, 2019

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Transmission Systems

Prof. Dr.-Ing. Werner Henkel

The modern online world relies on the transmission of information. Our group has a strong foundation in communications and coding, which we apply to a diverse range of problems, from joint source-channel coding, jamming and anti-jamming designs, and physical-layer security, to even the analysis of the DNA. We investigate various aspects of transmission systems, covering all kinds of channels, be it wireless or wireline. We particularly specialize in DSL, powerline communications, wireless LAN, and satellite communications.

Specific themes and goals

Physical-layer Security

We are currently concentrating on the key generation for frequency-division duplexing systems, and are possibly the first group to realize that despite the use of different frequency ranges for both directions, still, there is a reciprocity in the channel properties. This is due to the fact that the paths between two users trying to communicate are essentially the same. We have shown that phase differences between received signals arriving at two antennas can directly be used to generate cryptographic keys. We are currently extending the work to key distribution for multiple users or devices. We have also used power-line connections that provide reciprocity to generate new keys. However, to generate new keys all the time, we showed that one would have to randomly change the channel, which is not possible for power lines as the channel is within cables laid out in walls, ceilings, and floors of buildings. Randomisation is however possible by, for example, changing one end randomly at unused wires of the three-wire power-line system. This leads to sufficient modifications and the required common randomness for physical-layer key generation. Such common randomness in physical-layer key generation can be harvested very cheaply compared to quantum key generation, which is essentially based on the same principle.

Channel coding

We incorporated other aspects of communications into the decoding of LDPC codes, one of the major modern coding schemes. This means integrating source coding, equalization, and the treatment of non-stationary impulse noise by dedicated adaptation or integrating into the underlying code graph.

DNA analysis

By regarding mutations as a communication channel and applying typical tools from information theory, coding, and machine learning, we were able to formally derive the very irregular mapping between base triplets (codons) and amino acids. Additionally, we directly related chemical relations between amino acids to the probability of mutations transferring one into the other. Furthermore, using parameters from information theory and probability theory, we determined which genes are essential for an organism's survival.

TEMPEST

We also work to detect and understand compromising radiation that is emitted by, for example, circuitry. We are developing methods to make use of radio-frequency emissions of circuitry to first determine points of strong and usable egress and furthermore, determine the type of signal causing the emissions. We are also working to localize special function components, such as synchronization headers. In the end, we hope to possibly synchronize the signal and detect the underlying data. Furthermore, we are also working on countermeasures, like intentional jamming that could make it difficult or impossible to detect such signals.

Highlights and impact

- We have registered four patents in physical-layer key generation.
- Werner Henkel was invited to give one of the opening talks of an National Science Foundation workshop in the United States, which was set up to investigate joint projects between genetics and engineering in the US.
- TEMPEST activities are part of a publicly funded project in cooperation with another university and a company.
- Among other conferences, Werner Henkel is constantly invited as a TPC member of the security-related sessions of IEEE ICC and Globecom. After having assisted in organizing the ISTC coding conference, he has continuously served in the TPC.

Group composition & projects / funding

In 2019-2022, the group comprised three to five PhD students and research associates, funded through four different DFG projects and a BMWi-funded collaborative project.

Selected publications

W. Henkel, A. Turjman, H. Y. Kim, and H. Qanadilo, "Common Randomness for Physical-Layer Key Generation in Power-Line Transmission," IEEE ICC 2020 (CISS), Dublin, Ireland, 2020.

W. Henkel, H. Y. Kim, A. Turjman, and M. Bode, "A Simple Physical-Layer Key Generation Scheme for Power-Line Transmission," IEEE ISPLC, Aachen (hybrid), Germany, October 26-27, 2021.

W. Henkel and M. Namachanja, "A Simple Physical-Layer Key Generation Scheme for FrequencyDivision Duplexing," ICSPCS, online, December 13-15, 2021.

E. O. Torshizi, U. Uprety, and W. Henkel, "Highly Efficient FDD Secret Key Generation using ESPRIT and Jump Removal on Phase Differences," IEEE CNS (CPS), Austin, TX, USA (hybrid), October 5, 2022.

E. O. Torshizi and W. Henkel, "Reciprocity and Secret Key Generation for FDD Systems using NonLinear Quantization," IEEE Globecom, 7th IEEE Wireless-Sec workshop, Rio de Janeiro, Brazil (hybrid), December 4-8, 2022.

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Nanoelectronics

Prof. Mojtaba Joodaki

Nanoelectronics is a major technology boomer in the 21st Century, with many current applications and enormous potential to alter humanity's future in areas such as electronics, computers, information technology, aerospace defense, and consumer goods. Our research interests lie at the interface of high-frequency engineering and nanoelectronic devices and materials. We focus on developing devices, circuits and systems for memories, sensors, energy harvesting and communication applications.

Specific themes and goals

Organic solar cells characterization and modeling

In recent years, there have been impressive breakthroughs to enhance the structure of organic solar cells (OSCs) in order to improve the performance. The power conversion efficiency of polymer solar cells has increased from 3% in 2001 to 18.2% in 2021, and these thin, flexible, eco-friendly and low-cost photovoltaic devices are promising for a wide range of applications, such as the Internet of Things, sensors and wearable electronics. Theoretical analyses and characterizations of OSCs are of great scientific and economic value. We have undertaken valuable work in this area, with our results published in several high-impact journals.

Thin-film microwave, mm-wave and THz devices

Flexible and non-flexible thin-film electronic components are key to improving people's quality of life. Such devices can be used on infrastructure, vehicles and the human body for control, monitoring and energy harvesting purposes. They can also be cheap to make. For example, flexible substrates, such as plastic, are cheaper compared to crystal wafers like silicon wafers. Thin-film sensors and energy harvesters are two important building blocks of electronic circuits and systems, and these are interesting topics of future research, complementing our expertise. In addition, we are very eager to work on low cost wireless sensors or antennas for medical and Internet of Things (IoT) applications.

Electromagnetic shielding

In the field of electromagnetic compatibility (EMC), shielding is becoming an increasingly important topic, as our technology and circuitry becomes more sensitive and sophisticated. However, shielding requires air ventilation, input/outputs and other means of connections between either side of the shields, and these gaps cause emission leakage and degraded shields. Recently, our research group has undertaken successful shielding analyses and measurement of metal enclosures with apertures on different walls. We developed a method of calculating shielding effectiveness (SE) with respect to a metallic enclosure with arbitrary shape apertures on different walls. With our method, there is no need for antennas and reverberation chambers.

Hetero-integration and packaging of microwave and optical devices

This area of research consists of three parts. The first technological part focuses on implementing techniques in micro and nano electro-mechanical systems techniques. The goal is to integrate high power µ-wave or optical devices based on different materials into a single substrate. The second part deals with the electrical, optical, electro-thermal, and electro-thermo-mechanical modeling and simulation of new packaging structures; the third part concentrates on characterizing and measuring integrated devices, as well as an investigation of packaging environmental effects on their electrical and optical behaviors.

Flexible electronics especially high frequency flexible devices and circuits

Although electronic circuits are often firm and rigid, some may need to be bent to fit into a particular product while some others may need to undergo continuous flexing if they are moving parts. Specifying the flexible circuit materials and characterizing them for microwave and mm-wave applications are vital for their development. Therefore, we are investigating the flexibility and mechanical properties of circuit materials to determine the extent to which a circuit board can tolerate bending and flexing.

Highlights and impact

Prof. Joodaki joined Constructor University in 2020. Since then, one of his PhD students has graduated successfully. His group has also initiated industry collaborations with HELLA GmbH in Bremen and Schaeffler Automotive GmbH in Buehl.

Group composition & projects / funding

Prof. Joodaki research team is currently composed of one PhD student at Constructor University and three PhD students at his previous university.

Selected publications

Ghorab M, Fattah A. and Joodaki M., Fundamentals of Organic Solar Cells: A Review on Mobility Issues and Measurement Methods, Optik-International Journal for Light and Electron Optics, vol. 267, p. 169730, 2022.

Ghorab M, Fattah A. and Joodaki M., Tensile Mechanical Strain Effects on the Electrical Characteristics of Roll-to-Roll Printed OSC, IEEE Journal of Photovoltaics, vol. 12, no. 3, pp. 737-743, 2022.

Hsu C.-C., Zhang X.-Z, Jhang W.-C., Cheng C.-W., Wu Y.-M., Tsaiand J.-E and Joodaki M., Write-Once-Read-Many-Times Characteristics of CuO Layer with Ag Conductive Bridges, Semiconductor Science and Technology, vol. 36, no. 9, p. 095016, 2021.

Feghhi R. and Joodaki M., Odd-Mode Instability Analysis of fT-Doubler Hybrid Power Amplifiers Based on GaN-HEMT, IEEE Trans. on Circuits and Systems II: Express Briefs, vol. 68, no. 4, pp. 1193-1197, 2021.

Ghaneizadeh A., Joodaki M., Börcsök J. and Mafinezhad K. Anal sis, Design and Implementation of a New Extremely Ultra-Thin 2D-Isotropic Flexible Energy Harvester Using Symmetric Patch FSS, IEEE Trans. on Microwave Theory and Techniques, vol. 68, no. 6, pp. 2108 -2115, 2020. doi: 10.1109/TMTT.2020.2982386.

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Complex Systems

Prof. Stefan Kettemann

Complex Systems are composed of many constituents which interact with each other, and include technical systems, such as power grids; physical systems, such as quantum spin systems or quantum glasses; and natural systems like ecosystems. The interactions between the constituents can give rise to new, emergent phenomena which have very different properties from their individual constituents. We model complex systems through networks where nodes represent the constituents and link the interactions. This network perspective on complex systems often reveals insights between different disciplines.

Specific themes and goals

Disordered Quantum Spin Systems

We investigate disordered systems with local quantum degrees of freedom, such as spins or tunnel systems with long-range interactions. Such systems exist in metals with magnetic impurities, doped semiconductors, and glasses and can be used as qubits for quantum computers. In order to control and read out qubits, we need a detailed understanding of their properties. The combination of disorder and long-range interaction makes this a challenging fundamental problem (funded by DFG in cooperation with S. Haas, USC LA, R. Bhatt, Princeton Univ. in the United States).

Metal-insulator Transitions

We are conducting research into the theory of metal-insulator transitions in disordered quantum systems. This requires the nonperturbative modeling of localisation, multifractality of electron wave functions, and dynamic local magnetic moments. We are undertaking this research in collaboration with K. Slevin at Osaka University in Japan, T. Ohstuki Sophia University in Japan, and K.-S. Kim at Postech in South Korea).

Inhomogeneous Superconductors

We are researching the theory of inhomogeneous superconductors and the crossover between BCS-Superconductivity and Bose-Einstein condensation. We are investigating novel quantum states of matter at the BCS-BEC crossover in a two-dimensional crystalline material at the atomic scale. We are exploring new physics at the junction of the BCS-BEC crossover regime such as enhanced critical current and novel Andreev bound states. We are undertaking this research in collaboration with S. Haas at the University of Southern California Los Angeles in the United States; G. Raj at Hamburg University in Germany; and X. Chen and S.-H. Ji at Tsinghua University in China.

Dynamics and Stability of Transmission and Distribution Grids

We are modeling and analyzing the propagation of disturbances in transmission and distribution grids. Building on new insights, we aim to develop appropriate control strategies to prepare for the transition towards high shares of renewable energy. We employ response theory combined with spectral analysis of the nonlinear coupled differential equations, together with numerical differential equation solvers and deep learning methods. This research is funded by BMBF-CoNDyNet and CoNdyNet2 in cooperation with H. Meyer-Ortmanns, G. Brunekreeft and several institutes including the Potsdam-Institut für Klimafolgenforschung and Forschungszentrum Jülich in Germany.

Fig. 1

Fig. 2

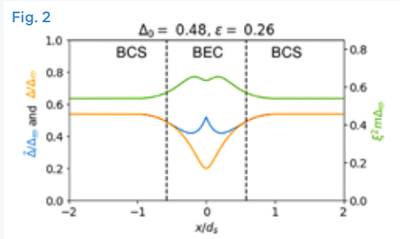

Fig. 3

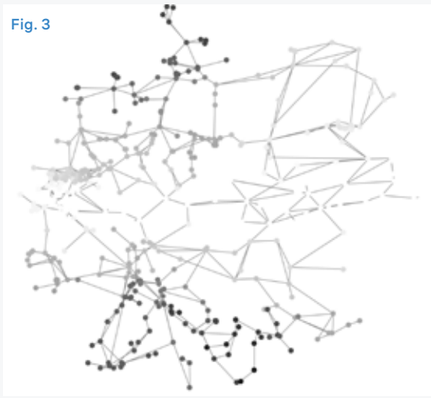

Fig. 1: A Rainbow State: Discovered to be a highly entangled Eigenstate of Disordered Spin Chain with Long Range Couplings [1]

Fig. 2: BCS-BEC crossover at a superconducting pn-junction [2].

Fig. 3: Eigenstate of Graph Laplacian of German Transmission Grid [3,4,5]

Highlights and impact

- We discovered novel excited states, so called Rainbow states, with supercritical entanglement in disordered quantum spin chains with power-law long-range antiferromagnetic couplings, see Fig. 1 and Ref. [1].
- We discovered spatial BCS-BEC crossover in superconducting pn-junctions, see Fig. 2 and Ref. [2].
- We developed a real-time response theory with delayed control for the 3rd model of transmission grids, see Fig. 3 and Refs. [3,5].
- We modeled and conducted a disturbance analysis of transmission grids of African countries, including Nigeria, Ghana, and Rwanda [4].
- We co-organized the international conferences Localisation 2020 and Localisation 2022 in Sapporo, Japan and coedited its Proceedings in Annals of Physics in memory of P. W. Anderson, Princeton University.

Group composition & projects / funding

In 2022 the Complex Systems Group consisted of one Postdoctoral fellow and two PhD students funded by the joint BMBF project CoNDyNet and one DFG individual grant.

Selected publications

Y. Mohdeb, J. Vahedi, S. Kettemann, Excited-Eigenstate Entanglement Properties of XX Spin Chains with Random Long-Range Interactions, Phys. Rev. B 106, 104201 (2022).

A. Niroula, G. Rai, S. Haas, S. Kettemann, Spatial BCS-BEC Crossover in Superconducting pnJunctions, Phys. Rev. B 101, 094514 (2020).

P. C. Böttcher, A. Otto, S. Kettemann, C. Agert, Time delay effects in the control of synchronous electricity grids, CHAOS 30, 013122 (2020).

K. P. Nnoli, S. Kettemann, Spreading of Disturbances in Realistic Models of Transmission Grids: Dependence on Topology, Inertia and Heterogeneity, Scientific Reports 11, 23742 (2021).

D. Witthaut, F. Hellmann, J. Kurths, S. Kettemann, H. Meyer-Ortmanns, M. Timme, Collective Nonlinear Dynamics and Self- Organization in Decentralized PowerGrids, Reviews of Modern Physics, 394, 015005 (2022).

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Marine Systems and Robotics

Prof. Dr. Francesco Maurelli

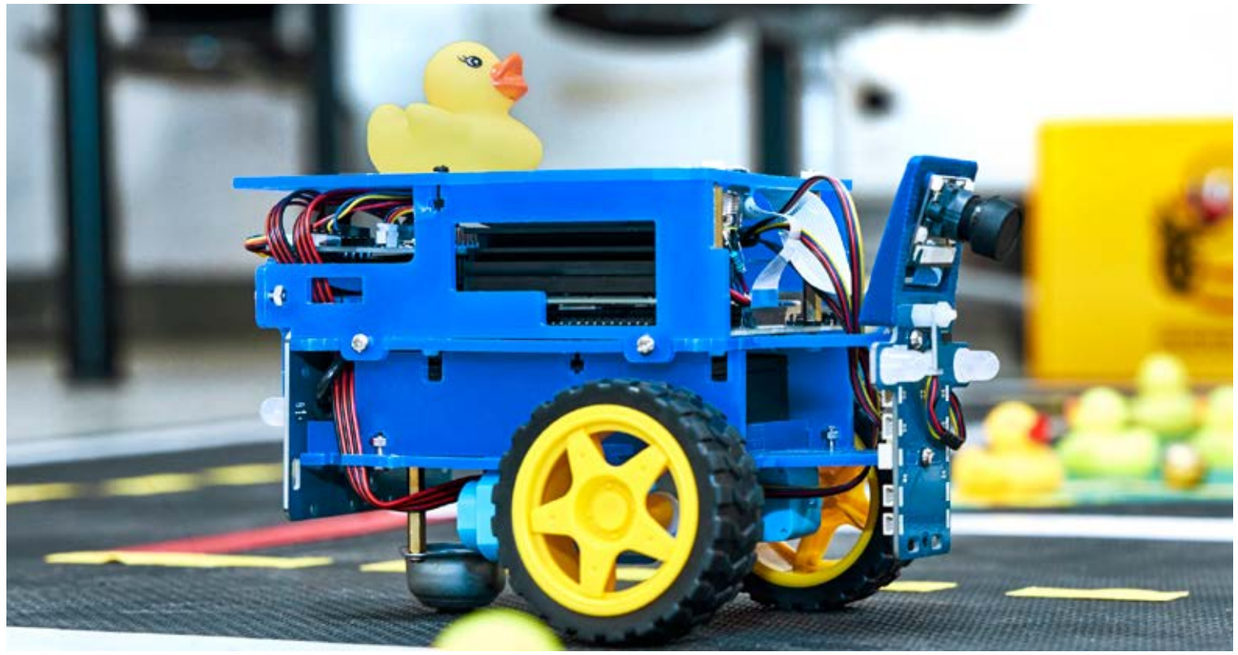
In Marine Systems and Robotics, Prof. Francesco Maurelli's group applies robotics, automation, artificial intelligence and algorithmic approaches to autonomous robots operating in the marine domain — whether underwater, on the surface, or above the water. Such research can be applied to, for example, ocean exploration, subsea installation management, maritime traffic automatisation, and improving the safety and efficiency of operations at sea. While many techniques in this field are tailored to the marine domain, its robust intelligent systems can be applied to other areas. The group is involved in research projects spanning a variety of domains — from underwater to space — using a diversity of research methodologies, from theoretical scientific research to industrial applications to operations in the field.

Specific themes and goals

The group's main research focus is on developing and improving intelligent capabilities for autonomous platforms, with an emphasis on positioning and navigation methods, advanced filtering and data fusion, fault management, and perception. Its researchers use sensors such as inertial, acoustic, video and LIDAR to aid informed and autonomous real-time decision-making. With a strong focus on autonomy, the group works on all the underlying aspects which make systems more intelligent. Ultimately, the group applies machine Intelligence combined physical systems to different domains, from underwater to space.

Highlights and impact

- We developed a fault management system in autonomy architecture, focusing on navigation errors in autonomous underwater vehicles that are generated by thruster or sensor failure;
- We investigated improvements in underwater navigation and localisation, adopting an active approach and embedding the planning system in the problem. We applied a semantic representation of the environment. In addition to individual research papers, we also published an extensive review on AUV localisation;
- We used new deep learning approaches to effectively identify underwater features. We undertook research in in the Mediterranean sea, analyzing volcanic natural gas emissions;
- In a work with the European Space Agency, we designed a novel robotics system and its autonomy architecture for exploring tunnels of the Moon, a potential location for human colonization;
- The pandemic radically changed aspects of education, and we worked on remote education and remote access to robotics infrastructure;
- Sustainability is a key question of fundamental importance, and we lead an international project linking the United Nations Sustainable Development Goals with marine systems and marine robotics;
- Frequent outreach and citizen-science activities brought our research closer to the general public and to young students; and
- Our proposals on autonomous driving in collaboration with the City of Bremen have the potential to create long-term impact in the local community.



Group composition & projects / funding

The group includes Prof. Maurelli; four PhD students, one of whom is close to their thesis proposal defense and three who have just started; and one lab technician. Two postdocs were also involved in projects in the 2019-2022 period and have now moved to their next step in their careers.

Selected publications

Francesco Maurelli, Szymon Krupinski, Antonio Pascoal, Nikola Miskovic, Kostas Kyriakopolous, Pere Ridao, Maarja Kruusmaa, Ralf Bachmayer, "IMPACT: a strategic partnership for sustainable development in marine systems and robotics", 2020 IEEE/ITU International Conference on Artificial Intelligence for Good (AI4G)

F Maurelli, S Krupiński, X Xiang, Y Petillot; AUV localisation: a review of passive and active techniques; International Journal of Intelligent Robotics and Applications, 1-24, 2021

F Maurelli, E Dineva, A Nabor, A Birk; Robotics and intelligent systems: a new curriculum development and adaptations needed in coronavirus times; International Conference on Robotics in Education (RiE), 2021

D Borrmann, A Nüchter, A Bredenbeck, J Zevering, F Arzberger, ..., F Maurelli; Lunar Caves Exploration with the DAEDALUS Spherical Robot; Lunar and Planetary Science Conference 2021

F Maurelli, S Mazhar, SA Mehdi; Exploration of Canals: a German-Pakistani collaboration in education and research in marine robotics; OCEANS 2021: San Diego–Porto

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Theoretical Physics: Complex Systems

Prof. Hildegard Meyer-Ortmanns

Complex systems comprise both natural and artificial systems and include, for example, neuronal networks in the human brain, ecological systems with a high biodiversity, and power grids. While vastly different, they have some characteristics in common: they contain nonlinear interactions between many individual constituents, often based on feedback reactions, and different sources of intrinsic uncertainties. These features make the control and prediction of the systems' behavior challenging. Prof. Hildegard Meyer-Ortmanns' group investigates these systems and uses tools from statistical physics, nonlinear dynamics and network science to analyze their behavior.

Specific themes and goals

Aging of dynamic systems

We are interested in artificial and natural systems, for which we distinguish two types of dynamic processes: production processes that require high-precision manufacturing, and the repair processes needed to maintain this precision and thus guarantee the quality or functioning of products. The challenging question is whether error accumulation can be avoided and if so, under what conditions if a finite amount of resources is accessible in a finite interval of time. Inspired from biological experiments, the costs are assumed to diverge for perfect precision, thus, errors are inherent to both production and repair processes. If errors accumulate beyond a tolerable threshold in the course of time, we term this accumulation process "aging of the dynamic system".

Criticality in dynamical systems

Criticality is assumed to be one of the important organization principles of living organisms. It includes, for example, high sensitivity to perturbations, critical slowing down and characteristic scaling behavior. For biological or artificial systems, which perform computations, operating near critical points has functional advantages for information processing. Criticality in brain dynamics is currently a hot topic. We have searched for critical phenomena in heteroclinic dynamics, which researchers use to describe in particular transient cognitive processes.

Physical basis of cognitive processes

Cognitive processes in the human brain are transient, but usually exactly reproducible. A fundamental question in neuroscience concerns physical mechanisms that allow dynamics which is transient and reproducible at the same time. We are exploring heteroclinic dynamics as a possible framework, in which signals are forwarded in a well-controlled temporal order. In neuronal systems, we assume that information is encoded both in space and time coordinates, in particular also in the temporal order of spiking neuronal populations.

Stability of power grids

Renewable energies account for a larger percentage of power supply than ever before, but wind and solar are intrinsically uncertain and this uncertainty poses challenges for the management and performance of the grid. Nowadays, consumers can also act as producers and feed locally produced power into the distribution grid. In addition, the energy market is becoming increasingly delocalised with less centralized control. In view of these challenges, we developed algorithms which allow a fast estimation of the state of the grid, fast enough to be applicable to large grids. Moreover, we estimate the frequency of rare blackout events to quantify what 'rare' means. For the energy market we propose statutory and economic measures to stabilize it.

Highlights and impact

- We analyzed the conditions under which aging in the sense of error accumulation can be kept below a tolerable threshold. We found that the fate of the system (as to whether this threshold is exceeded or not) depends on the relationship between the costs and the required precision.
- We identified typical features of critical phenomena at bifurcation points in networks, at which heteroclinic dynamics are ongoing at each site of a spatial grid.
- We have shown how the information inherent in the temporally ordered neuronal excitation patterns can be processed over space when a few pacemaker cells entrain many other cells to synchronize their oscillations with the pacemakers. Our description realizes in common to brain dynamics: these are processes which are hierarchically organized locally, but ongoing in parallel in different areas of the brain.
- Our analysis of the volatility of the energy market with tools from statistical mechanics and nonlinear dynamics complements the perspective of economists. It points to collective phenomena such as tipping points. Intuitively, these features are not predictable, neither are they understandable from the mere perspective of economics. understandable from the mere perspective of economics.
- Prof. Meyer-Ortmanns contributed to two books, one entitled From Electrons to Elephants and Elections, published in 2022, the other one entitled The Energetics of Computing in Life and Machines, published in 2019.

Group composition & projects / funding

The Statistical Physics/Nonlinear Dynamics group, headed by Prof. Meyer-Ortmanns, comprised one postdoc and two PhD students. Project funders included the BMBF and the DFG.

Selected publications

M. Voit and H. Meyer-Ortmanns, How aging can be an unavoidable fate of dynamical systems, New J. Phys. (2019).

M. Voit and H. Meyer-Ortmanns, Emerging criticality at bifurcation points in heteroclinic dynamics, Phys. Rev. Res. 2. (2020).

B. Thakur and H. Meyer-Ortmanns, Heteroclinic units acting as pacemakers: Entrained dynamics for cognitive processes, J. Phys. Complex. (2022).

T. Ritmeester and H. Meyer-Ortmanns, The cavity method for minority games between arbitrageurs on financial markets, J. Stat. Mech. (2022).

D. Witthaut, F. Hellmann, J. Kurths, S. Kettemann, H. Meyer-Ortmanns, M. Timme, Collective nonlinear dynamics and self-organization in decentralized power grids, Rev. Mod. Phys. (2022).

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Computer Networks and Distributed Systems

Prof. Jürgen Schönwälder

Computer networks are a key enabling technology. The Internet has not only changed the global economy — it also affects our private lives in many ways. The Internet has become a critical infrastructure, often considered alongside food, water, and energy supply. To provide robust and resilient network services that can scale to support large numbers of users, it is necessary to design the network and services as distributed systems that can tolerate failures, dynamically shift work loads, and stay responsive even in the face of attacks on the infrastructure. The group of Prof. Jürgen Schönwälder researches computer networks and distributed systems.

Specific themes and goals

Standards

The Computer Networks and Distributed Systems (CNDS) group has been involved in the development of international standards for more than 15 years. These standards enable robust automation of computer network operations. This includes standards that support the configuration of large, decentralized collections of networking devices as well as standards that enable the efficient monitoring of networking infrastructure.

Measurement systems

Recently, we have focused on the development of standards for large-scale distributed measurement systems that can provide a global view on Internet performance. Since the Internet is essentially a large collection of networks that are all under different administrative control (also known as autonomous systems), regulators are interested in unbiased independent measurements that describe network performance from a large collection of independent and decentralized vantage points. Such large-scale measurement activities are important to understand how technical changes, that are deployed incrementally, impact network performance and ultimately the experience delivered to users and businesses.

Resilient, secure technologies

Our overall goal is to develop technologies that help to provide resilient and secure services over the Internet even in the face of failures and attacks on the infrastructure. Furthermore, we are interested in novel technologies that can bolster the security of computing elements within complex distributed systems. Increasingly, our research focuses on device, network, and system security aspects, with a special focus on secure embedded systems.

Highlights and impact

- We worked on an architectural framework, which introduced an extensible set of configuration datastores for network protocols that allow for the automatic changing of device configuration. These datastores can, for example, differentiate between the intended configuration of a device and the currently applied configuration of a device. Exposing these differences is necessary to monitor device behavior and to implement robust automated control loops. In 2019, we completed this work, which we performed in close collaboration with industrial partners. We published two more proposed standards that support the new architecture by defining extensions of the NETCONF and RESTCONF protocols.
- The OpenWRT operating system is a Linux-based operating system for embedded devices with a very small memory footprint. It is popular on networking devices such as access points or small-scale home routers. We designed a RESTCONF implementation that specifically targets the OpenWRT system. A paper describing the design of our implementation received the best experience paper award at IEEE/IFIP NOMS 2020.
- We measured how the deployment of the Internet Protocol version 6 (IPv6) affects Internet services delivered to end users. In 2019, we published a summary of our findings on how the transition affects web sites accessible by both the old and the new version of the Internet protocol.
- We investigated how metamorphic testing can be applied to homomorphic cryptography. Homomorphic encryption schemes allow us to perform computations on encrypted data without revealing the data. Metamorphic testing is a property-based software testing strategy that does not require oracles to predict expected test outcomes. By applying metamorphic testing to an open-source homomorphic cryptography library, we were able to reveal several shortcomings.
- With an increased interest in security, we started to investigate active malware analysis techniques. We executed malware samples in a sandbox environment to detect malicious behavior. To be effective, we had to stimulate the malware samples since specific user action or network input is often required to trigger malicious behavior. A challenge in active malware analysis techniques is to generate suitable inputs that are likely to trigger malicious behavior. We are investigating learning techniques to generate these inputs.

Group composition & projects / funding

The research of the CNDS group has been largely funded by EU grants. The EU project CONCORDIA (2019-2023) provides funding for a PhD student as well as support for external PhD students and collaborators of associated research groups.

Selected publications

V. Bajpai, J. Schönwälder: A Longitudinal View of Dual-stacked Websites: Failures, Latency and Happy Eyeballs. IEEE Transactions on Networking 27(2), April 2019

M. Björklund, J. Schönwälder, P. Shafer, K. Watsen, R. Wilton: RESTCONF Extensions to Support the Network Management Datastore Architecture. RFC 8527, March 2019

M. Granderath, J. Schönwälder: A Resource Efficient Implementation of the RESTCONF Protocol for OpenWrt Systems. 17th IEEE/IFIP Network Operations and Management Symposium (NOMS 2020), April 2020

M. Wolf, J. Schönwälder: Applying Metamorphic Testing to Homomorphic Cryptography. 6th IEEE/ACM International Workshop on Metamorphic Testing (MET 2021), June 2021

A. Hota, J. Schönwälder: A Bayesian Model Combination based approach to Active Malware Analysis. IEEE Conference on Cyber Security and Resilience Workshop on Data Science for Cyber Security, 2022.

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School of Business, Social & Decision Sciences

Bremen International Graduate School of Social Sciences (BIGSSS)

Prof. Dr. Adalbert F. X. Wilhelm — Vice Dean
Prof. Dr. Ulrich Kühnen — Academic Chair

The Bremen International Graduate School of Social Sciences (BIGSSS) is a leading school of doctoral training in the social sciences. As an inter-organisational unit of University Bremen and Constructor University, it provides a vital and inspiring landscape for doctoral candidates and postdoctoral scholars. BIGSSS integrates most major social-science disciplines into one school, with its researchers looking at the interplay of individual attitudes, capabilities, behavior, changing demographics, social structures, cultures, and institutions.

Specific themes and goals

BIGSSS research projects investigate the complex intertwining of multiple inequalities, new political divisions, technological changes, and environmental challenges. Our academic programme aims to investigate the responses of individual and collective actors to these challenges and the manifold crises of social and political integration. In doing so, we seek not only to complement, but also to integrate and further develop the research agendas that are being pursued in Bremen, serving as a focal point where scholars can explore new perspectives.

Social Cohesion

A core research goal of BIGSSS scholars at Constructor University is to contribute to the ongoing attempt to adequately define the concept of social cohesion and to examine its determinants and outcomes. This is essential for the understanding of the functioning of modern societies in a globalized world. Social cohesion is an important precondition for political stability and economic success and thus BIGSSS researchers work to specify determinants and correlates of social cohesion and how to measure them accurately and compare them across regions.

Intergroup Conflict

Intergroup conflict is another focus area, and BIGSSS researchers are working to disentangle mechanisms of intergroup conflict by testing different hypotheses derived from game theoretical and social identity perspectives.

Societal Change and Migration

Societal change in general and changes in social values, in particular, have always been a core interest of all social sciences. Recently, societal and political developments, such as international migrant flows and political discourses on how to deal with that, have again shown the importance of dealing with social values. Researchers at BIGSSS have been particularly active in that and have turned explicitly to the political debate concerning migration flows in Germany from a social psychology perspective.

Highlights and impact

The DFG-Research Training Group (RTG) 2513 Social Dynamic of the Self (SELF) is BIGSSS' newest PhD program in the social sciences. Since the self and society make each other up in an ongoing cycle of mutual constitution, they need to be studied simultaneously and in concert. SELF focuses on investigating the interactions between individuals and their social environment, providing a platform for early-career researchers from various social science disciplines to study the self's embeddedness in diverse social systems, ranging in complexity and dynamically changing over time. In addition to their responsible role of counseling BIGSSS PhD-Fellows, researchers from Constructor University are especially engaged in the BIGSSS Method Center and contributed to various research activities between 2019 and 2022.

- BIGSSS faculty at Constructor University also hosted and co-organized Computational Social Science Summer Schools, one with a thematic focus on Migration (June 2019) at Università degli Studi di Cagliari (Italy) and one on Social Cohesion at University of Groningen. The summer schools followed the idea of a research incubator and brought together experts in computational social sciences and conflict research, and junior researchers. During the summer schools, junior researchers teamed up with senior experts to work through the whole research process on one specific research topic.

BIGSSS has launched a small doctoral programme funded by the German Academic Exchange Service (DAAD) directed at early-stage researchers from the Global South. With its thematic focus on "Global Inequality, the Middle Classes and the Welfare State" (GloWel), the program aims to strengthen synergies between various regional research initiatives, involving faculty from University of Bremen and Constructor University in the supervision of our students.

Group composition & projects / funding

BIGSSS consists of faculty from Constructor University and the University of Bremen; affiliated postdocs; regular, affiliated and associated PhD fellows. There are currently about 20 PhD fellows affiliated at Constructor University and one Postdoc.

Selected publications

Belic, J., Djordjevic, A., Nikitović, T., & Khaptsova, A. (2022). The diversity of value construal: A constructivist approach to the Schwartz theory of basic values. Journal of Constructivist Psychology, 35(4), 1276–1300

Arant, R., Larsen, M., Boehnke, K. (2021): Acceptance of Diversity as a Building Block of Social Cohesion: Individual and Structural Determinants. Frontiers in Psychology 12

Boehnke, M., Larsen, M, Deutsch F. (2021): Consequences of feminized migration: How are family gender relations affected? In: S. Scherger, R. Abramowski et al. (Eds.):

Geschlechterungleichheiten in Arbeit, Wohlfahrtsstaat und Familie. Festschrift für Karin Gottschall. Frankfurt, New York: Campus Verlag, pp. 413 435

Deutschmann, E., Lorenz, J., Nardin, L.G., Natalini, D., Wilhelm, A.F.X. (eds): Computational Conflict Research, Springer Nature

Ponizovskiy, V., Ardag, M., Grigoryan, L., Boyd, R., Dobewall, H., Holtz, P. (2020) Development and Validation of the Personal Values Dictionary: A Theory-Driven Tool for Investigating References to Basic Human Values in Text, European Journal of Personality, 34(5), p. 885-902

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Political Socialization

Prof. Klaus Boehnke

Political socialization is an interdisciplinary research field drawing on developmental psychology, social psychology, political science, and political sociology. It addresses how people grow into becoming involved with politics (in a comprehensive understanding) and continue their involvement across their lifespans. The field also addresses the question of how political events affect citizen activism and how involvement strengthens the fabric of societies, and thereby the social cohesion of geopolitical entities. Research in political socialization is largely based on survey and in-depth interview studies.

Specific themes and goals

For more than three decades, Klaus Boehnke and his research teams at the Free University of Berlin (1986-1993), Chemnitz University of Technology (1993-2002), and Constructor University (since 2002) have been working on different angles of the 'political lives' of citizens. Boehnke is the principal investigator of the worldwide longest-running active panel study on life trajectories of adolescent sympathizers and activists of the peace movement in the mid-1980s. That study has seen 11 waves of data gathering, and participants are currently in their early 50s. Boehnke has always adopted a cross-cultural comparative approach, looking at political and civil-society engagement in a multitude of countries. This has also made him an expert in methods of cross-cultural psychology. In recent years, topics like the intergenerational transmission of values ("Under which circumstances do children have the same value preferences and worldviews as the parent generation?"), and societal cohesion have moved to the forefront of Boehnke's research agenda. For Bertelsmann Stiftung, Boehnke's team has developed a conceptual model and measurement approach for the assessment of the social cohesion in different-level geopolitical entities — neighborhoods, communities, federal states, or countries — around the globe.

Highlights and impact

- Early in 2017, Boehnke was asked to become the Deputy Director of the Center for Sociocultural Research at the National Research University Higher School of Economics (HSE) in Moscow alongside his Jacobs professorship. He did, however, cut his ties with HSE in February 2022 upon Russia's military attack on Ukraine, upholding individual cooperation with Russian academics.
- Boehnke and his team completed their study on Attachment to Heimat for the Federal Ministry of the Interior, Building and Community. The study led to a contract with Oxford University Press to publish a book titled Heimat — A Safe Haven in a Globalized World?
- Together with Professor Jan Lorenz, Boehnke is principle investigator (PI) of a four-country study entitled 'ToRealSim: Towards realistic computational models of social influence dynamics', funded by —among others— Deutsche Forschungsgemeinschaft (DFG).
- Boehnke is one of nine PIs of DFG Research Training Group (RTG) 2513 "Social Dynamics of the Self" (SELF), which has been established at the Bremen International Graduate School of Social Sciences (BIGSSS), an institution of doctoral education, jointly run by Constructor University and the University of Bremen.
- In 2019, Boehnke received the Fukuhara Award from the International Council of Psychologists and in 2022, he received the Award for Distinguished Contributions to the International Advancement of Psychology from the American Psychological Association.

Group composition & projects / funding

In 2019-2022, Boehnke's research team consisted of two postdoctoral fellows and two to three PhD students at Constructor University and one part-time postdoctoral researcher at HSE in Moscow (until Boehnke suspended his HSE affiliation). His team has been funded by the Bertelsmann Stiftung, Deutsche Forschungsgemeinschaft, and the Federal Ministry of the Interior, Building and Community, as well as from the internal funds of HSE and of Constructor University. For 10 years, Boehnke has been Vice Dean of BIGSSS, funded through the Excellence Initiative of the German Federal Government and the Länder, and he has also been able to draw upon research input from various BIGSSS fellows.

Selected publications

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Well-Being and Social Data Science

Prof. Dr. Hilke Brockmann

For centuries, happiness was a theoretical concept. But in the last three decades, happiness and subjective well-being (SWB) research has transformed the field into an empirical interdisciplinary science. There is now fast-growing demand for empirical happiness findings — inside as well as outside academia — due to their innovative insights, global applications, and predictive behavioral power.

Specific themes and goals

During 2019-2022, I returned from the European University Institute after a three-year leave of absence. My first goal was to set up a new study program on data science for social scientists and use data science techniques for subjective well-being research. My second goal was to design studies that could prove causal relationships. My third goal was to continue my international collaborations, and establish a new research group.

Happiness of migrants, happiness of natives

Migration numbers are rising, and in aging populations, they are the only dynamic growth factor and are highly dependent on political decision making. Migration also causes social integration problems. To better understand and respond to integration challenges, we broke down and studied the dynamic process of migration and happiness over decades. We found different adaptation patterns for different domains and for different social environments. Timing during the migration process with respect to family unification also plays an important role. Migration often ignites political polarization and so we also studied the happiness of the local population in response to different in-migration scenarios. We used advanced designs and econometric techniques to identify the causal effect of migration on the subjective well-being of the native population.

Causality

Empirical happiness research has mainly produced correlational results. With innovative experimental designs, longitudinal data, advanced econometric models and cross-validation techniques, we are trying to close the explanatory gap between correlation and causation in multiple studies.

Elites

Contemporary societies show a growing gap between the rich and poor. Sociological research has long ignored the super wealthy, but given the high concentration of economic, often political, and military power, researchers and society at large are increasingly questioning this omission. We researched the world views of the super wealthy tech elite and found both material as well as immaterial shared patterns. We also studied the tech elite during the COVID-19 pandemic and derived policy recommendations. Since wealthy and powerful people are super selected and difficult to reach through standard social science methods and techniques, we used data from the internet and social data science tools.

Highlights and impact

Besides a solid publication output, highlights of the period 2019-2022 include:

- Hilke Brockmann received a funded research fellowship at the Robert Schuman Centre for Advanced Studies at European University Institute in Florence, Italy
- She was appointed Editor of a new Encyclopedia of Happiness, Quality of Life and Subjective well-being
- Brockmann developed and achieved accreditation for a new study programme called Data Science for Society and Business
- She maintained international co-operations with European University Institute, City University of New York in the United States, Shanghai University in China, University of Santiago de Chile, National Autonomous University of Mexico, and University of Cape Town in South Africa
- She was also involved in outreach to media, industry and political institutions, and was the author of op-eds in a daily newspaper.

Group composition & projects / funding

Brockmann was a fellow of the European University Institute. Since 2022, she has supervised a DAAD funded PhD project (GloWell) on happiness and sustainability, and has worked on two projects on learning during COVID as well as Ageing and the Internet, funded by the Konfucius Institute.

Selected publications

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Energy Economics

Prof. Gert Brunekreeft

Bremen Energy Research, headed by Prof. Gert Brunekreeft and fully third-party funded, deals with issues in energy economics and energy policy. Energy policy aims to ensure uninterrupted supply of energy (security of supply), at competitive prices (affordability), which contributes to EU's wider social and climate goals (sustainability). Within this EU energy policy triangle, our core competence is on "competitiveness" as part of the sustainability goal, namely delivering energy in a cost-effective and economically efficient way. Based on the interdisciplinary competences of the team, our common research approach relies on micro-economics. Focusing on applied research of energy supply, we address real-world problems with academic tools and cooperate with academia, government, industry and consultants.

Specific themes and goals

Energy Regulation

As the world aims to decarbonise and digitalise, regulated energy infrastructure, namely the electricity and gas networks, need to adapt to a changing environment. Most prominently, renewable electricity supply needs to be integrated into the networks. Regulation now needs to enable the development of the networks to deal with the new tasks while still maintaining incentives to choose economically efficient solutions. We developed a new regulatory approach, the output-orientated-regulation (OOR), which can be combined with the existing incentive regulation scheme, to improve incentives to further develop the network efficiently and effectively. We have developed this approach in different research projects and applied it in projects for German transmission network operators, such as TransnetBW and Amprion.

Market design

We work on potential changes in the energy market design to facilitate the transition towards a net zero economy. For example, in the dena pilot study "Towards Climate Neutrality", we analyzed how so-called Carbon-Contracts for Differences (CCfD) could be applied to facilitate investments by the industry, faced with uncertain future CO_2-prices, into carbon neutral production facilities. Furthermore, in different projects, such as enera, one of five SINTEG-projects, we evaluate how the market design could be adapted to allow network operators to use the potential flexibility of electric vehicles or small-scale battery storage to decrease the costs of network services.

Digitalization of the energy system

With the increasing digital connectivity of assets connected to the electricity network, from electric vehicles to industrial compounds, the economic framework needs to adapt. Prof. Brunekreeft headed up a working group called "Resilience of Digitised Energy Systems" at acatech, the National Academy of Science and Engineering. This working group focused on the opportunities and challenges for the electricity system arising from digitalization. The insights gleaned from the working group form the basis of a number of our research projects.

Highlights and impact

- **enera (SINTEG-project)**: enera was a large demonstration project of a local flexibility market and the required digital solutions to facilitate this market. enera comprised 32 partners investing €175 million into the model region in the north of Germany. The Bremen Energy Research group coordinated the regulatory analyses in enera.
- **dena pilot study "Towards Climate Neutrality"**: The study aimed to identify the key challenges to, solutions for and next steps on Germany's path towards carbon-neutrality by 2050 with a specific focus on cross-sectoral approaches. Bremen Energy Research undertook the economic evaluation of different adaptations of the energy market design. We identified the key challenges in the given energy market design that impede decarbonisation across different sectors and discussed different approaches to overcome these hurdles.
- **dena "Blockchain Machine Identity Ledger"**: On behalf of the German Energy Agency (dena) our team at Bremen Energy Research, together with the IT experts from OFFIS and lawyers from Ernst & Young, scientifically evaluated different blockchain-based solutions. These solutions aim to include smart meters in a blockchain environment in order to connect digital identities with network users like battery storages or electric vehicles. Such connections would allow these assets to provide services to different markets in the future. The project was conducted in cooperation with 21 partners, including companies like SAP, EnBW and Deutsche Telekom and players in the digital sector and start-ups specializing in blockchain technology like the Energy Web Foundation.
- **Smart meter data management, flexibility markets, hydrogen and the future of natural gas infrastructure**: In a long-lasting research cooperation our research group supports EWE NETZ in Oldenburg by developing analytical models to better understand different policy options to cope with the changing institutional environment in the energy sector. Within this cooperation we have focused on different issues, most recently on the potential regulation of hydrogen pipeline projects as well as the different regulatory options to cope with the phase-out of natural gas consumption by 2045 and the resulting challenges for a network operator.

Group composition & projects / funding

During the reported time frame, our research group consisted of four to six people: a professor, post-docs and doctoral candidates. The group is 100% third-party funded, with roughly 50% public- and 50% industry-funded projects. The Ministry of Economics and Climate (BMWK) dominates public funding, while industrial funding comes from, for example, dena as well as energy companies.

Selected publications

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Sustainable Consumer Behaviour

Dr. Stanislav Chankov

If the world is to meet the United Nations' sustainable development goals, consumers need to make more sustainable purchasing choices. Encouraging more sustainable behavior is vital for both environmental and social sustainability. However, the factors that influence sustainable consumption are not yet fully understood. It remains unclear how much consumers value sustainability and what trade-offs they are willing to make when they have to choose between sustainability factors, such as carbon emissions, and other drivers, such as their comfort, money and time. Moreover, to make informed decisions, consumers need transparent information on the sustainability impact of the product or service they are purchasing. Dr. Stanislav Chankov's research investigates the behavior of consumers when they are presented with information on the sustainability impact of their decisions in different contexts.

Specific themes and goals

Last-mile delivery

The customer perspective on sustainable delivery is often ignored in the last-mile delivery research and practice. When e-commerce customers place online orders nowadays, they choose between different last-mile delivery options only based on economic factors. Retailers currently do not provide information on the environmental and social impact of the different delivery options. Thus, even if e-commerce customers wanted to choose a more sustainable delivery option, they are currently faced with only economic differences, ignoring environmental and social impacts. Dr Chankov's research investigates whether e-commerce customers change their preferred last-mile delivery, when offered additional information on the sustainability impact of the available options. His results clearly show that transparent information sharing makes e-commerce customers more likely to choose a more sustainable last-mile delivery.

Flight selection

Popular flight search engines have recently started to display the CO_2 emissions of different flight options. However, several aspects still remain unclear, such as whether the display of CO_2 emissions changes consumers' behavior towards more sustainable flying; how consumers choose between the flight's environmental impact and traditional concerns such as price, duration, and comfort; and which display of a flight's CO_2 emissions results in more sustainable flight selection. Dr Chankov's results showed that displaying environmental attributes such as CO_2 emissions does influence consumer intention and can hence be used to increase consumers' pro-environmental behavioral intention.

Smartphone selection

The current linear economic model of buying products and then throwing them away is not sustainable. The circular economy, which involves reusing, repairing and recycling products rather than disposing of them, is necessary. This economy hinges on product repairability. European policy makers have started giving consumers the "right to repair" and France has introduced a legally binding repairability index that has to be displayed on the packaging of certain electronic devices. This repair index shows consumers how repairable products are on a scale from 1 to 10, so consumers can use this information when choosing which electronic device to purchase. Still, there is a lack of research on the consumer attitudes towards repairability and on the trade-offs consumers are willing to make between repairability and traditional electronics' attributes such as price and functionality. Our results showed that consumers significantly value repairability. Displaying the repair index influenced consumer behavioral intention and can hence be used to increase pro-environmental behavioral intention amongst consumers. Consumers wanted products that could be repaired, irrespective of their demographic group. The detailed analysis of consumers' thoughts around repairability found no significant differences between age, gender, education level and income level.

Highlights and impact

- Dr Chankov's research on sustainable last-mile delivery showed promising results. Two-thirds of the people were willing to wait longer for a delivery once they understood that a fast delivery might have negative environmental impacts. Almost half of the participants were willing to pay more for a more environmentally and socially-sustainable delivery.
- The results from the sustainable flight selection indicate that air travelers are willing to pay more (6.7-21.2 €/100 kg) or travel longer (13-41 minutes/100 kg) to reduce the environmental impact of their trip. Moreover, displaying CO_2 emissions as a percentage of an individual's annual carbon budget increased air travelers' perceived monetary and temporal value of environmental sustainability, to 11.8-26.3 €/100 kg and 22-65 minutes/100 kg respectively.
- The research on smartphone repairability showed that the average consumer in the collected sample would pay an extra 65 €, forgo 1.1 hours of battery life and 47 GBs of digital storage capacity for a one-point increase in the smartphone repairability rating.

Selected publications

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Digital Transformation of Production and Manufacturing Systems

Dr. Fatahi Valilai Omid

Information technology has revolutionized business models, and some industries, such as manufacturing, have struggled to adapt to these changes. In part, this is because manufacturing deals with physical material processing and logistics, and IT capabilities need to be tailored to manufacturing's computation and communication requirements, especially considering the vast interconnections of these industries with their supply networks. IT offers manufacturing several disruptive business models to replace traditional operations, and our research investigates how such models affect manufacturing and how they can be implemented.

Specific themes and goals

Our research focuses on the Industry 4.0 paradigm to define the interaction of agents in manufacturing supply networks and proposes ways to exchange data between the virtual and physical world.

Digital twins

We research CPS (Cyber-Physical systems) and Digital Twins, in which digital models replicate physical systems, to understand how agents, many of which are in different physical spaces, collaborate. We propose a Cloud-manufacturing with XaaS (Everything as a Service) approach to enable service-oriented manufacturing systems rather than product- or process-oriented manufacturing systems.

Cloud manufacturing

Production industries need to realize globalized collaboration especially in early phases of product design and development. This necessitates service-oriented interoperability and integration for product lifecycle management. Companies can enhance their supply networks through new platforms offered by cloud manufacturing.

Supply network management

Manufacturing industries need to adopt cloud-based platforms and CPS solutions to support their operations. Such platforms would boost early product design, development and then production and delivery. The design of new platforms and architectures could enhance disruptive business models which could further challenge the current product design and manufacturing processes.

Operation management models

Businesses can use new operation management models to govern agent interactions. Traditional frameworks are no longer capable of managing the very large number of interactions enabled by the Internet of Things and Digital Twinning.

Game theory

We are using Game Theory to investigate the interactions between manufacturing service providers and customers.

Sustainability

Additionally, we are looking at how the sustainability paradigm could be extended to manufacturing industries. We use operations research and system analysis and design approaches to model, simulate, and optimize production systems under the Industry 4.0 paradigm.

Additive manufacturing

Additive manufacturing, in which complex objects are built one layer at a time, is another major disruptor for manufacturing. We are researching how the technology allows for smart product design and development through the interactions on social media platforms. These interactions enrich product requirements, with a technology that already lends itself to a high level of customisation. The vast and seamless information exchange for transferring customers preferences to product specifications and then additive manufacturing process planning is a major research topic in this area.

Blockchain

Recent advancements in Web 3 (Blockchain Technology) have initiated the idea of distributed autonomous operations management concepts. The Web 3.0 paradigm offers new collaboration and operations management mechanisms, and can be used in several applications such as autonomous peer-to-peer manufacturing machine service composition models, logistics models in last mile delivery especially for drone applications, supply data traceability, and integrated smart energy consumption models in homes and factories.

Highlights and impact

- In January 2020, Dr. Valilai was appointed the Associate Editor of 'Software Technologies', Frontiers in Manufacturing Technology Journal.
- Dr. Valilai was appointed the chair of Mobility in CIP (Community Impact Project) at Constructor University in January 2022.

Group composition & projects / funding

Our research group was established in early 2020. We currently have five doctoral candidates in the group.

Selected publications

Delaram, J., Houshamand, M., Ashtiani, F., & Fatahi Valilai, O. (2022). Development of public cloud manufacturing markets: A mechanism design approach. International Journal of Systems Science: Operations & Logistics, 1–27.

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Rezapour Niari, M., Eshgi, K., & Fatahi Valilai, O. (2021). Topology analysis of manufacturing service supply–demand hyper-network considering QoS properties in the cloud manufacturing system. Robotics and Computer-Integrated Manufacturing, 72, 102205.

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Behavioral and Cognitive Neuroscience

Prof. Dr. Ben Godde

Behavioral and cognitive neuroscience is the study of neural processes and mechanisms associated with human behaviors. In terms of applied methods, we conduct laboratory experiments combining behavioral tests with brain imaging methods such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). We also apply computational methods and machine learning algorithms to brain data to classify brain states, diagnose brain diseases, and predict learning outcomes.

Specific themes and goals

The plastic capacity of the adult and aging brain is at the core of its ability to continuously adapt to new demands and to learn new skills throughout life. Our research focuses on identifying mechanisms underlying cortical plasticity and the structure/function relationships between cognitive, sensory, and motor performance and learning. Based on our findings, we develop interventions to improve perception, motor control, and cognition and to thwart age-related decline. Interventions include perceptual or motor training, physical activity for improving cognitive abilities, or even transcranial direct current stimulation (tDCS) of the brain. Using very low currents, with tDCS we modulate neural activity to interfere with brain processes and to facilitate learning. Because it is absolutely safe and non-harmful to the participant, this technique has become a standard tool for brain stimulation.

Plasticity of the minimal self in aging (PALMS)

In this project, which is part of the DFG priority program “The Active Self” (www.activeself.de), we investigate how Body Ownership and Sense of Agency emerge through embodiment of a virtual tool and ask which neural mechanisms underlie the construction of the minimal self. We also probe the extent to which the minimal self is plastic and affected by sensorimotor experiences. In a lifespan developmental perspective, we show that ownership and agency depend on integration of the virtual tool into the own body schema; in other words, the representation of the body in the brain. Our results help to understand how professionals (surgeons, sportsmen and -women, and musicians) gain mastery of their tools and how interventions for facilitating learning might be developed based on these findings.

Tactile aging and plasticity in musicians (TAPmusic)

With transcranial direct current stimulation (tDCS), we examine how age and expertise affect the mutual balance between excitation and inhibition within the somatosensory cortex. Tactile perception is important to manual dexterity and therefore to the mastering of many daily activities. Impairment of tactile perception in older age often results in the loss of independence. However, age-related decline in tactile performance can be delayed or prevented by training and acquisition of tactile expertise in middle adulthood, for example in musicians. With this follow-up study to the Bremen Hand Study @ Jacobs, we use tDCS to modulate intracortical excitation and inhibition within the somatosensory cortex and by that facilitate tactile perception and manual dexterity.

The creative mind

Having a creative mind is one of the gateways for achieving fabulous success and remarkable progress in professional, personal, and social life. In this project, we contribute to an overarching model of creative performance and its dependency on creative cognitions, creative drive, neural mechanisms, and neuromodulatory factors. Using tDCS over the frontal cortex we interfere with cognitive functions such as inhibition control and thus also experimentally manipulate creative performance. In the future we aim to develop creative activity interventions to activate and facilitate cognitive abilities in older adults.

Balance and gait in the elderly

Falling has various physical and psychological consequences in older adults. In a recent study, we confirmed that perceived autonomy was negatively associated with a history of falls. With higher self-efficacy, the association between falls and autonomy was less substantial. Further, we extend previous findings in that self-efficacy also mediated the effect of falls on perceived autonomy and conclude that interventions facilitating self-efficacy might ameliorate negative effects of falling on autonomy of older adults. Based on these findings, we further develop and evaluate training interventions for elderly people for enhancing gait and balance and to reduce the risk for falls. We used transcranial direct current stimulation to facilitate balance training.

Group composition & projects / funding

Prof. Godde’s group currently consists of one postdoctoral fellow and two PhD students. His research is funded by PALMS (Plasticity of the minimal self in aging; GO 802/12) within the DFG priority programme, The Active Self, and TAPmusic (Tactile aging and plasticity in musicians; GO 802/11).

Selected publications

Khalil, Radwa; Godde, Ben; Karim, Ahmed A (2019) “The link between creativity, cognition, and creative drives and underlying neural mechanisms”, Frontiers in neural circuits, 13:18.

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International Business — Doing Business within Developing Economies

Prof. Dr. Tilo Halaszovich

Developing economies, such as several countries in Sub-Saharan Africa, are often characterized by large populations, poverty, and political instability. At the same time, many of those countries have shown remarkable economic growth over the last decade. While there are some exceptions, such as China and India, firms and people from developed countries tend to view many developing countries critically. Within our field of research, we aim to identify ways that enable foreign and local firms to jointly develop their business models and, thereby, cope with the specific situations imposed by their environment.

Specific themes and goals

Our research projects revolve around two main themes: “Which strategies enable firms from developed and developing countries to cooperate and mutually benefit from the cooperation?” and “What role can entrepreneurship and entrepreneurial ecosystems play within the context of developing countries?” While the first theme includes traditional aspects of international business research, such as control and coordination of firm networks, the second theme involves the interplay between the environment and business more closely by identifying ways and means to exploit opportunities arising from the specific conditions in developing countries.

Highlights and impact

Since 2019, our group has been involved in research projects aimed at advising public policy makers regarding the German involvement in Sub-Saharan Africa. Most notably:

- **German “Mittelstand” in Africa (2019/20)** — The study analyzed the involvement and procedures of medium-sized German firms who invested in Sub-Saharan Africa. The results were presented at a GIZ forum and stimulated ongoing discussions with business associations and policy makers.
- **The impact of Covid-19 on German-African business networks (2020/21)** — Roughly six months into the pandemic, this was the very first study shedding light on how 100 German firms handled the impact of lockdowns and travel restrictions on their African business activities. The study directly informed the former German government and the former German chancellor.
- **The role of the African diaspora for German firms in Africa (2022)** — Together with the Deutsche Afrikastiftung, this study identified the role and potential of the African diaspora in Germany, specifically regarding the involvement of German firms on the African continent. It was the first study that focused on members of the diaspora as key informants and was presented to the public at the annual Ansperger-Symposium in Berlin.

Group composition & projects / funding

The group is led by Prof. Halaszovich. It currently has four PhD students. Between 2019 and 2022, the group’s projects have been funded by GIZ, Deutsche Afrikastiftung, DAAD, and Volkswagen Stiftung, as well as individual firms from the region of Bremen.

Selected publications

Mattfeld, S., Piaskowska, D., Halaszovich, T.F. (2022): Digital outsidership: the practical and affective effects of digitalization in international business relationships between Kenyan and German firms, in: Research Handbook on Innovation in International Business, 177-205.

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Gentile-Lüdecke, S., Halaszovich, T. F., Lundan, S. M. (2019): What role does the CEO vision play in the internationalization process of firms? Evidence from the banking sector in Africa, Thunderbird: International Business Review, 61(1), 13-27.

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Law and African Studies

Prof. Dr. Manfred O. Hinz

I am an adjunct professor at Constructor University, specializing in law and African studies, as well as a professor emeritus at the University of Bremen, focusing on public law, political sociology, and the sociology of law. I am particularly interested in international and environmental law, and the legal and political aspects of the development of states and society.

Specific themes and goals

My research is still influenced by my experience of working in Namibia in southern Africa for 20 years. I was involved in the post-independence restructuring of the political and legal system of the country, including the establishment of its first university and the creation of a faculty of law, of which I was a part. After returning to Germany, I broadened my research activities to include post-colonialism and the reflection of colonialism as part of the history of Bremen.

Highlights and impact

- **Book writing** — After almost three years, the second edition of a substantial work on the 1991 constitution of Namibia — amounting to 450 pages — is about to go to press. I am the lead author of the book. Dr. Anne Schmidt, an attorney at law who did her doctorate in law under my supervision, is the co-author.
- **Western Sahara** — The Spanish-colonized Western Sahara is still on the United Nations' list of non-self-governing territories. Public and private institutions in Bremen have supported the peoples of Western Sahara and the efforts of the United Nations to find a solution to the conflict about the territory and the claim of the people for self-determination. The citizens of Bremen founded a non-governmental organization, "Freiheit für die Westsahara", which members of the German Parliament (Bundestag) from different parties included on its advisory board. I am the speaker of the board.
- **Exhibition** — As part of a partnership between the Free Hanseatic City of Bremen and Namibia (including the support of Bremen to the Namibia Project at the University of Bremen under my leadership), we prepared a documentary exhibition under the title "Bremen — Namibia, History of a Partnership 1975–2019". Gunther Hilliges, the former head of the Office for Development Cooperation of Bremen, and I authored the documents, and the exhibition is planned for Windhoek in the near future. The COVID pandemic has so far prevented the completion of the project.

Selected publications

Indigenous knowledge and soil protection in Namibia. In: H. Ginsky; E. Dooley et al., eds. International Yearbook of Soil Protection and Policy (Springer) 2019: 107–125

Customary Law Ascertained — project completed? In: Namibia Law Journal (11,1) 2019: 47–65

Westsahara. Afrikas letzte Kolonie. ed. with J. Tavakoli; W. Ruf and L. Gaiser. Berlin 2021. regiospectra

Legal protection of biodiversity in Namibia. (together with O. C. Ruppel). In: O. C. Ruppel; K. Ruppel-Schlichting, eds., Environmental law and policy in Namibia. 4th ed. Baden-Baden 2022. Nomos: 231–245

Customary law and the environment. In: O. C. Ruppel; K. Ruppel-Schlichting, eds., Environmental law and policy in Namibia. 4th ed., Baden-Baden. 2022. Nomos: 609–642

Laufzeitverlängerung für Atomkraftwerke: Ausstieg aus dem Ausstieg? In: Universitas 2022, 9 : 38 – 58Brazil (hybrid), December 4-8, 2022.

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Emotion Science

Prof. Arvid Kappas

Prof. Arvid Kappas' interdisciplinary work, which spans more than 30 years, investigates emotions and related affective processes, with an emphasis on their psychological underpinnings. While there has been more than a century of emotion research, there are still many open questions. Some of these questions include what elicits emotions; what physiological changes happen in the body and the brain in affective states; what determines which emotional expressions and related nonverbal behaviors are shown and when; how motivational states change; how these aspects differ between people; and to what degree they are controlled and how. All of these questions inform the research agenda of the X lab (Emotion, Cognition, and Social Context). In recent years, most of Kappas' work applies emotion research to the interaction between humans and machines. Two new scientific disciplines — affective computing and social robotics — provide the framework for much of Kappas' workgroup activities.

Specific themes and goals

Trust in robots

In the context of the EU-funded project ANIMATAS (Advancing intuitive human-machine interaction with human-like social capabilities for education in schools), we studied trust in social robots. Social robots tend to make mistakes, such as not understanding a comment or not recognizing a person with whom they have interacted before. What happens in the mind of a child when a robot displays such "faulty" behavior? Dr. Rebecca Stower, in collaboration with Australian colleagues, investigated the effects of different types of "errors" in a series of studies in which videos were shown to children. In other studies, robots interacted directly with children and made mistakes. Their findings help us understand the ways in which robots can be used in education in schools and at home.

Confiding in robots

Will adults share their worries and concerns with a machine? Informal caregivers of chronic patients experience considerable stress and there is ongoing research to assess and support the health of these individuals. In one study in our lab, researchers conducted 10 repeated interactions between a humanoid robot and caregivers over the course of five weeks to see whether there was evidence of self-disclosure. Guy Laban, a visiting scholar from the University of Glasgow in Scotland, showed that self-disclosure increased, suggesting that social robots could provide a valuable contribution to social support, which is known to have beneficial effects on health.

Deciding on whether a robot has a self

In the DFG-funded project Reconstructing the Naïve Theory of the Self, researchers showed participants videos of little autonomous driving robots. The robots manifest several behaviors, such as moving at varying speeds or colliding with other objects. Study participants had to report whether they felt that the robot exhibited agency and was a sentient being that wanted to do something or whether it was mindlessly pursuing some action. The study aimed to find the minimal conditions that give the impression of self in robots. The results of these studies will help us to better understand how individuals construct the concept of self in others, not only machines.

Highlights and impact

- Our research has demonstrated that children and adults often interact with robots as if they were people. Children prefer robots that make mistakes, apparently because they appear more human. Even if robots make mistakes, children are willing to continue to interact with them.
- A literature review has shown that previous research in this area is very unsystematic and characterized by statistical problems, as studies are often not large enough to draw reliable conclusions.
- The findings are of relevance within psychology, social robotics, and artificial intelligence. The research has been presented at international meetings and published in renowned international journals.

Group composition & projects / funding

The group has received funding from the EU Marie Skłodowska-Curie Actions Innovative Research Training Network and the DFG, among others.
Prof. Kappas co-supervised several doctoral candidates from across Europe, and also collaborated with international scholars during the course of his research.

Selected publications

Krumhuber, E.G., & Kappas, A. (2022) More what Duchenne Smiles do, less what they express. Perspectives in Psychological Science, 17(6), 1566-1575. doi: 10.1177/17456916211071083.

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Kappas, A., Stower, R. & Vanman, E. J. (2020). Communicating with robots: What we do wrong and what we do right in artificial social intelligence, and what we need to do better. In R. J. Sternberg & A. Kostić. (Eds.) Social Intelligence and Nonverbal Communication (pp. 233-254). Cham, Switzerland: Palgrave Macmillan. doi: 10.1007/978-3-030-34964-6_8

Vanman, E. J., & Kappas, A. (2019). "Danger, Will Robinson!" The challenges of social robots for intergroup relations. Social and Personality Psychology Compass, 13(8), e12489.

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Socio-Cultural Psychology

Prof. Dr. Ulrich Kühnen

Culture affects the way we think, feel, and act. How we act has in turn consequences for others in the immediate context and for larger societal contexts in the long run. Humans are socio-culturally shaped shapers of their interpersonal contexts. Understanding the processes that underlie this mutual constitution of culture and the self is at the core of my research. In an interdisciplinary cooperation that emerged from the Bremen International Graduate School of Social Sciences, BIGSSS, several colleagues of mine from Jacobs University and University of Bremen successfully applied for a DFG grant to establish the Research Training Group (Graduiertenkolleg) Social Dynamics of the Self which opened in 2021.

Specific themes and goals

Culture and decision-making

We are living in a consumer society where choosing according to one's preferences is a common and everyday activity. In fact, the proliferation of choice has increased enormously over the last decades. What are the psychological consequences of making frequent consumer choices? We speculated and found that the act of making consumer decisions could temporarily increase narcissism (including self-aggrandising tendencies), because it directs one's attention to the self (for example, personal preferences or internal standards, etc.). In another set of studies, we asked whether belief in free will facilitates or impedes decision making. From an existentialist perspective one might argue that free will imposes anguish and hesitation and thus might impede decisions by increasing indecisiveness. In contrast, an evolutionary view would argue that free will is a driver of effective social functioning, and this view would predict that free will facilitates decisions by reducing indecisiveness. Our results mainly provide support to the evolutionary hypothesis. Belief in free will is consistently associated with lower indecisiveness. However, one boundary condition of this effect is that it is limited to individuals with high self-concept clarity.

How to increase students' intercultural competence?

Based on many previous findings, we argue that teaching cultural intelligence should focus on the role of self-reflection, mindfulness, and self-efficacy. Based on these theoretical propositions, we designed, conducted, and evaluated a university course aimed at promoting students' cultural intelligence and self-efficacy. Quantitative and qualitative data provide evidence for its effectiveness. Overall, the data offer insights into how to teach transferable skills at universities to prepare students to become global leaders, able to confidently engage with cultural diversity in a globalized world. This long-standing research also resulted in a cooperation with DIE ZEIT Akademie Hamburg, an important supplier of online seminars in various fields. Together we produced an online seminar on intercultural competence and an accompanying text book.

Highlights and impact

- Decision-making is much more than choosing one option out of various provided ones. It is a social act with social meaning.
- Intercultural competence is a key competency in our modern world. Knowing what it comprises allows us to teach and improve it. This was recently done with our international student body, but also in collaboration with an important provider for online seminars, namely DIE ZEIT Akademie, Hamburg.

Group composition & projects / funding

I am involved in the Bremen International Graduate School of Social Sciences as a faculty member and Academic Chair. Between 2019 and 2022, three of my PhD students graduated (funded by the DFG). In September 2021, our DFG Research Training Group Social Dynamics of the Self opened. Through that group, I am involved in the supervision of two PhD students.

Selected publications

Binder, N., & Kühnen U. (2021). Teaching Cultural Intelligence for a VUCA World. European Journal of Cross-Cultural Competence and Management, 5, 252-270.

Binder, N. & Kühnen, U. (2020). Interkulturelle Kompetenz - Strategien für eine erfolgreiche

Zusammenarbeit. Die Zeit Verlag, Hamburg.

Baur, C., Soucek, R., Kühnen, U. & Baumeister, R. F. (2020). Unable to resist the temptation to tell the truth or to lie for the organization? Identification makes the difference. Journal of Business Ethics, 167, 643-662.

Kokkoris, M., Sedikides, C. & Kühnen, U. (2019). Do Consumer Choices Augment

Narcissism? The Role of Self-Referent Processing. Self & Identity, 18, 550-575 Kokkoris, M. D.,

Baumeister, R. F., & Kühnen, U. (2019). Freeing or freezing decisions? Belief in free will and indecisiveness. Organizational Behavior and Human Decision Processes, 154, 49-61.

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International Business, Innovation and Information Management

Prof. Dr. Christoph Lattemann

The activities of the I3 research group, led by Prof. Lattemann, encompass two global issues: Digital transformation with particular emphasis on innovation management in the service sector, and international business and globalization. The two research topics are interrelated: To achieve a competitive advantage, multinational companies need to work more closely with business partners in their service ecosystems, such as suppliers, customers, competitors, and governments. At the same time, advanced Information technologies (such as distributed ledger technologies) and innovation management approaches (such as open innovation and design thinking) enable new organizational concepts that empower companies to develop new services for and with their customers.

To study digital transformation in the service sector, Prof. Lattemann founded a Design Thinking lab at Jacobs University in 2011, the D-Forge. Research related to the D-Forge deals with the user-centered adoption of innovative technologies in the service industry to establish new entrepreneurial opportunities, ICT-based business models, and novel, creative ways to collaborate, and innovate. The D-Forge is a place for creative thinking. In this context, the I3 Group brings together not only many international students, but also SMEs, multinational companies, and non-profit organizations.

In 2012 Prof. Lattemann established the “Center for the Study on China and Globalization” (ChinaGlobal Center). Since 2012, Lattemann has held the position as a vice president of the Chinese Globalization Association, an NPO registered in the USA. Under his direction, the I3 research group, together with the research group of Prof. Tobias ten Brink from Constructor University, investigates important emerging questions related to China’s globalization.

Specific themes and goals

The I3 Group is currently involved in projects in the context of digital transformation, service industry, design thinking, and creativity. The major aim of the research group is to design state-of-the-art ICT applications for innovation management, service provision, and education, in particular in the creative sector.

DETHIS

The outcome of the BMBF-funded project “DETHIS — Design Thinking for Industrial Services” (2016-2019) is the specification of a Design Thinking process dedicated to SMEs (see also DINSpec 33453), including an IT-supported toolbox and a platform to facilitate the application of design-thinking processes in the industrial service sector.

BeDien

In the BMBF-funded meta-project “BeDien — Personal Services” (2018-2022), we conducted state-of-the-art research in the area of personal services in the age of digitisation. The project collaborated with and supported eight other BMBF projects (with more than 50 partner organizations) to discover new techniques to improve personal service experiences.

StudyBuddy

In the BMBF-funded project StudyBuddy, a team of four business and research organizations developed an artificial-intelligence-based learning companion for professional development. AI plays a crucial role in the development of individualized services for learning. While interacting with users, StudyBuddy identifies their needs and provides learning support that adapts to their habits and circumstances.

Imparting Creativity in Distance Learning

In this project, funded by the Jacobs Foundation, in an international consortium, the I3 group designed an e-learning solution to foster students’ creativity in higher education. Creativity is perceived as one of the major required soft skills for future workforces but is barely included in existing e-learning programmes or courses. The developed solution allows instructors from various academic areas such as business, engineering, design, and social, natural and computer sciences to foster creativity in their courses and study programmes.

AI- and ML-based price determination

In two projects (funded by industry and by the BMEL), we used highly sophisticated AI- and machine-learning algorithms to determine the prices of non-standardised products in complex markets.

Highlights and impact

BMBF-funded projects on digital transformation and servitization were an integral part of the last four years. Since 2019, the I3 team has published five books, 14 journal articles, 10 book chapters, 15 conference papers and one DIN-Spec. The group has also developed innovative hybrid Design Thinking Methods for creative work, and is also involved in the development of new and successful BA and MA programs at Constructor University.

Group composition & projects / funding

Between 2019 and 2022, Prof. Lattemann graduated three PhD students as first supervisor and six PhD students as second supervisor. In September 2022, the I3 Group consisted of five PhD students funded by BMBF, Jacobs Foundation, and other projects.

Selected publications

Robra-Bissantz, S. Lattemann, C. (2022) Service for Good Playbook, ISBN: 978 -375622480-7

Michalke, S., Lohrenz, L., Lattemann, C., Robra-Bissantz, S. (2022) Exploring Engagement, Well-being and Welfare on Engagement Platforms: Insight into the Personal Service Sector from the DACH Region. Journal of Electronic Markets, accepted for publication

Fischer, S., Lattemann, C., Redlich, B., Guerrero, R. (2020) Implementation of Design Thinking to Improve Organizational Agility in an SME, Die Unternehmung — Swiss Journal of Business Research and Practice, Vol. 74(2), pp. 136-154

Xing, Y., Liu, Y., Lattemann C. (2019). Accommodating institutional logics in social enterprises: the entry mode choices of foreign hospitals in China, Journal of World Business, published online

Liu, Y., Lattemann C., Xing, Y., Dorawa, D. (2019). The emergence of collaborative partnerships between knowledge intensive business service (KIBS) and product firms: The case of KIBS in Bremen, Germany, Regional Studies, 53 (3), pp. 376-387.

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Health Psychology and Behavioural Medicine

Prof. Dr. Sonia Lippke

Health Psychology and Behavioural Medicine is the science of behavior and mental processes in connection to health and morbidity. It covers risk and health behaviors, psychological processes, and social-cognitive factors, as well as their interrelation with physical diseases and constraints.

Specific themes and goals

Sonia Lippke and her group engage in self-regulation research and patient safety focusing on self-efficacy, motivation, behavior, loneliness, and communication. They have published on a wide range of health-related research topics, such as prevention and rehabilitation, long-COVID and aging, e-health, and co-creation.

The results have received a great deal of interest in terms of citations, media response and invitations to give presentations and workshops. A core goal of research in Health Psychology and Behavioural Medicine is to help people cope with crises such as the Covid pandemic, mobilize professional and social support, and help people to age healthily. We are using the lessons learned to assist rehabilitation patients.

We produced a brochure outlining key results and achievements in the BICC project, which we completed in 2021. We also contributed to a science truck to disseminate findings and contribute to the Bundesteilhabebericht and the Altenbericht by the German Government. Our research was disseminated to different target groups such as the general public at the Vegesacker Bürgerhaus and the Haus der Wissenschaften in Bremen City, experts such as peers and medical doctors (Ärztefortbildungen) besides colleagues at regular scientific conferences, online and in person.

Highlights and impact

Besides the research projects in which we work on the planned milestones, deliverables and publications, we have talented students illuminating psychological processes in different contexts.

- Two Masters theses provided evidence on how to design prevention and treatments — in the school setting to prevent absenteeism and in medical rehabilitation: School Absenteeism from a Multiprofessional Perspective. A qualitative account of perceptions, intervention options, and the subjectively perceived influences of the corona pandemic on school absenteeism. Christin Hensel (MSc in Psy, 2022) and Group Therapy Sessions in the Age of COVID-19: A Mixed-Method Study on Digital Group Therapy Offers in Medical Rehabilitation. Florence Maggs (MSc in Psy, 2022).
- In addition, many bachelor students researched societally relevant aspects. In one study “Associations of sleep deprivation and mental health among undergraduate students.” (Edin Isljami, BA in Psy, 2022), we concluded that some Constructor University students only sleep four hours per night, but most students sleep recommended hours. Another study — “A study of the consequences of the COVID-19 pandemic on the physical and mental health of the population in Germany versus China” (Octavian Tropin, BSc in BCCB, minor in Psychology, 2022) — suggest different Covid-pandemic outcomes in China and Germany. Moreover, a previous graduate published her bachelor thesis in a peer reviewed journal with us.
- We also had a number of findings from doctoral theses. For example, one thesis found that physical activity intervention is effective in helping older people to remain and become sufficiently active. Another project determined that patient safety could be measured by a questionnaire and that rehab patients were more satisfied with healthcare communication than the general population. Many people from the general population did not feel sufficiently catered for and understood by healthcare professionals during the pandemic.
- Also, Prof. Lippke is the past president of Div. 8: Health Psychology/ Int. Association of Applied Psychology and is co-editing a special issue (Loneliness and health: Understanding and overcoming challenges in times of crisis and beyond; in AP:HW 2023).

Group composition & projects / funding

Our research group consists of four guest-researchers (Postdocs), six PhD students, and one student intern. Our research is currently supported by the DFG and the EU (Marie Skłodowska Curie Innovative Training Networks project funded by the European Union, H2020 MSCA ITN), and was funded during the last years also by the Bundesministerium für Bildung und Forschung (BMBF), the Bundesministerium für Gesundheit (BMG) and Bayrischen Staatsministerium für Gesundheit und Pflege.

Selected publications

Lippke, S., & Derksen, C. (2023). Gesundheitskompetenz lehren und lernen: Trainingsprogramm für Sozial-und Gesundheitsberufe [Teaching and learning health literacy: training program for social and health professions]. Hogrefe AG.

Lippke, S., & Warner, L. M. (2023). Understanding and overcoming challenges in times of personal or global crisis – Editorial on the Special Issue on Loneliness and Health. Applied Psychology: Health and Well-Being, 15(1), 3-23.

Keller, F. M., Derksen, C., Kötting, L., Dahmen, A., & Lippke, S. (2023). Distress, loneliness, and mental health during the COVID-19 pandemic: Test of the extension of the Evolutionary Theory of Loneliness. Applied Psychology: Health and Well-Being, 15(1), 24-48.

Rinn, R., Gao, L., Schoeneich, S., Dahmen, A., Anand Kumar, V., Becker, P., & Lippke, S. (2023). Digital Interventions for Treating Post-COVID or Long-COVID Symptoms: Scoping Review. Journal of Medical Internet Research, 25, e45711.

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Data-driven Agent-based Modeling in Computational Social Science

Prof. Jan Lorenz

With agent-based models, computational social scientists want to explain the emergence of social phenomena, such as ethnic and social segregation, opinion polarization, the rise of mass protests, economic and political cycles, and the ups and downs of epidemic spreading of infectious diseases.

While modeling, researchers experiment with theories and assumptions about the behavior of individuals and link them to the societal level through computer simulations of repeated social interactions of many artificial individuals. Similarly, researchers play with institutional settings modifying the context in which agents interact. Such agent-based models are a tool to explore multiplayer games where actors' rationality is bounded. In both senses, agent-based modeling is intrinsically theory-driven.

Agent-based modeling offers a quantifiable causal understanding of how situations come about in the real world.

Specific themes and goals

We are working to develop and integrate dynamic models of segregation, polarization, inequality and growth.

We are applying our models and ideas to quantify attitude polarization with respect to extremists, moderates, and centrists.

Scholars within the group integrated the functional form of psychological behavior of attitude change and implemented these forms in a society model to study what individual mechanisms produce different attitude distributions.

Another investigation modeled social activation based on the observations of two quite different protest movements in Germany and Iran.

One team located a model of segregation in a setting of real geography and demography including not only ethnicity but also socio-economic status. They built a model which is able to reproduce segregation patterns observed in the real world, starting from a nonsegregated town.

Highlights and impact

- The group organized three two-week BIGSSS summer schools and research incubators in Computational Social Science on Conflicts 2018 at Constructor University, Migration on Sardinia 2019, and Social Cohesion in Groningen 2022. The first school produced an edited volume with Springer, while the second school resulted in a special issue in the Journal of Ethnic and Migration Studies.
- We integrated into the DFG Research "Social Dynamics of the Self", and will apply agent-based models to that work.
- We were part of an international project "Towards Realistic Models of Social Influence" (ToRealSim) with partners in the United Kingdom, France, and the Netherlands.

Group composition & projects / funding

Our research comprises a network of collaboration. We work on ToRealSim together with Prof. Klaus Boehnke and our two PhD students; Prof. Adalbert Wilhelm and Prof. Boehnke for the BIGSSS Summer School in Computational Social Science (which is funded by the Volkswagen Foundation); and within the "Social Dynamics of the Self" consortium.

Selected publications

Zuccotti, C. V., Lorenz, J., Paolillo, R., Rodríguez Sánchez, A., & Serka, S. (2022). Exploring the dynamics of neighbourhood ethnic segregation with agent-based modeling: an empirical application to Bradford, UK. Journal of Ethnic and Migration Studies, 1-22.

Gestefeld, M., Lorenz, J., Henschel, N. T., & Boehnke, K. (2022). Decomposing attitude distributions to characterize attitude polarization in Europe. SN Social Sciences, 2(7), 1-35.

Lorenz, J., Neumann, M., & Schröder, T. (2021). Individual attitude change and societal dynamics: Computational experiments with psychological theories. Psychological Review, 128(4), 623.

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Digital Accounting, Finance, and Tax

Prof. Dr. Andreas Seebeck

The Digital Accounting, Finance, and Tax research group focuses on empirical financial accounting and capital market research that uses recent technological developments to answer research questions closely tied to economic theories. It is an interdisciplinary research field drawing on knowledge from accounting, finance, and tax as well as from natural language processing, machine learning, and artificial intelligence. Besides empirical archival research methods, we also follow a design-science approach.

Specific themes and goals

Disclosure and audit regulation — In a research project with Prof. Dr. Devrimi Kaya from Ruhr University Bochum in Germany, we examined the communicative value of extended auditor reports in the United Kingdom. By using innovative methods from computational linguistics, we found that communicative values improve in response to new auditor reporting requirements. Cross-sectional tests showed that the improvement differs across audit firms and audit clients. Importantly, we found initial evidence that a more specific reporting of auditors is significantly and positively associated with capital market reactions. This suggests that investors value precise information by the auditor. In a follow-up project, we examined how the auditors' reports evolve over time.

Sustainability and diversity — With researchers from Friedrich-Alexander-Universität Erlangen-Nürnberg, we investigated the impact of board gender diversity on risk reporting by UK companies. By applying sophisticated two-stage estimation procedures, we accounted for the endogeneity risk typically inherent in such diversity studies. We found that board gender diversity is positively related to corporate risk disclosure. However, our results also indicated that the proportion of female directors needs to reach a critical level to impact the decision to disclose Brexit-related risks. Collectively, our results show that board gender diversity promotes the disclosure of decision-relevant information through improved board group dynamics. In a follow-up project, we are investigating the potential multiplier effects resulting from FüPoG II in Germany.

Evidence-based optimisation of accounting and management education — We also research the evidence-based optimisation of accounting and management education. For instance, we published a study together with Robin Wolter (a former student and teaching assistant at Constructor University) which investigated the impact of accounting and finance courses on student founding teams. Our empirical results provide valuable input for teaching and course composition. In addition, we developed new teaching approaches and scientifically monitored their effectiveness. Finally, we used innovative approaches based on machine learning and artificial intelligence to screen the existing literature for relevant topics.

Highlights and impact

- Our rigorous research has been published in renowned journals such as Journal of Business Ethics, European Accounting Review, and Journal of Accounting and Organizational Change. Moreover, it has been recognized by a series of awards, for instance from the ACCA Research Symposium at the University of St. Gallen.
- Aside from our international research activities in Accounting, Finance, and Tax, we are also involved in the startup community at Constructor University.
- We also have a strong publication record related to German practice-oriented research in the fields of accounting, finance, auditing, and tax

Group composition & projects / funding

The Digital Accounting, Finance, and Tax research group was founded in 2022 and currently consists of Prof. Seebeck, one postdoctoral researcher, one PhD candidate, and five student assistants. We are carrying out research projects in Sustainable Finance and Tax with renowned researchers from leading universities, such as FAU Nuremberg and the University of St. Gallen. The research is funded by Stiftung Innovation in der Hochschullehre, Stiftung Prof. Dr. oec. Westerfelhaus, and several partners from industry.

Selected publications

Seebeck, A., Kaya, D. 2022. The Power of Words: An Empirical Analysis of the Communicative Value of Extended Auditor Reports, European Accounting Review.

Seebeck, A., Vetter, J. 2022. Not Just a Gender Numbers Game — How Board Gender Diversity Affects Corporate Risk Disclosure, Journal of Business Ethics.

Seebeck, A., Wolter, R. 2022. Financial Education of Founders, is it important? A case study of Jacobs Startup Competition, International Journal of Entrepreneurial Venturing.

Lutz F., Seebeck A. 2020. OECD veröffentlicht aktualisierte Guidance zum Country-by-Country Reporting, Internationales Steuerrecht.

Kaya, D., Seebeck, A. 2019. The dissemination of firm information via company register websites — Country level empirical evidence, Journal of Accounting and Organizational Change.

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Political Science — International Energy and Resource Governance, Sustainability and Transitions

Prof. Karen Smith Stegen

Prof. Karen Smith Stegen's group researches traditional political science topics, such as elections, but also energy and resource issues from the perspectives of both geopolitics and sustainability.

Specific themes and goals

Renewable energies first gained significant traction during the oil crises of the 1970s. In the decades that followed, interest in renewables waxed and waned, usually contingent on geopolitical necessity. However, as global warming gained prominence, renewables became a lasting component of energy security. Just as interest in renewables has evolved, so has our understanding of the implications of renewables for international politics. Initially, many observers believed that renewable energies would end energy geopolitics. About a decade ago, however, scholars began systematically exploring how renewables might affect interstate relations. The conclusion is that, just as past energy transitions had profound effects on politics, so will the transition to renewables. Smith Stegen and colleagues examine renewables from two vantage points: the transition itself and the geopolitical implications. Some of the key questions include: "What are the obstacles to the renewable energy transition?" and "How will the transition affect interstate relations?"

Highlights and impact

- **Constructor University's contribution to new research field and today's leaders** — The first-ever workshop featuring the "geopolitics of renewable energies" was co-hosted by Constructor University (represented by Smith Stegen) and the Hanse-Wissenschaftskolleg Institute for Advanced Study in 2011. Interest in the workshop's topics quickly expanded, and many participants are now leaders in the field, producing many of the seminal publications.
- **International Renewable Energy Agency** — In 2018-2019, IRENA recognized the significance of the new field and convened the "Global Commission on the Geopolitics of Energy Transformation", comprising member state dignitaries such as ministers and former heads of state. The Commission was supported by an international team of experts, and the German Foreign Ministry appointed Smith Stegen as one of Germany's three experts.
- **The Economist magazine** — The Economist magazine published a special report in 2018 on energy geopolitics and "The New Power Superpowers", which mentioned the work of Smith Stegen.
- **Scientific Impact** — A bibliometric analysis of all researchers at Constructor University revealed that the scientific impact—the mean normalized citation score—of Smith Stegen was 2.55. This was the top score for all female researchers and number six overall. It was also above the average of the 10 other benchmarked universities and research institutions.

Group composition & projects / funding

Recent and ongoing primary and secondary supervision of PhD projects include:

- Emerging Powers, Climate Change, and the Global Order: Analyzing the National Role Conceptions of Brazil, South Africa, India and China (Expected Completion: 2022).
- En route to sustainable transport? Critical reflections on the narratives and actor constellations in the German "Verkehrswende" (Expected Completion: 2023).
- Assessing the Potential Synergistic Effects of Deep-Sea Mining and a Comparison to Onshore Mining (2021).

Selected publications

Richter, I. and Smith Stegen, K. "A choreography of delay: The response of German auto incumbents to environmental policy." Environmental Innovation and Societal Transitions 45 (2022).

Tomberg, L., Vance, C. and Smith Stegen, K. "The mother of all political problems? On Asylum seekers and elections in Germany." European Journal of Political Economy 67 (2021).

Kusznir J. and Smith Stegen, K. "Europe's New Green Deal's Hydrogen Strategy and EU Energy Issues", Baltic Rim Economies Review (2020).

Von Wirth, T., Loorbach, D., Wagner, A., Koretskaya, O., Wade, R., Krupnik, S., Rudek, T., Foulds, C., Adem, C., Akerboom, S., Batel, S., Caspar Rabitz, F., Certoma C., Cherp, A., Chodkowska-Miszczuk, J., Denac, M., Dokupilová, D., Dotterud Leiren, M., Frolova Ignatieva, M., Gabaldón-Estevan, D., Horta, A., Karnøe, P., Lilliestam, J., Markard, J., Mišik, M., Mühlemeier, S., Nemoz, S., Nilsson, M., Osička, J., Papamikrouli, L., Pellizioni, L., Sareen, S., Sarrica, M., Seyfang, G., Smith Stegen, K., Sovacool, B., Telesiene, A., and Zapletalova, V. "100 Social Sciences and Humanities priority research questions for renewable energy in Horizon Europe." Cambridge: Energy-SHIFTS (2020).

De la Esperanza, M., D. Scholten, and K. Smith Stegen, "The multi-speed energy transition in Europe: Opportunities and challenges for EU energy security." Energy Strategy Reviews 26 (2019).

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Digital Assistants for Individualised Learning Systems (DAISy)

Prof. Christian Stamov Roßnagel

Reinforced by the Covid-19 pandemic, the demand for computer-supported learning formats (“e-learning“) has been growing steadily both in higher education and in corporate training. More individualized e-learning programmes increase both the effectiveness and efficiency of learning, as well as foster individual learning motivation. In our research, we pursue a dual approach to contribute to the development of individualized learning solutions. Collaborating with Airbus, Festo, and the German Research Centre for Artificial Intelligence (DFKI), we have gained deep insights into contemporary learning design and the drivers of learning engagement.

Specific themes and goals

Adaptive learning platforms

Adaptive learning platforms provide immediate and personalized support of technology-enhanced learning without intervention from a human instructor. They also cater for the training needs of an increasingly diverse workforce where other training methods often fail. Such platforms provide individualized learning by, for instance, aligning the specific content learners are given with their prior knowledge, and the amount of learner control may co-vary with prior knowledge. When learning content is largely predetermined, instructors can scaffold learning processes by using data on observable learning behaviors, which is often referred to as adaptive tutoring.

Real-time learning analytics

Such adaptive tutoring is one of the two main lines of our research. We develop digital assistance tools to support self-directed e-learning, by defining a content-specific prototypical learning path through the content. This path includes, for example, expected study times for each content section. The prototypical path is generated from off-line (including prior knowledge level) and on-line (such as responses to assessment questions) data. If a learner deviates from the prototypical learning process, this triggers specific prompts to identify their learning support needs as they arise.

Self-directed learning

Our studies show that stimulating self-directed learning can increase learning efficiency and reduce the time required for learning. It is possible to promote such learning by identifying individual support needs in real-time data and covering them through self-directed immersion opportunities for specific learning content. At the same time, learners report that they experience learning as less stressful.

Digital assistant

We also look at the role of instructional design in e-learning. Our guiding assumption is that beyond learners’ self-regulation skills, self-directed learning depends on certain features of the instructional design underlying e-learning offers. That design can support self-direction — or make it more difficult. In response to this, we developed a digital assistant. Together with learning authors and/or instructors, the assistance tool analyzes the instructional design of a given learning unit according to the CALL model (Constructive alignment of learning activities) of action-oriented learning. The tool makes specific suggestions to authors on how they can make a given learning unit even more competence-oriented by aligning intended learning outcomes, learning content, and learning activities. Building on the competency models in a specific domain, the tool helps establish and integrate the instructional core of effective and efficient courses into e-learning offerings.

Design guidelines

Considering that we work with authors in a broad range of domains, we aim to develop guidelines for comprehensive instructional design that supports learning authors in virtually any domain. The authoring tool has graded functionality, ranging from a check-list function (tool checks the instructional design of an e-learning for CALL compatibility) to dialogue-based template creation. For example, the tool creates the basic framework of a learning unit from a dialogue with the author and suggests design guidelines for the content that the author adds to that basic framework.

Highlights and impact

- Through our individualized learning research, we see increases in the effectiveness and efficiency of learning, and empowering learners to assume more responsibility for their learning progress. In the longer run, the instructional design principles we elaborate may enable the creation of a comprehensive portfolio of learning and training formats beyond e-learning that provide a sustainable basis for competence-building training.
- Prof. Christian Stamov Roßnagel was appointed as an advisory board member at the Institut für Betriebliche Bildung. In collaboration with major companies, the institute develops evidence-based standards for effective training.
- Prof. Stamov Roßnagel was commissioned by AOK Gesundheitskasse to consult personnel managers on their organization-wide learning-platform relaunch.
- He was also invited as the keynote speaker at the “Future of Competence Development” workshop funded by the Federal Ministry of Labour and Social Affairs

Group composition & projects / funding

Prof. Stamov Roßnagel’s research group includes a postdoctoral fellow and a PhD student. They contributed to our LeADS research which was funded through grants from the Federal Ministry of Labour and Social Affairs and the Jacobs Foundation.

Selected publications

Langen, I., Stamov Roßnagel, C. (2023). East is East: Socratic classroom communication is linked to higher stress in students from Confucian heritage cultures. Heliyon, 9 (5),

Bittner, J.V., Stamov Roßnagel, C. & Staudinger, U.M. (2021). Educational self-regulation competence: toward a lifespan-based concept and assessment strategy. International Journal of Educational and Vocational Guidance, 22, 307–325 (2022).

Stamov Roßnagel, C., Lo Baido, K., & Fitzallen, N. (2021). Revisiting the relationship between constructive alignment and learning approaches: A perceived alignment perspective. PLOS One 16 (8), e0253949.

Stamov Roßnagel, C., Fitzallen, N., & Lo Baido, K. (2020). Constructive alignment and the learning experience: relationships with student motivation and perceived learning demands. Higher Education Research & Development 40 (4), 838-851.

Rinn, R., Stamov Roßnagel, C., & Navin Lal, T. (2019). Development

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Implications of the Rise of China and Non-Western Emerging Economies

Prof. Tobias ten Brink

This research group uses theories from political science, global political economy, innovation and business studies to analyze China and other emerging economies such as Brazil and India, and to understand the international repercussions of the rise of these countries.

Specific themes and goals

Inclusion and Benefit Dynamics in the Chinese Welfare Regime

This project analyzes how social insurance programmes in the People's Republic of China have evolved from the 1990s to 2020. Specifically, we want to contribute to the understanding of social-policy dynamics in the risk fields of old age, sickness, maternity, and unemployment. We scrutinize how national factors, global economic interdependence, and ideational linkages in the East Asian region influence changes in coverage and generosity. In our data preparation and analysis, we follow a mixed-methods approach. Headed by Prof. Tobias ten Brink and Dr. habil Armin Müller, the project is part of the Collaborative Research Center at the University of Bremen, funded by the German Research Foundation DFG.

Cooperation of European Firms with Chinese Universities: Forms and Effects

This project provides evidence on collaborations between European firms and Chinese research institutions. We ask: What forms of collaboration can be identified between Chinese research institutions and European firms? From the firm's viewpoint, what effects does the collaboration generate? Under which conditions can more legitimacy and innovation be achieved? To answer these questions, we combine web-scraping, survey questionnaires, and statistical analysis with qualitative methods. We aim to better understand university-industry collaboration in China, and be able to better assess the opportunities and risks of international university-industry collaboration. The BMBF project is co-led by Prof. Cornelia Storz at the University of Frankfurt.

Challenges for the Stability of the Chinese Economic Model

The DFG-funded project examines if and to what extent current socio-economic and political challenges are destabilizing China's state-permeated economic model. In particular, we are asking whether recent reforms initiated under the Xi Jinping government undermine or sustain the model. The project expects new insights into China's socio-economic development as well as a better understanding of the processes enabling institutional stabilization. We hereby want to further our understanding of how the Chinese economy moved from a low-tech "workshop of the world" into a center of high-tech digital industries.

China in Europe Research Network

Foreign direct investment from China to Europe has been growing strongly over the past decade. The perceived challenges posed by investment and other activities have led to increasing political and media attention across Europe, including calls for EU vetting and regulation of acquisitions. In this EU Cost Action project, Prof. Tobias ten Brink is working with other researchers to pool and stimulate research on China's deepening economic engagements with Europe, and develop an interdisciplinary, holistic, cross-sectoral and pan-European understanding of the variegated impacts and strategies associated with these engagements. The project also expects to comprehend likely political and geo-political consequences of these engagements, and generate input on policy implications. Prof. ten Brink is a management committee member on the project.

China Global Center

Next to academic research, the group has created dialogue forums for the general public sphere and local businesses, especially with the China Global Center.

Highlights and impact

- The research group has successfully acquired particularly prestigious third-party funding, including five DFG research grants.
- Our research results we have achieved — including numerous publications in top journals and an award-winning book — have all been very well received both nationally and internationally.
- As network organizers of the annual SASE conferences (Society for the Advancement of Socio-Economics, Network Q "Asian Capitalisms"), we have built bridges between political scientists, sociologists, economists, scholars from business studies, and area-studies specialists. As a result, SASE Network Q has become a very important international hub for socioeconomic debate on Asia.

Group composition & projects / funding

The group consists of several postdoctoral researchers, one coordinator for the China Global Center, and three to five research assistants. Also, Prof ten Brink is currently supervising three PhD students. The group and its projects are funded by the DFG, the BMBF, and Horizon 2020.

Selected publications

China's Capitalism. A Paradoxical Route to Economic Prosperity. University of Pennsylvania Press, 2019.

Innovation in emerging economies: How do university-industry linkages and public procurement matter for small businesses? Asia Pacific Journal of Management, 2021, (with C. Storz, Na Zou).

University satellite institutes as exogenous facilitators of technology transfer ecosystem development. The Journal of Technology Transfer, 2022 (with M. Conlé, H. Kroll, C. Storz).

The Externalization of China's Technical Standardization Approach. Development and Change, 2021 (with T. Rühlig).

Varieties of Contestation: China's Rise and the Liberal Trade Order. Review of International Political Economy, 2020 (with C. Weinhardt).

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Modern and Contemporary History

Dr. Julia Timpe

Our research encompasses the history of modern Europe and especially modern Germany, with a particular focus on the history of Nazi Germany, World War II and the Holocaust, Digital History, and the History of the Everyday.

Specific themes and goals

History of the Everyday and Cultural History (time period: Nazi Germany)

We have focused on themes and questions related to everyday life in the Third Reich, examining activities and propaganda of the Nazi leisure organization “Kraft durch Freude” (in English: “Strength through Joy”). In the more recent publications, we specifically looked at the area of sports offered in companies by the Nazi leisure organization. In another project, several undergraduate students are contributing to “Home & Away/ Fern & Nah: An ordinary man’s experience of Nazi Germany and World War II.” The project is based on an analysis of documents from the private archive of a man from Northern Germany, who served as a soldier in the Wehrmacht during World War II.

Social and Economic History (time period: Nazi Germany)

In 2020, a doctoral researcher joined the History group, and is working on the history of the circle of Nazi-period industrialists known as the Freundeskreis Reichsführer SS.

Digital History

Some of our recent publications deal with digital history approaches when studying Nazi Germany. In collaboration with Constructor University’s robotic group, we have used digital tools to explore and map the unfinished World-War-II submarine yard in Bremen-Farge, “Bunker Valentin”. We are conducting two funded projects — namely “Digital Contingencies: Prospects and Limitations of Technology in Digital Humanities” and 3D Erfassung der Gedenkstätte U-Boot Bunker Valentin durch Luft, Boden- und Unterwasserroboter (Valentin-3D) — with Prof Andreas Birk’s robotics group. The projects are funded by Jacobs Foundation and BMBF respectively.

Highlights and impact

In December 2019, we co-organised a workshop on digital history in the research field of Nazi Germany (titled “Zeugnisse des Nationalsozialismus, digital – Projekte, Methoden,Theorien”) at Constructor University. It was hosted by the history group together with the Robotics Group. The scholarly workshop led to the publication of an edited volume, entitled “Writing the Digital History of Nazi Germany”.

Group composition & projects / funding

The history group includes one doctoral researcher, as well as several undergraduate students. It receives funding from the Jacobs Foundation and the BMBF.

Selected publications

Julia Timpe and Frederike Buda (eds.), Writing the Digital History of Nazi Germany: Potentialities and Challenges of Digitally Researching and Presenting the History of the Third Reich, World War II and the Holocaust. Berlin: DeGruyter 2022.

Frederike Buda, Julia Timpe, and Christiane Charlotte Weber, “Digitale NS-Geschichtsschreibung. Herausforderungen im Umgang mit digitalen Quellen in der Geschichtsforschung und -vermittlung zum Nationalsozialismus.” Journal für Kultur und Geschichte der Deutschen im östlichen Europa 2 (2021): 57-77.

Julia Timpe, “Mit Sport und Spiel zur ‘Volksgemeinschaft’: Betriebssport der NS-Organisation ‘Kraft durch Freude’.” Industrielle Arbeitswelt und Nationalsozialismus: Der Betrieb als Laboratorium der Volksgemeinschaft 1920–1960, edited by Frank Becker and Daniel Schmidt, 183–194. Essen: Klartext, 2020.

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Logistics Engineering

Prof. Yilmaz Uygun

The Logistics Engineering and Technologies Group focuses on how to increase efficiency in logistics and production systems with the help of digital methods and emerging technologies in various basic and application-oriented projects as well as technology transfer projects.

Specific themes and goals

Sustainable logistics and supply chain management

Material flows in supply chains need to be designed properly to ensure environmentally-friendly sourcing and delivery. We worked with a large automotive supplier on a simulation-based supplier network analysis to detect anomalies. Through this we optimized their network and routes. Additionally, we are currently analyzing the potential of implementing a circular economy approach in the automotive supply industry. We are also investigating a potential material change in the automotive accessory industry to achieve better sustainability scores, while considering total costs. In addition, we work on the deep understanding of outsourcing decision making. Here, we have developed a simulation-based decision support tool for outsourcing, which shows all the effects of such a strategic decision.

Smart Logistics Systems Design

Logistics and production systems are nodes in supply chains that need to be designed for efficient operations. We are working on adopting virtual-reality applications in logistics systems, and are currently developing a self-learning methodology for dynamic layout re-planning in virtual reality. We are also investigating the effects of Industry 4.0 applications on employees in the design stage. In addition, as part of a publicly funded research project, we are developing a predictive cost-benefit analysis for the implementation of Industry 4.0 technologies in production.

Intelligent Management of Logistics Processing

The planning and organization of logistics-related processes in the value creation is of utmost importance for efficient operation. We are currently investigating the root causes of quality-related problems in collaboration with a large automobile manufacturer. Our aim is to reduce rework in the automotive value chain. Together with Prof. Marc-Thorsten Hütt from the Computational Systems Biology group at Constructor University, we have been working on holistic scheduling with the help of machine learning and emerging algorithms, especially in the steel industry. Some of these projects have led to prototypes. Prof. Uygun has also developed a proprietary algorithm-based method of adaptive inventory planning in a volatile environment. This method has been successfully tested and validated in several companies.

Innovative logistics technologies

Novel technologies directly affect production and logistics requirements. We are working on the further development of 3D printers and were able to produce the largest industrial delta-type 3D printer from scratch. Currently, we are working to push boundaries in terms of print speed and costs. Furthermore, we developed and produced a novel small-scale vertical axis wind turbine to be used in electric vehicle charging stations. Currently, we are extending its applications to buildings and lighting systems.

Highlights and impact

- We developed a holistic model to better understand the implications of outsourcing.
- We built the largest industrial delta-type 3D printer.
- We developed a proprietary inventory management model for highly volatile demands.
- We developed a proprietary vertical axis wind turbine.
- We developed a VR-based layout planning tool.

Group composition & projects / funding

Currently, there are eight research associates working on projects within the group. Our main funders are the Federal Ministry of Economic Affairs and Climate Action, the Kieserling Foundation, Bremen Development Bank, and several industrial companies in steel, automotive, and logistics.

Selected publications

Uygun, Y., Schupp, F., Gotsadze, N., Gzirishvili, L., Tindjou, S. A Holistic Model for Understanding the Dynamics of Outsourcing. International Journal of Production Research. 2022.

Merten, D., Hütt, M.-T. and Uygun, Y. A network analysis of decision strategies of human experts in steel manufacturing. Computers & Industrial Engineering. 2022.

Lyutov, A., Uygun, Y. and Hütt, M.-T. Machine learning misclassification of academic publications reveals non-trivial interdependencies of scientific disciplines. Scientometrics. 2020.

Özgür, A., Uygun, Y. and Hütt, M.-T. A review of planning and scheduling methods for hot rolling mills in steel production. In: Computers & Industrial Engineering. (CiteScore 2021: 9,6). 2020.

Lyutov, A., Uygun, Y. and Hütt, M.-T. Managing workflow of customer requirements using machine learning. Computers in Industry. 2019.

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Quantitative Methods

Prof. Dr. Colin Vance

Prof. Colin Vance is a professor of quantitative methods at Constructor University, with a particular focus on environmental economics and econometrics.

Specific themes and goals

His research focuses on applying econometric methods to topics in the field of environmental and resource economics. He is particularly interested in the nexus of transportation and land use, and uses spatially explicit data, such as satellite imagery, to study patterns of mobility and its influences. He concurrently serves as the Deputy Director of the Environmental & Resources division of RWI, an economics institute in Essen, Germany.

Highlights and impact

His research has been published in prominent journals and publications, including Economics Letters, Energy Journal, Regional Science and Urban Economics, and World Development.

I am also a principal investigator on several projects, including:

- 2021 – 2025: "JUSTNature: Activation of Nature-Based Solutions for a Just Low Carbon Transition. European Commission — Horizon 2020.
- 2019 – 2023 "Human-Centric Energy Districts: Smart Value Generation by Building Efficiency and Energy Justice for Sustainable Living," European Commission - MARIE SKŁODOWSKA-CURIE ACTIONS.
- 2018 – 2022 "Evaluating Germany's Climate Mitigation and Adaptation Practice 2 (Eval-MAP2)," German Federal Ministry for Education and Research (BMBF).
- 2018 – 2022 "Deep Transformation Scenarios for Informing the Climate Policy Discourse (DIPOL) — WP3: Socio-Economic Implications of the Transformation Process,"German Federal Ministry of Education and Research (BMBF).
- 2019 – 2021 "Price formation on the futures market and the physical market for cocoa," German Federal Ministry of Food and Agriculture (BMEL).

Selected publications

Eilers, L., A. Paloyo, C. Vance (2021) Rental Prices in Germany: A Comparison Between Migrants and Natives. Scottish Journal of Political Economy, 2021;00:1 33.

Frondel, M., C. Marggraf, S. Sommer, C. Vance (2021) Reducing Vehicle Cold Start Emissions through Carbon Pricing: Evidence from Germany. Environmental Research Letters 16(3): 034041.

Goetzke, F., C. Vance (2021) An Increasing Gasoline Price Elasticity in the United States? Energy Economics 95: 104982.

Sommer, S., C. Vance (2021) Do More Chargers Mean More Electric Cars? Environmental Research Letters, 16 (2021) 064092.

Tomberg, L., K. Smith Stegen, C. Vance (2021). "The Mother of all Political Problems"? On Asylum Seekers and Elections. European Journal of Political Economy, 67, 101981.

Frondel, M., A. Gerster, C. Vance (2020) The Power of Mandatory Quality Disclosure: Evidence from the German Housing Market. Journal of the Association of Environmental and Resource Economists 7 (1): 181-208.

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Political Science

Prof. Marco Verweij

Political science is the study of who gets what, when and how, according to American political scientist Harold D. Lasswell.

Specific themes and goals

In our research, we aim to explore how complex environmental and social problems can be resolved through the combination of (inter)governmental action, entrepreneurship, technological innovation, as well as civil society engagement.

We analyze which policy failures have fuelled the global rise of (authoritarian) populism, how this could have been prevented, and how the support for populism can be drained.

We explore the possible synergies between social and political theory, brain research and the analysis of human complex systems. al climate change and ocean acidification.

Highlights and impact

- The United States' Environmental Protection Agency, the largest of its kind in the world, uses Prof. Verweij's research for policy planning and to structure its interactions with stakeholders. The Dutch Environmental Assessment Agency does the same.
- He has co-authored articles with three of the most-cited scholars of the past 50 years: anthropologist Mary Douglas, neuroscientist Antonio Damasio and neurophysicist Robert Turner.
- Prof. Verweij has published articles in leading journals in political science, public policy, sociology, neuroscience, philosophy, economics, engineering and general science.
- He has also co-authored an article in a leading journal on sociological theory with 11 Constructor University alumni from a variety of disciplines.
- In 2022, Prof. Verweij's work was twice featured in Psychology Today.

Group composition & projects / funding

Prof. Verweij has co-supervised four PhD students (three in political science and one in engineering), however much of his work is in research networks that extend beyond Constructor University and that include the Brain and Creativity Institute at the University of Southern California in the United States, the Oxford Institute for Science, Innovation and Society, and the International Institute for Applied Systems Analysis in Laxenburg, Austria.

Selected publications

Verweij, M. (2022). Clumsy solutions and climate change: A retrospective. WIREs Climate Change, 13, e804.

Verweij, M., Ney, S., & Thompson, M. (2022). Cultural theory's contributions to climate science: Reply to Hansson. European Journal for Philosophy of Science, 12, 34.

Verweij, M., Alexandrova, P., Jacobsen, H., Beziat, P., Branduse, D., Dege, Y., Hensing, J., Hollway, J., Kliem, L., Ponce, G., Reichelt, I. J., & Wiegmann, M. (2020). Four galore? The overlap between Mary Douglas's grid-group typology and other highly cited social science classifications. Sociological Theory, 38(3), 263-294.

Favre, M., Swedlow, B., & Verweij, M. (2019). A cultural theory and model of power relations. Journal of Political Power, 12.

Verweij, M., & Damasio, A. (2019). The somatic marker hypothesis and political life. In D. P. Redlawsk (Ed.), The Oxford Research Encyclopedia of Politics. Oxford: Oxford University Press.

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Data-Driven Collaborative Decision Making in Complex Industrial Systems

Prof. Hendro Wicaksono

The German government has developed a high-tech strategy called Industry 4.0, which shifts the industrial technology paradigm by adopting the internet of things. This shift aims to connect human and cyber-physical systems and allow them to communicate and collaborate via the Internet of Things or services. However, many of these cyber-physical systems have been developed by different vendors, and contain various incompatible structures, formats, and vocabularies for exchanging information. In our group, we work to provide decision-makers in complex industrial systems with useful descriptive and diagnostic information, prediction, and simulations.

Specific themes and goals

Semantic modeling

An Ontology or Knowledge Graph is an information model, which integrates different schema and data sources. We apply a W3C standard, called The OWL (Web Ontology Language), as a model representation, and this serves as a shared vocabulary and schema among the heterogeneous systems and humans. Thus, it creates a model that machines and humans can understand. It provides flexibility to express statements described in description logic and integrate first-order logic. Therefore, logical reasonings, including fuzzy reasoning, are also possible in the knowledge model.

Semantic extraction

Semantic uplifting and linking extracts the semantics of exchanged data, which have various formats such as structured, semi-structured, natural language texts, and images. A single industrial data exchange standard cannot fully fulfill an application's data requirements in complex industrial systems. There is increased interest and research on sharing data and schemas from different domains on the internet (open data). We developed methods to reuse linked data and link available data and schemas.

Machine learning and knowledge extraction models

such as linear, non-linear, ensemble, time series, and deep learning models — identify interesting patterns in data. Using these models, we extract the information or knowledge required to solve particular problems, convert the information into ontology elements or rules, integrate them with formalized human knowledge, and store it in a knowledge graph.

Explainable artificial intelligence (XAI)

Explainable AI (XAI) aims to improve the explainability, interpretability, and usability of machine learning models generated from data so that people unfamiliar with AI can use the models to make decisions. It links machine learning models to the knowledge graph. Our research also focuses on modeling and extracting causal relationships among data instead of correlations to enable causal inferences.

Data-driven simulation and optimization

We have developed different approaches for optimisation problems, such as production scheduling, logistics, and product configuration. Current approaches are not able to solve large problems timeously. Meta-heuristics, by contrast, work on general models that do not correspond to reality. For this reason, we developed a hyper-heuristic approach, creating a flexible but real problem-relevant model. Furthermore, we develop a deep reinforcement approach to provide generic and scalable solutions for industrial optimization problems.

Applications

We apply our approaches in various complex industrial settings. For example, we optimized renewable energy sources in manufacturing processes; assessed risk and optimized processes in the automotive supply chain; and developed automatic assessment and optimisation tools for environment and social government (ESG) in manufacturing and supply chain. We also assessed and improved the explainability and deployment of AI models in agri-food supply chain, as well as for industry 4.0 maturity and architecture implementations. Other applications included transforming the automotive supply chain towards the circular economy; and developing a data-driven collaborative platform for smart cities and digital twin creation.

Highlights and impact

We have been collaborating with various large, small, and medium enterprises across Europe in our research projects. The collaboration projects have been funded by the German Federal Ministry of Economics and Climate Protection (BMWK), and the German Federal Ministry for Digital and Transport (BMDV). Our role is to support enterprises, especially small and medium enterprises (SMEs), to develop innovations and solve their operational problems. For example, we developed semantic middleware that facilitates energy-related data exchanges between manufacturing SMEs and utility companies. We also worked on machine-learning models to forecast power consumption and generation for setting up dynamic electricity pricing. Furthermore, we are also developing a digital-twin platform to facilitate digital model exchanges among SMEs. We are also collaborating with a large automotive manufacturer to assess supply chain risks and optimize the supply chain processes using causal AI.

Our works in semantic linking and knowledge graph contribute to open source energy management solutions (OpenEMS). We were also one of the initiators of the W3C LBD community group and are currently active as a member. Prof. Hendro Wicaksono has been a visiting professor in six different universities in Indonesia, and since 2018, he has supervised 146 Master and Bachelor theses.

Group composition & projects / funding

Currently, we have eight PhD students, two non-PhD research associates, and five student teaching and research assistants, and two PhD students. The group receives funding from BMWK, BMDV, and the private sector, among others.

Selected publications

Wicaksono, H.; Yuce, B.; McGlinn, K. (2022): Smart Cities and Buildings, in Buildings and Semantics. CRC Press.

Wicaksono, H.; Boroukhian, T.; Bashyal, A. (2021): A Demand-Response System for Sustainable Manufacturing Using Linked Data and Machine Learning, Dynamics in Logistics. Springer, Cham, 2021.

Farooq, Y.; Wicaksono, H. (2021). Advancing on the analysis of causes and consequences of green skepticism: causal inference methods. Journal of Cleaner Production.

Fajrul Falah, M.; Sukaridhoto, S.; Udin Harun Al Rasyid, M.; Wicaksono, H. (2020): Design of Virtual Engineering and Digital Twin Platform as Implementation of Cyber Physical Systems, Procedia Manufacturing.

Schneider G.F.; Wicaksono, H.; Ovtcharova, J. (2019): Virtual Engineering of Cyber-Physical

Automation Systems: The Case of Control Logic, Advanced Engineering Informatics.

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Statistical Learning and Data Science

Prof. Adalbert F. X. Wilhelm

"Data is the new gold." This prominent mantra in today's digital age has led to an increase in the recognition and appreciation of statistics in its new guise as data science, business intelligence and data analytics. Complementary to machine learning, statistical learning emphasizes the role of modeling in understanding complex data sets, and merges with parallel developments in computer science. Typically categorized as supervised and unsupervised learning, it provides both statistical modeling for predicting or estimating an output based on one or more inputs, as well as learning relationships and patterns in data without a measurement target.

Specific themes and goals

Prof. Adalbert Wilhelm's research group has a long history of working with and advising experts from various research fields. We focus on incorporating domain knowledge into statistical modeling by developing visual representations of both the raw data and the models.

Ice sheets

We are currently undertaking research within MarData, the Helmholtz School for Marine Data Science. In one project, we are developing a suitable algorithm for the automatic analysis and categorisation of radio-echo sound data in order to detect ice layers in Antarctica and Greenland. This has traditionally mostly been done by a flawed semi-automatic method. By using automatic image processing systems, we will significantly improve the efficiency and accuracy of layer detection. Based on a performance analysis of existing semi-manual algorithms, we will be able to understand how to develop hybrid algorithms using statistical properties and image processing. Furthermore, we will use the available manually annotated data to improve the evaluation of competing machine-learning.

Phytoplankton

In another project, we are developing a complete data processing chain for combining various Phytoplankton Functional Type (PFT) datasets and associated uncertainties at various spatial and temporal scales. Evaluating the distribution of phytoplankton in space and time is critical for assessing the impact of climate change on marine biogeochemistry and food web. Researchers can detect and quantify phytoplankton abundance and composition with optical sensors that are operated by different devices such as ship-towed undulators, ship-based inline systems or autonomous platforms such as satellites and profile floating. Combining these disparate data sources remains a major difficulty due to varying temporal and spatial resolution and insufficient definition of uncertainty.

Cocoa

In another research theme, we are merging econometric models and machine learning to investigate the price formation on the futures market and the physical market for cocoa. The project is run jointly with RWI - Leibniz Institute for Economic Research (RWI) in Essen.

Adaptive learning systems

We are also designing and implementing an adaptive learning system for statistics to reduce gaps in statistics education. With our system, we intend to offer an innovative tool to complement traditional courses in Statistics. It will offer personalized learning paths to students, particularly students from non-mathematical fields with a strong empirical focus, such as psychology, political science, humanities and social sciences.

Unsupervised learning

We are also developing basic methods in the area of unsupervised learning, in particular cluster analysis of mixed-type data. One of the few and probably the best-known approach to clustering mixed type data is the k-prototype algorithm. In this project, we aim to expand the scope of this clustering algorithm, covering the various aspects of validating the number of clusters, variable selection, imputation of incomplete data, and initialisation of the algorithm. By means of simulation studies on artificially generated data, we will gain a deeper understanding of mixed-type cluster analysis, and be able to suggest improvements to the algorithm that will make it more practical and, ultimately, to enable targeted data analyses that were previously not possible with sufficient quality.

Highlights and impact

In addition to its extensive external consulting activities, the group co-organised a number of conference events dedicated to community building in the field of data science and visualization. These include the European Conference on Data Analysis ECDA 2019 (University of Bayreuth), DAGStat 2019 (LMU Munich), ECDA-DSSV 2021 (Erasmus University Rotterdam), DAGStat 2022 (University of Hamburg), ECDA 2022 (University of Naples).

Group composition & projects / funding

The research group comprises five PhD students funded by different projects and sources, several masters and bachelor students, and visiting PhD students (one per year) from the University of Cagliari, Italy. The group received funding from Erasmus+ Program, the Volkswagen Foundation, and the Bundesministerium frü Ernährung und Landwirtschaft (BMEL)

Selected publications

Müller, L. Lausser, A. Wilhelm, T. Ropinski, M. Platzer, H. Neumann, H.A. Kestler. A perceptually optimized bivariate visualization scheme for high-dimensional fold-change data, Advances in Data Analysis and Classification 15(1), 463-480.

S. Friedrich, G. Antes, S. Behr, H. Binder, W. Brannath, F. Dumpert, K. Ickstadt, H. A. Kestler, J. Lederer, H. Leitgöb, M. Pauly, A. Steland, A. Wilhelm, T. Friede. Is there a role for statistics in artificial intelligence? Advances in Data Analysis and Classification 1-24.

Aschenbruck R, Szepannek G (2020) Cluster validation for mixed-type data. Archives of Data Science, Series A 6(1):1–12, DOI 10.5445/KSP/1000098011/02

C Koopman, A Wilhelm. The Effect of Preprocessing on Short Document Clustering, Archives of Data Science 6 (1): 1-16.

Rizkallah MR, Frickenhaus S, Trimborn S, Harms L, Moustafa A, Benes V, Gäbler Schwarz S, Beszteri S. (2020) Deciphering patterns of adaptation and acclimation in

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History and Theory of Art

Prof. Dr. Isabel Wünsche

Prof. Isabel Wünsche's research group examines the production of art from the 19th to the 21st century. Particular focus is on the art movements and artistic networks that shaped European modernism, including German Expressionism, the Russian avant-garde, and the Bauhaus, as well as the reception of these movements beyond Europe, in North and Latin America, and Australia.

Specific themes and goals

Bauhaus Australia

The goal of the project was to provide the first systematic examination of cross-disciplinary approaches to art, architecture, and design education brought to Australia by modernist émigrés from Germany, Austria, and Central Europe. The project, titled "Bauhaus Australia: Émigrés, Refugees and the Modernist Transformation of Education in Art, Architecture, and Design, 1930 to 1970" and funded by the ARC, 2016-2019, resulted in two exhibitions and a book publication.

German-Finnish Artistic Relations

This research project focused on German-Finnish artists' relations during the period 1890s to 1980s, which — although an important aspect of the artistic exchange between artists in the various European art centers — have, so far, found only little scholarly recognition. Particular emphasis was on the collaboration and cooperation of artists in the expressionist movement, the networks of Dada, Fluxus, and the neo avant-garde, and their significance for modern and contemporary art practices.

The Russian Art and Culture Group

This is a platform for discussing various aspects of Russian and Soviet visual arts, music, and literature; it brings together young researchers with established international scholars from East and West. Since 2014, graduate students affiliated with the group have organized eight workshops in Bremen, Berlin, and Vienna. Themes under consideration were East-West cultural relations; intersections of art, science, and technology in Soviet film; Russian art theory and criticism; and the problem of religion in art. From 2017 to 2021, the group's activities were generously supported by the Kroll Family Trust, Switzerland.

Highlights and impact

Prof. Wünsche was invited to give several talks during the period, including one at the online symposium: "What can can the Black Square do? On curiosities and utilities of avant-garde collections" and a keynote address at the Université libre de Bruxelles, Belgium in 2022.

The group held a number of events, including:

- "What is to be Done? — Discussions in Russian Art Theory and Criticism II", 7th Workshop of the Russian Art & Culture Group, Jacobs University Bremen in cooperation with and Forschungsstelle Osteuropa, Bremen, September 2019
- "The Problem of Religious Art in Modernity: Uses and Abuses of the Icon in Russia", 8th Workshop of the Russian Art & Culture Group in cooperation with the Institute for Human Sciences, Vienna, October 2020
- International Conference, "100 Years of German-Russian Cultural Exchange: The First Russian Art Exhibition", Staatsbibliothek Berlin, October 2021

In 2021, Prof. Wünsche was appointed a scout for the Henriette Herz Scouting Program of the Alexander von Humboldt Foundation. In 2022, she was awarded a research fellowship at the Robert Gore Rifkind Center for German Expressionist Studies at the Los Angeles County Museum of Art in the United States.

Group composition & projects / funding

Prof. Wünsche's research group consists of six PhD students and two postdoc research associates. Its various projects have been funded by the Australian Research Council (ARC), the German Academic Exchange Board (DAAD), the German Science Foundation (DFG), the Kroll Family Trust, Switzerland, and Kuhn & Bühlow, Insurance Broker Group, Berlin.

Selected publications

Isabel Wünsche, "The Evolution of Abstract Painting: Ludwig Hirschfeld-Mack's Coloured Light Plays," The Structurist, 51/52 (2018-2019): 87-98.

Philip Goad, Ann Stephen, Andrew McNamara, Harriet Equist, Isabel Wünsche (eds.), Bauhaus Dispora and Beyond: Transforming Education through Art, Design and Architecture, Melbourne: Melbourne University Publishing; Sydney: Power Publications, 2019.

Isabel Wünsche, "Liquid Crystals, Theories of Life, and Visual Perception in the Russian Avant-garde," Leonardo, 54 (Dezember 2021) 6: 680-684. Abstract: DOI: 10.1162/leon_a_02013.

Isabel Wünsche, "Experimentation and Invention in Weaving at the Bauhaus," in New Challenges to Artistic Conventions in the Weimar Republic, eds. Deborah Ascher Barnstone and Maria Makela, London: Bloomsbury, 2022, pp. 37-58.

Isabel Wünsche, Miriam Leimer (eds), 100 Years On: Revisiting the First Russian Art Exhibition of 1922, Cologne, Vienna: Böhlau, 2022.

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Name Index

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staying together is progress,
and working together is success.”

— Henry Ford

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