Institute of Computer Science (ICS-HSG)

Annual report 2023

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University of St.Gallen

Institute of Computer Science

Acknowledgements

The directors of the Institute of Computer Science would like to take this opportunity to express their gratitude for the support that we, as individuals and as an institute, continue to receive from a broad range of individuals and offices affiliated with the University of St.Gallen and beyond.

As an institute, we are supported by an Advisory Board (Geschäftsleitender Ausschuss GLA in German) chaired by *Prof. Ernst Mohr*. The Board comprises of *Doris Albisser*, *Markus Bänziger*, *Prof. Elgar Fleisch*, *Prof. Dietmar Grichnik*, *Prof. Manfred Hauswirth* and *Stephanie Schoss*. We would like to express our gratitude to all members of our Board (GLA) for their precious advice and continuous commitment to the institute's ideals and vision.

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Introduction

The Institute of Computer Science (ICS-HSG) includes eight research groups: Artificial Intelligence and Machine Learning, led by *Prof. Dr. Damian Borth*; Data Science and Natural Language Processing, headed by *Prof. Dr. Siegfried Handschuh*; Foundation of Computation, under the guidance of *Prof. Dr. Anna-Lena Horlemann*; Interaction- and Communication-based Systems, directed by *Prof. Dr. Simon Mayer*; Cyber Security, managed by *Prof. Dr. Katerina Mitrokotsa*; Programming Languages, overseen by *Prof. Dr. Guido Salvaneschi*; Human-computer Interaction, chaired by *Prof. Dr. Johannes Schöning*; and Software Systems Programming and Development, led by*Prof. Dr. Barbara Weber*. In 2023, the respective professors (Borth, Handschuh, Mayer, Mitrokotsa, Schöning, Weber, Horlemann, Salvaneschi) formed the board of Directors of the ICS-HSG. Prof. Mayer is the Managing Director of the ICS-HSG, a position he has held since November 2019. From February 2024 the task will be taken over by Prof. Salvaneschi. The role of the Managing Director is a coordinating one and it does not involve any authority to issue directives to other members of the board of Directors.

The chart below shows the key figures the Institute has achieved this year. As ICS-HSG accumulates more data, we will be able to make valuable comparisons over the years.

The research of ICS-HSG spans various areas, including deep neural networks, language models, coding theory, cryptography, ubiquitous computing, autonomous systems, cybersecurity, programming languages, HCI. It addresses diverse topics and employs interdisciplinary collaboration, with numerous publications in prestigious venues.

The details of our research achievements are discussed extensively in the rest of this document. We now would like to present a research project by one of our Master's students.

The Swiss Artificial Gravity Experiment (SAGE) is an ambitious student-led project that aims to send a CubeSat, a small type of satellite, into Low Earth Orbit. The primary goal of this mission is to conduct biological experiments in space, focusing on how human cells react to the unique conditions found there. The CubeSat will house a specialized, miniaturized laboratory designed for human cell culture, which is expected to provide valuable insights into cellular aging in space. Key to this endeavor, the team has developed a custom mi-

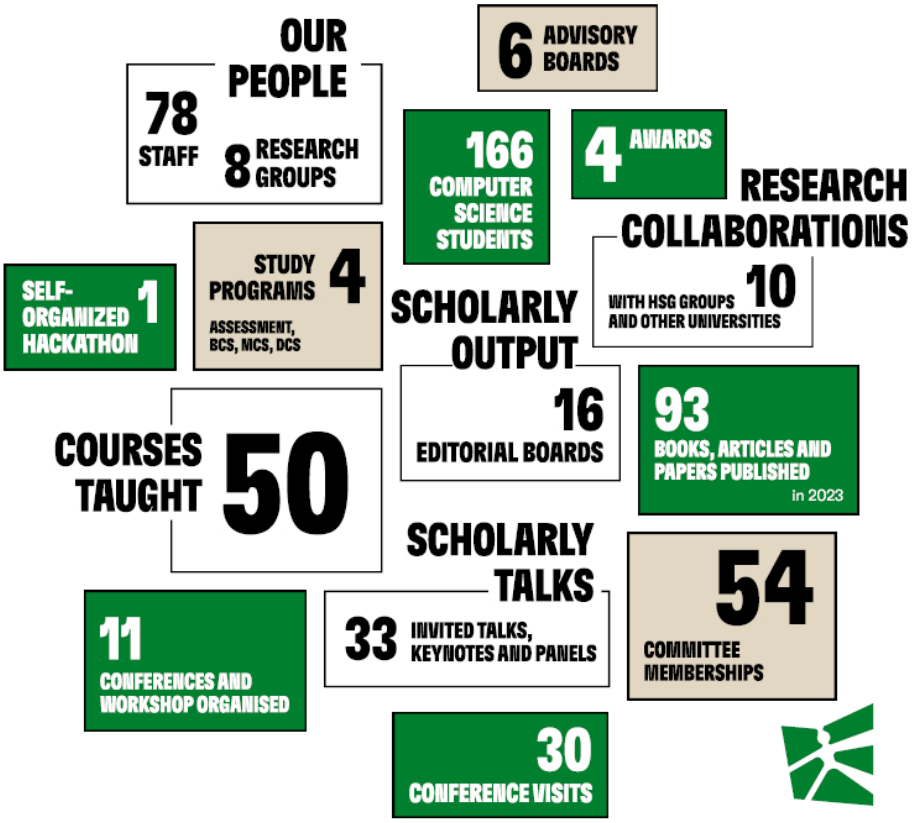


Figure 1: key figures.

crofluidic system and a miniaturized fluorescence microscope, essential tools for their research in orbit.

Beyond its scientific objectives, SAGE also has educational aspirations. The CubeSat includes an amateur radio transponder and two Global Navigation Satellite System (GNSS) modules developed at ETH Zurich. The radio transponder serves a dual purpose: it allows amateur radio enthusiasts worldwide to connect via satellite, and it also supports educational workshops. These workshops are intended to introduce students to the world of amateur radio, sparking interest in science, technology, engineering, and mathematics (STEM) fields.

Another innovative feature of SAGE is its onboard computer (OBC), which is responsible for managing the satellite's operations. Besides its main microcontrollers, the OBC features also a new, fault-tolerant RISC-V microcontroller called Trikarenos, developed by ETH Zurich's Integrated Systems Laboratory. This microcontroller is designed to withstand radiation in space, and its performance will be closely monitored during the mission. The OBC is the "brain" of the CubeSat, controlling all subsystems, managing tasks, and ensuring the overall health of the satellite. It also stores the experimental data collected.

The SAGE project has already achieved significant milestones. These include a successful parabolic flight, testing of its centrifuge system, and winning the ESA's "Fly Your Satellite!" Design Booster Program. Currently, the team is in the Final Design Phase, refining their designs and testing components. The final design will be presented at the ESA Final Design Review in April 2024.

Following this review, the CubeSat will undergo manufacturing, assembly, and thorough environmental testing, leading up to its scheduled launch in 2025. After launch, the satellite's operations will be managed from a ground station in Zurich, also developed by the SAGE team.

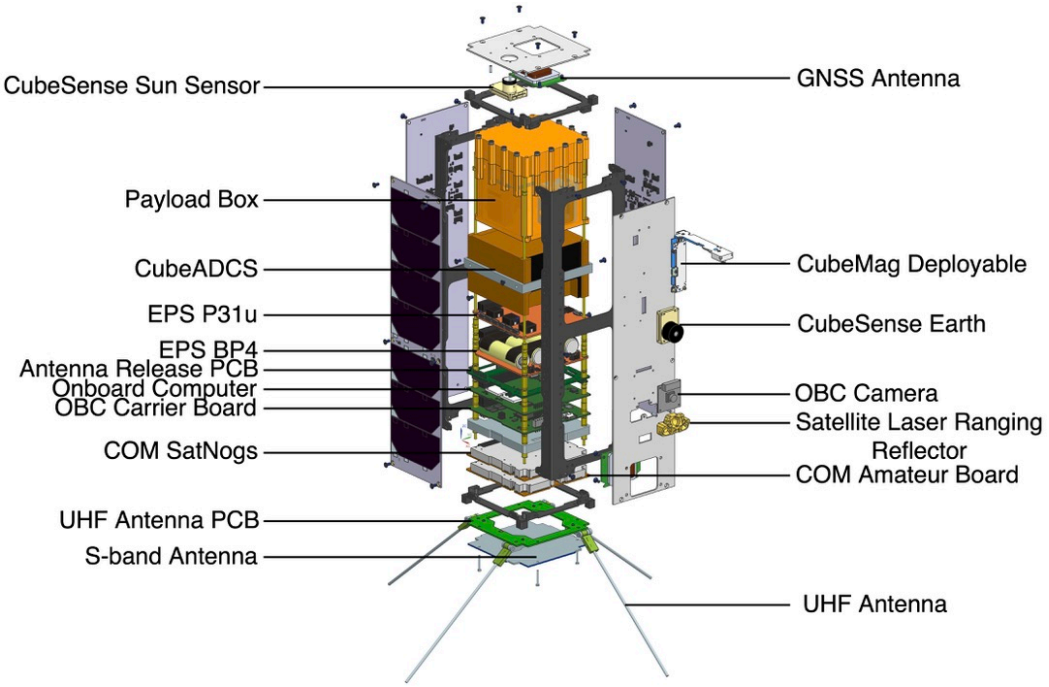


Figure 2: An overview of the CubeSat hardware components.

In addition to our joint *teaching and research activities* at the ICS-HSG, in 2023, we organized the first Computer Science Day to establish a network of collaborations between the ICS-HSG and industry. Given the positive outcome, and based on the feedback received by the participants, we are planning our second CS-Day in May 2024.

With this annual report, we provide an overview of the activities of the ICS-HSG and its chairs in 2023. Details and current news are presented on our institute website, `https://ics.unisg.ch/`

Artificial Intelligence & Machine Learning (AIML)Damian Borth

The **Artificial Intelligence & Machine Learning** lab lead by Prof. Damian Borth performs research on deep neural networks in representation learning with the aim to make such models more robust, more performant, and trustworthy when applied to real world data.

In 2023, first PhD candidates graduated from the aIML lab and the lab's international collaborations have been extended and strengthened. Highlights of 2023 were (i) the *ACM SIGMM Test of Time Award* handed over for Prof. Damian Borth's work "Visual Sentiment Analysis" as published at ACM Multimedia 2013, (ii) the *HSG Impact Award* for the work on representation learning from populations of neural networks, (iii) the successful graduation of two PhD candidates from the lab, and (iv) Prof. Damian Borth invitation to the Ringier AI Advisory Board.

Team Members

The chair of Artificial Intelligence and Machine Learning consists of 10 members including Prof. Michael Mommert, who is affiliated with the lab. In 2023 the lab's first two PhD candidates graduated. This was Dr. Shijun Wang with his work on "**Deep Learning for Paralinguistic Representation Learning**", and Dr. Marco Schreyer with his work on "**Representation Learning in Financial Auditing using Deep Neural Networks**". Dr. Wang started a position at the ETH Startup LatticeFlow and Dr. Schreyer went to the International Computer Science Institute (ICSI) and UC Berkeley as postdoc and will start at the Eidgenössische Finanzkontrolle soon after his six month stay in Berkeley.

Additionally, two PhD students were successfully able to defend their PhD proposal. This was Linus Scheibenreif with external examiner Prof. Konrad Schindler from ETH Zurich and Joëlle Hanna with external examiner Prof. Ribana Roscher from Uni Bonn / Forschungszentrum Jülich.

With Marco Schreyer, one of the lab's PhD candidates came back from his research stay abroad at Rutgers University early 2023. Given a newly established collaboration with Prof. Michael Mahoney at UC Berkeley, Konstantin Schürholt, one of the lab's PhD candidates was sent for a three months stay to Berkeley.

With Joëlle Hanna, and Konstantin Schürholt, two members of the lab went for internships with Google Zurich (Joëlle Hanna) and Google DeepMind Mountain View (Konstantin Schürholt). Finally, a new PhD student Léo Meynent, who graduated in Computer Science from EPFL, joined the lab in September 2023.

Research

The AIML lab continues its research focus along the four research areas (a) **Representation Learning of Deep Neural Networks**, (b) **Remote Sensing and Earth Observation**, (c) **Text-to-Speech Synthesis**, and (d) **Financial Audit and Fraud Detection**. With the departure of two PhD candidates the lab will strategically strengthen its focus on (a) and (b), while discontinuing research directions (c). In total in 2023, the lab was able to get **14 publications accepted**. This includes one journal publication, 8 conference publications, and 5 workshop publications.

In the research area "Representation Learning of Deep Neural Networks", the lab has been awarded the **HSG Impact Award** [1] for the research on *"Hyper-Representations: Learning from Populations of Neural Networks"*. This work extended the previous work on ModelZoos by learning lower-dimensional representations of neural networks useful for multiple down-stream tasks such as testing neural networks without testdata or sampling new neural networks able to outperform pretrained models in transfer learning scenarios. Additionally, the lab has expanded its research into the area of "continual learning", where representations are continuously updated instead of learned from scratch. In this area the lab was able to position two publications at CoLLA in 2023.

After the shift towards self-supervised learning, the area "Remote Sensing and Earth Observation" currently moves into foundation model research. Our previous work on Vision Transformer has been used extensively as the baseline for most of the published foundation models in the community including works from UC Berkeley, University of Stanford and others. With regard to this, we were able to publish the first Vision Transformer models on the challenging domain of hyper-spectral remote sensing data serving as a benchmark for future work in the community. Additionally, we published work on CO_2 estimation of fossil fuel power plants from space at IEEE Transactions of Geo Science and Remote Sensing contributing to the domain of sustainable AI.

[1] https://www.unisg.ch/en/news/video-series/impact-awards/

In “Text-to-Speech Synthesis”, the lab did publish two works at IEEE Interspeech and IEEE ICASSP on learning affective voice and speech representations. These works presents the first task-agnostic backbones useful for both tasks: emotion detection and emotion generation. Finally, in the research area “Financial Audit and Fraud Detection”, the lab was prominently visible with its diffusion publications at the ACM AI in Finance conference. This work defines the first diffusion model for tabular data generation.

Summarizing, the published 14 publications were written in collaboration with authors of Reykjavik University and Rutgers University, and the ACA-HSG underpinning the labs national and international research collaboration network. An overview of all published work can be found at the University of St.Gallen Alexandria platform [2]. As in the previous year, members of the lab were serving as areas chairs, technical program committee, and reviewers of international conferences (NeurIPS, ICLR, ICML, IEEE CVPR, IEEE ICCV, ACM ICAIF), journals (Nature Communication, IEEE TGSRS, Remote Sensing and Environment, Remote Sensing Letters), and governmental funding programs (Helmholtz Society, DFG, DOE).

Projects

The currently running SNF funded project: *“Self-Supervised Learning for Earth Observation: Leveraging a wealth of multi-modal data”* went into the first year of work. This four-year-project does focus on novel methods for self-supervised learning of multi-modal streams of satellite data. In scope of this project, the lab was invited to organize a day-long tutorial about multi-modal, multi-task learning, and self-supervised learning at the IEEE IGARSS conference in Pasadena, USA. This tutorial was very well visited and allowed team members of the lab to present first results of the project.

Our Swiss Front-Runner project in collaboration with St.Galler Stadtwerke is in its final year. The project focuses on the prediction of photovoltaic power production in the city of St.Gallen. The final year aims at extended evaluations of the developed prediction methods and its integration to the Stadtwerke St.Gallen infrastructure.

Finally, the project *“HumAIn – A Human Rights Approach to AI”* funded by Botnar Foundation has successfully ended. This project was done in collaboration with

[2] https://www.alexandria.unisg.ch/view/pub_alex_user_id/7781.html

Prof. Florian Wettstein, Prof. Veronica Barassi and the Economist group, UK and focuses on the human rights aspect of generative AI.

Teaching

In 2023, the members affiliated with the chair organized and held multiple courses. For the Master of Science in Computer Science (MCS), the AIML lab hosted the *"Machine Learning"* course in spring 2023 and *"Deep Learning"* in fall 2023. In fall 2023, Prof. Michael Mommert has taught his new course "Computer Vision" in the MCS program for the first time.

Additionally, several service teaching courses were held by lab members. These were the Bachelor BWL "Machine Learning" course, the Master in General Management (MGM) "Introduction to Machine Learning and Deep Learning" course, and the Master in Business Innovation "Introduction to Artificial Intelligence and Deep Learning" course. Like in the previous year, in 2023 the "Deep Learning: Fundamentals and Applications" course of the "Global Summer School for Empirical Research Methods (GSERM)" was held in collaboration with Prof. Korbinian Riedhammer from TH Nürnberg, Germany.

With regard to bachelor and master thesis work, in 2023, the lab has supervised three bachelor theses and four master theses. Out of these, two theses lead to publications at IEEE IGRASS conferences and one lead to a publication at an ICLR workshop. Finally, three MCS master projects were supervised at the lab.

Lastly, members of the lab were active in multiple executive education programs with invited sessions, full days or their own electives. In particular, the elective course "Coding and AI", which is held in collaboration with Prof. Barbara Weber was successfully established in the EMBA and IEMBA program of the University of St.Gallen. Finally, Prof. Damian Borth in collaboration with Prof. Torbjørn Netland from ETH Zurich held for the first time their course at the newly established embaX joint executive education program between University of St.Gallen and ETH Zurich.

Outreach

The scientific work and expertise of the lab was highlighted and outlined in multiple events and articles in public media. One of the highlights of 2023 was the panel discussion about Responsible Technology with Google's Chief Privacy Office Keith Enright and Quantum Intelligence Machine's CEO Jan Goetz at the St.Gallen Symposium. Another highlight was the invitation to a Google Research Talk in Mountain View California to present our research on representation learning of neural network models. The third highlight of 2023 was the organization of the Swiss Remote Sensing Days at SQUARE in St.Gallen. The three-day conference was visited by almost 80 participants from all Switzerland including universities, governmental agencies and federal research institutions. The lab also organized two additional workshops, one workshop about AI Regulation and one workshop about Generative AI with the DuMont family and its advisory board.

Additionally, multiple invited lectures or seminars at universities such as Bundeswehr University Munich, Uni Kaiserslautern, International Computer Science Institute (ICSI) have been held. Lab members have given keynote at events invited by e.g., Deutsches Bundesministerium Bildung und Forschung, DAAD, MunichRe, IBM Research, AI GRID, Ory, Kanton St.Gallen, EMPA, and HSG Highlights. In total the AIML lab was able to communicate its research in 18 invited keynotes, lectures, and seminars.

In 2023, Prof. Damian Borth was invited to join the Ringier AI Advisory Board together with Ringier Group CEO Marc Walder, Anna Mossberg, and Léo Steinacker [3] As in the previous year, Prof. Damian Borth held elected positions at the board of the German Data Science Society, the board of Trustees at the Int. Computer Science Institute in Berkeley, the Scientific Advisory Board of the Roman Herzog Institute, and the Scientific Advisory Board of the DAAD IFI Program.

[3] https://www.ringier.com/ringier-nominates-ai-advisory-board/

Data Science and Natural Language Processing, Siegfried Handschuh

In 2023, our research efforts in the field of **Natural Language Processing** continued with a particular emphasis on **Large Language Models** (LLMs) and generative AI in general. These models have the ability to process natural language and are widely used for a variety of purposes, including speech recognition, machine translation, text summarization, and chatbots, among others. A prominent and recent example of this technology is **ChatGPT**. Developed by OpenAI, ChatGPT garnered significant attention towards the end of 2022, further fueling interest in LLM research.

Team

Our team welcomed a new member, Rositsa Ivanova, who joined us from our sister university, the Vienna University of Economics and Business in Austria. Prior to joining our team, Rositsa worked as a Research Assistant in the field of Data and Knowledge Engineering. She will be pursuing her PhD within the framework of our Swiss National Science Foundation (SNF) project on Conversational AI.

Research

Our focus in research is on the construction, interrogation, investigation, and optimization of **Large Language Models (LLMs)**. Despite their widespread usage and extensive study, LLMs remain incompletely understood, often presenting researchers with unexpected emergent capabilities. This necessitates a wide range of inquiry, demanding substantial experimentation to enhance our understanding of their functions. The effort put into basic research is worthwhile because these models are becoming increasingly ubiquitous and contribute to a homogenisation of the research landscape while offering immense downstream potential.

Large Language Models, such as **ChatGPT**, are closely related to generative AI and are critical tools in generative AI research. They have the ability to understand and produce natural language, making them capable of handling complex

tasks like text generation, translation, language processing, and even question-answering systems. By utilizing large amounts of training data and recognizing patterns and relationships in natural language, LLMs can push the boundaries of generative AI and enable new areas of application.

Our research endeavors to offer an in-depth understanding of LLMs, their underlying Transformer architecture, and associated scaling phenomena and prompting roles in model training. We analyse both the benefits and drawbacks of these models, assessing their impact on performance and accuracy. These insights contribute to a comprehensive understanding of LLMs, including their potential and limitations.

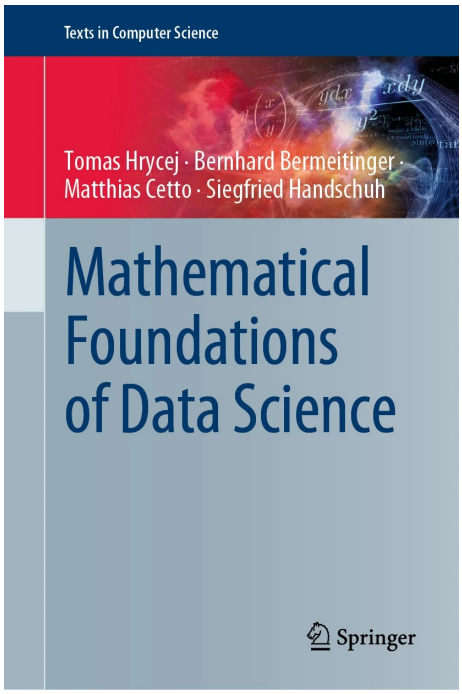
Our investigation shows that model optimization has often been neglected in the past, and the descriptions of Transformer architectures in the literature are often incomplete or different, leading to uncertainties in implementation. However, there are ways to improve and optimize existing architecture decisions. Additionally, systematic probing experiments have explored the performance of current models and highlighted their limitations.

Regarding Large Language Models, we conducted an extensive literature review that provided a thorough and comprehensive understanding of the field's current state of the art, emerging trends, and challenges. Accompanying the literature review, we carried out a series of **rigorous scientific experiments** using our **DGX-2 supercomputer**, allowing the research team to investigate the practical implications and potential constraints of these models. These experiments not only corroborated theoretical findings but also expanded domain knowledge by identifying novel research areas and opportunities for further innovation in the context of Large Language Models.

Books

In 2023, we celebrated the publication of our textbook "**Mathematical Foundations of Data Science**" (see Figure 3a) by the renowned Springer Verlag. This book, available at [4], represents a significant milestone in our academic journey. In the same year, we were actively involved in the editing and chapter writing process for an upcoming book titled "Generative KI,"[5] which is set to be published by the Haufe Group and its subsidiary, Schäffer-Poeschel Verlag.

[4] https://link.springer.com/book/10.1007/978-3-031-19074-2
[5] https://shop.haufe.de/prod/generative-kuenstliche-intelligenz



(a) Data Science Textbook

(b) Generative AI Book

Figure 3: Books written and edited by DS-NLP chair

The Data Science textbook aims to point out the most important principles of data analysis from the mathematical point of view. Specifically, it selected these questions for exploring: Which are the principles necessary to understand the implications of an application, and which are necessary to understand the conditions for the success of methods used?

The German-language publication "**Generative Künstliche Intelligenz - ChatGPT und Co für Bildung, Wirtschaft und Gesellschaft**", co-edited with Prof. Sabine Seufert – serves as a comprehensive guide to generative AI, providing insights into its basic concepts, its impact on innovation management, and its effects on the economy, education, and society. The book also includes tangible application examples to demonstrate the practical use of this technology

By contributing to both of these books, we were able to demonstrate the breadth and depth of our expertise, highlighting the practical applications and societal implications of our work in the fields of data science and generative artificial intelligence.

Projects

The completion of the following projects was achieved

- **Research Partnership Grant, Latin America**: "EVOLVE: language as a tool for EnVirOnmentaLly sustainable actions in deVEloping countries: for the right to healthy food". In collaboration with São Paulo State University (UNESP) in Brazil.

- **GFF-HSG**: "Probing & Improving Transformer-Based NLP Models' Understanding of Logical Relationships". The GFF project was led by Dr Reto Gubelmann.

The following projects were continued throughout the year 2023, building upon the progress made in the previous year

- **SNF**: "Conversational AI: Dialogue-based Adaptive Argumentative Writing Support". This project aims to develop adaptive writing support systems for students to improve their argumentation skills, using a novel machine learning-based method to assess the quality of argumentative texts and investigating chatbots as feedback providers, with the expected outcomes being a comprehensive approach to assessing text quality, a proof-of-concept argumentative dialogue agent, and a dialogue-based approach to providing interactive feedback.

- **SNF SPIRIT**: "Next Generation of Digital Support for Fostering Students' Academic Writing Skills: A Learning Support System based on Machine Learning (ML)". AI-based writing is a long-standing research program at our chair in collaboration with IBB-HSG. The research project investigates a new generation of digital support for academic writing and provides deep insights into how AI technology can transform academic writing and how it impacts changes in teaching approaches and adaptive coaching. The research project is a collaboration between the University of St.Gallen, also with Prof Sabine Seufert, and Mahidol University in Thailand. The target group of the studies are first-semester students at both universities. As part of this research project, in addition to the didactic designs for use in university teaching, we were also able to investigate the students' usage behaviour and ethical attitudes towards the use of AI by creating a framework for collaboration between humans and AI with six stages of AI-supported text creation based on Boyd-Graber et al. (2023). The survey of 699 students revealed varying use of ChatGPT at all six levels, with level 3 (literature search) being used slightly more. Students expressed mixed opinions on ethical issues such as the declaration of ChatGPT-generated content in academic papers. The results of the study highlight students' concerns about negative effects on grades, lack of clarity about university

policy on ChatGPT and fears that hard work will no longer be rewarded in the future. Despite these issues, most students support open access to ChatGPT

- **Swissuniversities**: This sub-project 4 of the Swissuniversities project "Digital Examinations" at the HSG aims to investigate and test the technological developments of automated examinations. We are carrying out this project in cooperation with Prof Dr Sabine Seufert (IBB-HSG) from 2021 to 2024. In the first year of the project, it was an important milestone to create a feasibility study for automated assessments. In the third year, 2023, we were able to carry out a further pilot for automated feedback. We were able to try out our Artist tool with tutors and exercise groups (approx. 100 students) in an exercise unit as part of the "Introduction to academic writing" course. This year, the students compared two language models: ChatGPT vs. Llama (open source model from Meta), and according to the students' feedback, both language models performed equally well in terms of feedback on argumentation structures.

In collaboration with Switzerland Innovation Park Ost AG [6] and with additional support from IHK-St.Gallen-Appenzell[7], we have initiated a new industry-funded project named **Locascope**. This project explores the field of **hybrid artificial intelligence**, focusing on the integration of Large Language Models and Knowledge Graphs. The proposed methodology seeks to synergize the strengths of the two paradigms while concurrently investigating and mitigating issues related to LLMs hallucination and resource-intensive executions. The primary goal of this research and development endeavor is to create a large-scale, intelligent skills repository. The proposed system is a tripartite structure, comprising a data lake, a semantic layer, and faceted browsing mechanisms. These components form the foundation of the system's architecture, enabling efficient management and querying of knowledge related to corporate skills, including comprehensive information about entities, their offerings, services, and their interactions within the larger industrial and market landscapes.

Furthermore, in collaboration with the startup Brian AG[8] and the IBB-HSG[9], we submitted a project proposal titled "**Integrating AI Chatbots into Social Learning in Higher Education**" to Innosuisse. The proposal was successfully accepted by the end of 2023. The project is set to commence in 2024.

[6] https://innovationspark-ost.ch/
[7] https://www.ihk.ch/
[8] https://brian.study/
[9] https://ibb.unisg.ch/

Community & Outreach

A video[10] featuring Prof Siegfried Handschuh, explaining the capabilities of ChatGPT has become the **most viewed video** on the University of St.Gallen's public YouTube channel at the end of 2023, amassing over 12,000 views.

In the video, he discusses the potential and weaknesses of large language models such as ChatGPT. Whether summarising texts, writing songs or generating code in different programming languages: the chatbot ChatGPT from OpenAI puts previous digital assistants in the shade. Further he explains how the AI behind the application works, what its weaknesses and potential are and whether it could even enable scientific breakthroughs in the future.

Along the same line, Siegfried was a sought-after speaker and gave numerous invited presentations about the Language of Generative AI at various educational institutions, businesses, and events. He was invited to speak at schools and universities, where he shared his expertise with teacher, students and faculty members eager to learn about the latest developments in Large Language Models, generative AI and its potential applications in various fields.

Interviews were held with various media outlets, ranging from local radio stations to national newspapers. NZZ – **Neue Zürcher Zeitung**, in particular, published two pieces, wich includes citatons of the chair: "Künstliche Intelligenz: Microsoft kann nur gewinnen, Google nur verlieren"[11] and "AI: Die Schweiz ist eine KI-Nation" [12].

Prof. Handschuh was also invited to participate in a panel discussion at the prestigious Frankfurt Book Fair[13]. The panel focused on the impact of generative AI on the future of content and software development.

Publications

https://www.alexandria.unisg.ch/entities/person/Siegfried_Handschuh/publications

[10] https://youtu.be/_UB1vD4ZhTY
[11] https://www.nzz.ch/wirtschaft/google-kann-im-abwehrkampf-gegen-microsoft-nur-verlieren-ld.1779492
[12] https://www.nzz.ch/wirtschaft/ai-die-schweiz-ist-eine-ki-nation-ld.1765298
[13] https://www.haufegroup.com/buchmesse-speaker/prof-dr-siegfried-handschuh

Foundations of Computation, Anna-Lena Horlemann

The group for **Foundations of Computation** is engaged in research and teaching in the areas of theoretical computer science, coding theory, cryptography and algorithmic mathematics. With our research results we aim to improve digital communication technologies in their reliability, efficiency and security.

Team

At the end of the summer of 2023 our Postdoc Dr. Habibul Islam left our group to start a professor position in India. On the other hand, our external PhD student Felicitas Hörmann (from the German Aerospace Center in Munich, Germany) spent the fall semester 2023 with us in St. Gallen and supported our research and teaching activities. The other team members, i.e., the head of the chair as well as the doctoral researchers Marc Newman, Nadja Willenborg and Adrien Pasquereau remained unchanged.

Research

In the area of coding theory we derived new results on quantum error correcting codes derived from the dihedral group. These codes have interesting parameters and could be useful to improve the efficiency of quantum computing. We presented these results at two international conferences: the YRCS in Germany and the *IEEE Information Theory Workshop (ITW)* in France. Furthermore, our paper *The Subfield Metric and Its Application to Quantum Error Correction* was published and received considerable attention in the research community. The chair presented the results of this paper at the *Nordic Congress of Mathematics* in Aalborg, Denmark.

In the area of post-quantum cryptography, we derived several results in our project on zero-knowledge proofs which are built on general linear codes. Moreover, we continued our collaboration with Dr. Karan Khathuria of Cambridge Quantum in which we analyze lattices in the Manhattan norm (or l_1 norm). Furthermore, we derived results on the use of linearized Reed-Solomon codes in code-based cryptography. The results were presented and published at the international conference *CBCrypto 2023*.

The head of the group is one of the main organizers of *CBCrypto 2024*, an affiliated event of *Eurocrypt 2024* in Zurich, one of the largest and most important annual conferences in cryptography. Much of the organization took part in 2023, including setting up the technical program committee, a call for papers and designing a web page.

Teaching

In 2023 the group taught several courses in various degree programs of the University of St.Gallen. These include *Fundamentals of Computer Science* and *Discrete Mathematics* in the Bachelor of Computer Science, as well as *Basics of Cybersecurity - From Safe Passwords to Blockchain* and *Mathematical Tools for Data Science* as electives for other schools at Bachelor level, and *Introduction to Cryptography and Cybersecurity* as an elective for other schools at Master level. Furthermore, we offered a PhD seminar on *Error Correcting Codes and Their Application* in the fall semester.

Additionally, the group supervised two Master's theses at the School of Computer Science, as well as several undergraduate theses at the School of Economics and Political Science (SEPS).

The head of the chair was invited as a leading expert in coding theory to a CIMPA school in Hyderabad, India. The *Centre International de Mathématiques Pures et Appliquées (CIMPA)* is a nonprofit organisation that promotes research in mathematics in developing countries. We supported this honorable project by joining the School of *Finite Geometry and Coding Theory* in November 2023, to teach PhD students and young researchers from developing countries about error correction in communication networks.

Interactions Research Team, Simon Mayer

The Interactions Research Team[14] investigates technology-mediated interactions in complex socio-technical systems. Within this broad field, we are interested in a great many aspects of the interaction of (computer) systems with other systems as well as with people, and specifically in pervasive computing environments.

In our group, the PhD work of Danai Vachtsevanou is on the bridging of affordance-driven and hypermedia-driven interaction in the design of adaptive interfaces for human and artificial agents in Web-based Multi-Agent Systems while Jérémy Lemée studies how heterogeneous agents can combine their own specialized knowledge and cognitive abilities in order to improve collaboration efficiency. Based on a fascination for bio-inspired technology in general and its application to software specifically, Alessandro Giugno is working on socio-technical systems as well, and currently applies this to the design and creation of information management systems for circular economy and sustainability. And Ganesh Ramanathan is striving to achieve autonomy in industrial control systems by making system and domain knowledge accessible to the automation agents, with a specific focus on autonomous buildings. More autonomous systems might behave in a way that is not so intelligible for their human users, and hard to interpret for other machines—hence, Sanjiv Jha works towards explaining contextual influences on the behavior of cyber-physical systems using multimodal scene understanding. Turning more towards people, Damian Hostettler investigates how the behavior of an industrial robot can be adapted to the implicit and explicit responses of humans to promote satisfactory human-robot interactions. Such personalization also features heavily in Jannis Strecker's research—Jannis studies how ubiquitous personalization systems can make our interactions with our environment more efficient, safer and more inclusive, and how they can be built in a responsible and societally beneficial way. Benefitting individuals and society is also core to Jing Wu: Her research work is about analytics-based behavior interventions to promote human health, specifically in the fields of nutrition and ambient lighting.

Kenan Bektas brings in the human eye—quite literally, as since his PhD and during his postdoctoral studies he has been using eye tracking as an interaction mechanism and to study the workload of operators in human-robot interactions. And Kimberly Garcia designs and studies systems that we refer to as Digital Com-

[14] https://interactions.ics.unisg.ch

panions; these are created to assist and protect their users while being aware of their privacy, and Kim uses a combination of machine-learning systems and symbolic approaches such as Knowledge Graphs in neuro-symbolic ensembles to achieve this. All our work interacts with society and societal processes, and hence regulation is a cross-cutting aspect—Clement Guitton brings in this dimension: He investigates the extent to which regulations (standards, laws, etc.) can and should be turned into an automatically processable format, for instance to automate compliance or facilitate their comprehension via querying possibilities.

To support bringing our research to practice, Lukas Eichelberger is our team's Research Entrepreneur—he is interested in exploring the commercial potential of newly emerging technologies and is particularly engaged in the fields of robotics (e.g., for Understanding Robots) and applications in the field of healthcare. And Jan Albert is a software developer who maintains our lab's infrastructure and supports other team members in their research work wherever possible.

Finally, our group is comprised of Andrei Ciortea and Simon Mayer. Andrei is Assistant Professor for Web-based Systems and his research focuses on designing a new class of Web-based multi-agent systems (MAS) that inherit the architectural properties of the Web, preserve the properties of MAS, and are human-centric. And Simon is fascinated by the integration of concepts and approaches from across the fields of pervasive computing, hypermedia, human-computer interaction, and embedded systems to realize ideal interfaces between ubiquitous machines and animals.

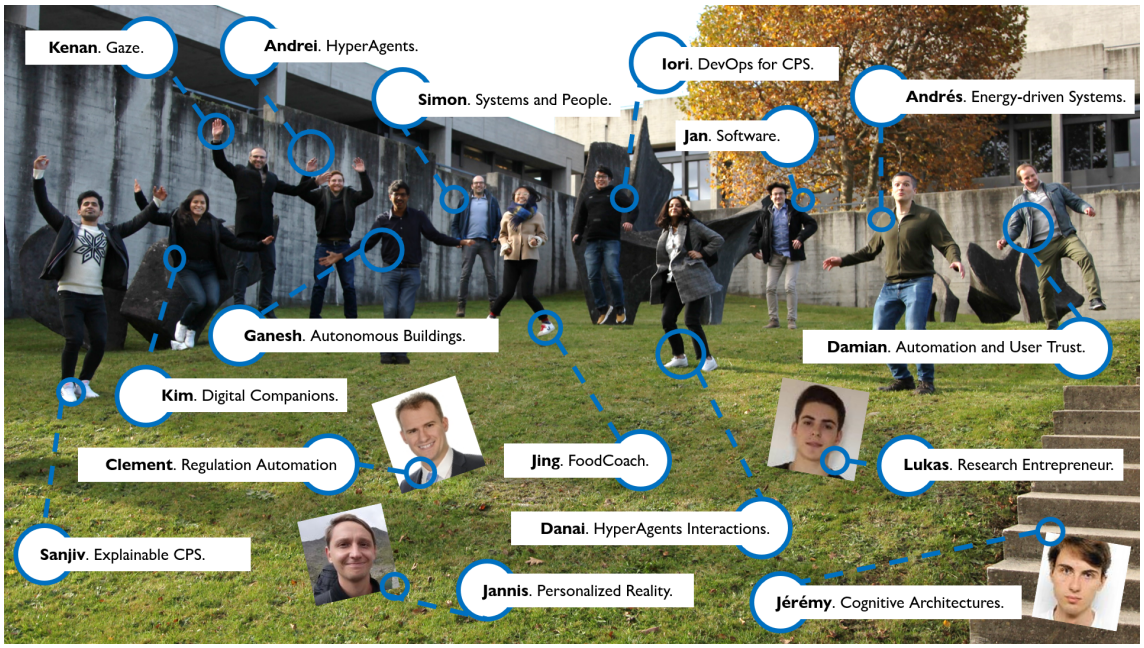


Figure 4: Most members of the Interactions Research Team.

Team Members

Early in the year 2023, our team celebrated the appointment of our former colleague Prof. Dr. Andrés Gomez as *Associate Professor of Reliable Hardware and Software Systems* at the Institut für Datentechnik and Kommunikationsnetze of the Technical University of Braunschweig. At the end of the year 2023, our team comprised 16 members, including eight PhD students, four postdoctoral researchers, a research entrepreneur, and a software engineer.

Teaching

Our group offers a series of challenging but rewarding courses on the topics of Ubiquitous Computing and Web-based Autonomous Systems as well as introductory courses to Computer Systems, Computer Networks, Distributed Systems, and Computer Science. In addition to the supervision of many Bachelor and Master theses, in the year 2023 our group's teaching comprised 10 courses that were attended by more than 1200 students in total. Overall, we are active in seven different degree programs at the University of St.Gallen and several of our courses are open to all students of the university. As part of his sabbatical in the Spring Semester 2023 that he spent at the University of Bologna (Campus Cesena), Simon in addition taught a course on *Digital Transformation*. Abroad and at HSG, we again received very good student evaluations across all our courses, where specifically our BCS and MCS courses stood out with excellent evaluations.

Research

Our team engages in two overlapping research fields. On the one hand side, we are investigating *Systems and People in Ubiquitous Computing Environments*. During the year 2023, we further deepened our expertise and increased our research output across the topics of novel user interfaces for pervasive computers, reasoning and explainability of (and in) ubiquitous computing environments, and on user trust in pervasive computing systems (especially robotics). We continued our collaboration with Inselspital Bern on the FoodCoach[15] system and application, and deepened our collaboration on automatically processable regulation with Prof. Dr. Aurelia Tamò-Larrieux at Maastricht University.

[15] `https://foodcoa.ch`

Our second major area of interest are *World-Wide Autonomous Systems*. In this field, we are investigating interactions of autonomous agents with each other, with their environment, and with people, where we continued our exploration of the application of concepts from ecological psychology to the interaction of *artificial* agents. Bridging with ubiquitous computing, we furthermore continued our investigation of the deployment of autonomous agents in embedded and low-power systems, and we remain active in the field of interoperable Web of Things systems. Across these research fields and in the context of several funded research projects, our group has in the year 2023 published more than 40 research articles at international journals, conferences, and workshops.

Cyber Security, Katerina Mitrokotsa

The **Chair of Cybersecurity** [16] was established in August 2020 and joined the Institute of Computer Science in February 2022. Our main research interests are centered around Information Security and Applied Cryptography, with the larger goal of safeguarding communications and providing strong privacy guarantees. More precisely, we are committed on contributing important advances in several areas of cybersecurity and applied cryptography, a subset of which include: secure multi party computation, verifiable computation and privacy-preserving and reliable authentication.

The Cybersecurity group at the Institute of Computer Science in St. Gallen has made significant contributions to the field of Cybersecurity and Applied Cryptography through their teaching, research, and outreach efforts. Furthermore, the group's commitment to interdisciplinary collaboration has resulted in fruitful collaborations with other leading cybersecurity and applied cryptography labs in the world (e.g., EURECOM in France and NTT in Japan).

Team

In 2023 the Cybersecurity group at the University of St. Gallen consisted of nine group members, including Prof. Katerina Mitrokotsa. The group was made up of four Doctoral Researchers, Jenit Tomy, Nan Cheng and Johannes Ernst, who continued on their work from the previous years, and Liujun Yu, who joined us in April. Furthermore, the two Post-doctoral Researchers was re-appointed as planned during 2023. Dr. Novak Kaluderovic, an EPFL-graduate joined us in April. Dr. Uddipana Dowerah transferred her position from Chalmers University of Technology to the University of St.Gallen in September. To support the group in implementation tasks, Frank Hartmann, a MSc graduate from TU Munich, joined our group as a Research Engineer. In autumn, one of the groups main collaborators, Dr. Tapas Pal from NTT Japan, visited our group for two months. A visit that was funded by the SNSF Scientific Exchange program.

[16] https://cybersecurity.unisg.ch

Research

The research of the cybersecurity chair focuses on all aspects of information and network security and especially on security and privacy issues resource constrained devices (e.g., for IoT devices, smart phones, sensors etc).

For instance, multiple resource constrained devices are used in our everyday life to measure our electricity consumption (smart meters), our activity levels (fitbit applications), to access/start our cars (keyless entry) or even to monitor our health conditions. These IoT devices collect sensitive, private information that is subsequently transferred to external untrusted cloud servers. At the cybersecurity chair, we focus on providing high security and privacy guarantees so that no sensitive information is leaked (according to the GDPR) as well as avoiding possible attacks to individuals (e.g., impersonation, identity fraud, profiling, tracking).

More precisely, we focus on designing provably secure cryptographic protocols and primitives:

- to guarantee reliable and privacy-preserving authentication (e.g., access control systems, electronic payments) relying for instance on biometric templates (e.g. fingerprints, voice recordings) and passwords.

- guarantee that data generated by individuals remain private, while still being useful in order to compute values on them.

In more details, we are interested in the design of provably secure cryptographic protocols that can be employed for reliable authentication (i.e., authorise only legitimate users to services and/or places) as well as cryptographic protocols and primitives that can be employed for secure and private cloud-assisted computing and machine learning algorithms. In the latter case, we design cryptographic protocols that allow us to check (control) the computations performed by untrusted cloud servers and make sure that our sensitive data are not leaked. In addition, we are working on network security problems e.g. privacy-preserving routing and detecting attacks in communication networks.

During 2023, we were involved in three main externally funded research projects: the EU-project TReSPAsS-ETN, the GFF project Secure and Private Aggregation for Federated Learning, the Armasuisse (Federal Office for Defence Procurement) project “Private, Robust, and Efficient Computation of Aggregate Statistics” as

well as the project "Enhanced Data Privacy" supported by the Hasler Stiftung.

- The EU-Project TReSPAsS-ETN[17] (TRaining in Secure and PrivAcy-preserving biometricS) funded by the Marie-Sklodowska-Curie Innovative Training Network entered into its third and final year and continued to be an important part of the group's research in 2023. As part of this project, we designed cryptographic protocols as well as cryptographic primitives (i.e., elementary building blocks from which cryptographic protocols can be built) to make sure that the authentication process is accurate but the biometric information remains private and confidential and hidden from untrusted servers and service providers. More specifically, our group performed research connected to biometric authentication protocols, password based authentication protocols and the modeling of security properties of these. Results of this research project was accepted to top research venues in 2023.

- The GFF-project Secure and Private Aggregation for Federated Learning started in 2023 and has a duration of two years. The main goal of this project is to provide secure and privacy-preserving aggregation protocols while providing privacy, security and efficiency of the aggregation process and making sure that the involved clients/servers do not tamper with the aggregation process. More precisely, our aim is to make good use of the distributed data without having to compromise user privacy and security. Our goal is to establish a foundation for secure, private and efficient aggregation that enable robustness of the whole process both from the clients' as well as the servers' side. To achieve the latter we investigate post-quantum zero knowledge proofs and how to integrate them in the aggregation process without compromising the efficiency of the designed protocols.

- The Armasuisse project Private, Robust, and Efficient Computation of Aggregate Statistics was initiated in spring 2023 and was completed by the end of the year. The main goal of this project was to provide robust, private and efficient computation of aggregate statistics, without centralising the data of the aggregation process. More precisely, our aim was to make good use of the distributed data without having to compromise user privacy and security. Our work was focused on providing efficient, privacy-preserving computation protocols that guarantee robustness against malicious clients and/or servers while minimizing the dependence on a single

[17] https://www.trespass-etn.eu

central authority; thus, reducing many of the systemic privacy and security risks resulting from a centralised setting.

- In the project supported by the Hasler Stiftung, we aim to address the growing concern of data privacy in today's interconnected world. The implementation of data privacy regulations, like the EU's General Data Protection Regulation (GDPR), highlights the need for privacy-preserving solutions in data analysis and processing. Further, the advent of cloud services has resulted in a significant transformation in the processing and utilization of data. Many applications use cloud services due to its widespread availability and accessibility of resources coupled with a reduction in computationally-intensive tasks. However, with the ever-increasing risk of cyber-attacks, the use of cloud computing also poses a risk of exposing sensitive data to third-party service providers. To mitigate this risk, data is often stored in encrypted form in the cloud. Yet, the major challenge lies in performing computations or processing on this encrypted data without compromising its privacy. Our research will primarily focus on exploring the application of Functional Encryption (FE) as a powerful cryptographic tool to address these privacy concerns and enable secure data processing and analysis in such cloud-based scenarios. FE is an advanced cryptographic primitive that offers fine-grained access control over encrypted data. We will use a special type of FE called Inner Product Functional Encryption (IPFE) as our building block. The project focuses on two critical applications of IPFE: (i) privacy preserving proximity testing, and (ii) secure and private aggregation statistics.

During 2023, our group published research papers that appeared in well-known venues in cybersecurity and cryptography including Asiacrypt 2023, Journal of Cryptology, ACNS 2023, and PST 2023, while some additional papers submitted in 2023 were recently accepted to the AsiaCCS 2024, Proceedings of Privacy Enhanced Technology (PETS 2024), PKC 2024, IEEE European Symposium on Security and Privacy (Euro S&P) 2024, SAC (International Conference on Selected Areas of Cryptography) 2024. In these works, we mainly proposed cryptographic protocols and cryptographic primitives that can be employed to guarantee secure and efficient computations when multiple parties are involved in the process and the corresponding data need to remain private, with applications to secure and privacy preserving inference in machine learning as well as secure and private aggregation statistics and access control.

Teaching

Our Chair offers multiple courses in the area of Cybersecurity and Applied Cryptography. During 2023 the cybercecurity chair offered three courses for the master level and two PhD courses. The courses were taught at the Computer Science master program and the Master in Business Innovation (MBI) program at the University of St.Gallen. More precisely, the mandatory course in *Cyber Security* was taught to the Master in Computer Science students for the third time. The group also supervised two students performing their *Integrative Master Project* in the area of Cyber Security. Furthermore, the group offered two courses to students of the Master in Business Innovation (*Cryptography* course and *Cybersecurity and Privacy* course) as well as the *Data Security and Privacy*. During 2023, two PhD-level courses were offered to further strengthen the knowledge within Security & Privacy to the PhD-Students at the Doctoral School of Computer Science. Based on the received feedback and course evaluations the courses were well acknowledged and highly appreciated by the students, while two students decided to pursue their master thesis under our supervision and have completed them (one in 2023 and one is about to complete it in spring 2024) .

Outreach

During 2023, the whole chair of Cybersecurity has participated at the Swiss Crypto Day 2023 hosted at ETHZ and Prof. Mitrokotsa has presented results of our research activities at the event. Members of our group have attended multiple conferences and summer schools related to cryptography and cybersecurity and disseminated our research results i.e., ACNS 2023, AsiaCrypt 2023, Eurocrypt 2023, PST 2023, Swiss Crypto Day 2023. In addition, the Chair of Cybersecurity and Prof. Mitrokotsa will be organising the Swiss Crypto Day in 2024 at the University of St. Gallen.

Furthermore, Prof. Mitrokotsa is currently serving as the track chair for Applied Cryptography in the flagship conference ACM CCS 2024, while she has served as program committee member of multiple top conferences in cybersecurity and applied cryptography including AsiaCCS 2023, AsiaCCS 2024, NDSS 24, and ACNS 2024. During 2023, Prof. Mitrokotsa has served as evaluation committee member of two PhD theses in area of privacy preservation and applied cryptography: one at EURECOM (France) and one at KTH (Sweden).

Since November 2022, Prof. Katerina Mitrokotsa is a member of the Sounding Board Researchers of the Swiss National Open Research Data Strategy[18]. The main task of the Sounding Board Researchers is to advise both the Swiss National Open Research Data Strategy Council and the Open Research Data Coordination Group by responding to their questions and issuing recommendations to enable the participation of research communities in the further development of the Swiss Open Research Data landscape. She continued her work at the Swiss National Open Research Data Strategy in 2023.

In addition, the Chair of Cybersecurity, has continued the collaboration with the Cyber Defence (CYD) Campus of Switzerland. During 2023, Prof. Mitrokotsa and a PhD student of our group (Mr. Nan Cheng) has participated at the Armasuisse Cyber defence campus workshop where they presented results of our research project funded by Armasuisse.

Furthermore, Prof. Mitrokotsa and the Chair of Cybersecurity have joined the SLICES Switzerland Association (SLICES-CH) which is established in the context of the European SLICES project to establish a large-scale research infrastructure for information and communication technologies. The Association ambitions to support the participation of the Swiss research community in this initiative and to take part in its governance process. Prof. Mitrokotsa has also joined multiple strategic meetings of the SLICES-CH association.

In addition, the chair of Cybersecurity has hosted several visitors and top researchers in the area of Cybersecurity and Cryptography that have also participated at the CSI seminar hosted at the School of Computer Science at the University of St. Gallen. Among the visitors are included Prof. Florian Tramer (ETHZ), Mallory Knodel (Center of Democracy and Technology, USA), Dr. Anwar Hithnawi (ETHZ), Prof. Christian Cachin (Univ. of Bern), Dr. Romain Gay (IBM, Zurich) and Dr. Tapas Pal (NTT Japan).

Finally, throughout 2023, Katerina Mitrokotsa continued to be a part of the Gender & Diversity Commission of the University of St.Gallen, which aims to further develop and ensure equal opportunities, diversity and inclusion within the university.

[18] https://akademien-schweiz.ch/en/themen/scientific-culture/open-science/

Programming, Guido Salvaneschi

The Programming group at the Institute of Computer Science is active in advancing research in programming techniques for developing more efficient, maintainable, and secure software systems.

Team Members

The Programming group at the University of St.Gallen includes three Ph.D. students and a Postdoc. One of the PhD students joined the group in May 2023 and another one is expected to defend his Thesis in April 2024. A student programmer also supports the research activities of the group since November 2022. One of the Ph.D. students and the postdoc are working on the research line that concerns programming language design and program verification for distributed software applications. The other two Ph.D. students are active on the research line on languages and systems for infrastructure as code.

One additional Ph.D. student supervised by Prof. Guido Salvaneschi is still at the Technical University of Darmstadt, the group's head's previous affiliation.

Teaching

The group offers a number of courses in the area of programming languages and software systems. In the year 2023, the group offered a total of 6 curses. Overall, the group is active in a number of programs, at the University of St.Gallen.

In the first semester of the Bachelor in Computer Science, the group is teaching the course *Introduction to Programming* where students learn the foundations of programming using the Python programming language, in the second semester it is reaching the course *Programming Methodology* on the Java programming language. In Fall 2023, the course Introduction to Software Engineering in the MBI program is an introductory course to Java programming and basic application engineering. The group has also offered a course on *Data Science* in the BBWL program providing an introduction to data analysis in Python and related technologies. Also in Fall, the group offers a Ph.D. course in collaboration with Prof Weber.

Research

The group's main research area is programming language design and its implication for the development of software systems. In more detail, the group engages in two research areas.

The first research area is concerned with language design and program verification for distributed systems. In this space, the group is shaping programming languages that help developers create distributed software that is more efficient, more secure, and more maintainable in the long run and is active in developing automated verification techniques for distributed programs.

A second research line is about a new class of software applications (Infrastructure as Code) that aim to configure infrastructural elements, such as networks and cloud resources, or other software systems, rather than offering services themselves. The quality of such applications is therefore crucial because a bug can compromise all the software systems that the application aims to configure. The group is now focusing on testing and verification Infrastructure as Code.

The results of these research lines have been published, respectively in PLDI, OOPSLA and are currently under submission at TSE – highly prestigious venues in programming and software systems.

The SNF project 'Multitier Programming Above the Clouds' entered its third year, the LOEWE project emergenCITY ended in December, the GFF postdoctoral fellowship of Dr. Pascal Weisenburger ended in Spring 2023.

Human-Computer Interaction, Johannes Schöning

The HCI Group at the Institute of Computer Science at HSG is committed to advancing research in Human-Computer Interaction. With a focus on developing user interfaces that empower individuals and communities with the information they need to make better data-driven decisions, the team comprises five PhDs and two PostDoc at HSG in St. Gallen. In addition, three PhDs still perform research at the University of Bremen, and Professor Dr. Johannes Schöning is leading both teams. The group joined the institute in February 2022 and was established at HSG in September 2021.

The HCI group at the Institute of Computer Science in St. Gallen has made significant contributions to the field of Human-Computer Interaction through their teaching, research, and outreach efforts. With a focus on developing novel user interfaces that empower individuals and communities, they have published high-quality research in various outlets and acquired funding for their projects. The group's commitment to interdisciplinary collaboration has resulted in fruitful collaborations with other leading HCI Labs in Europe and within HSG. Their summer workshop, "CHI Together", has promoted (inter)disciplinary exchange between PhD students, postdocs, and professors across different schools.

Team

At the end of 2023, the team consisted of 8 researchers. Dr. Florian Mathis joined the team after graduating from the University of Glasgow and spending some time at META in Canada. In his project funded by the HSG International Postdoctoral Fellowships, he investigates the use of assistive mixed reality technology to improve how people with special needs live and work. This project contributes towards an inclusive future reality where people with and without disabilities receive appropriate technical resources and are empowered to participate fully and autonomously in society.

Research

The HCI group's research focuses on understanding the interplay between rapidly advancing technologies and how digital interfaces can empower users

in their rich set of activities. They focus on various use cases from geographic information science, public health, medical contexts, and extreme conditions such as space missions. The team loves to work in interdisciplinary teams to create novel insights using rigorous methods from AI, computer graphics, and cognitive psychology. They commit to a theoretical and practice-based inquiry and are particularly interested in applying user-centred design methodologies and mixed methods approaches.

Their research resulted in various high-quality publications in 2023. For example, the team published at ACM CHI, ACM Interactions, and other high-quality outlets. Our research papers published in 2023 discuss various aspects of human-computer interaction, including technology and its impact on user experiences, design considerations for new technology, user studies to explore the effectiveness of new technology, and the importance of diversity in the human-computer interaction research community. A few examples are briefly explained below. A complete summary of the published works can be found at Alexandria [19].

In 2023, our research delved into various themes within human-computer interaction (HCI). The exploration of emerging technologies in HCI is still a central focus, investigating the profound impact of technology on user experiences. In this process, we developed design considerations for novel technologies [SBKS22, STSS22]. Additionally, our papers undertook user studies, evaluating the effectiveness of these technologies from diverse perspectives and within extreme environments such as space habitats [ZKW+23, ZKCS23].

Furthermore, our research offered insights into the broader implications of technological interventions on society, emphasising the responsibility of designers to consider not only usability but also the broader social consequences of their creations [DCWS22, JDS+21]. In a large study, we examined social reference cues' role in reducing misinformation sharing on social media through experimental studies [JDS+21]. In another smaller study, we assessed the impact of "Green Apps" on community engagement for sustainable HCI, emphasising technology's potential to foster environmental awareness [PS23].

Spatial exploration and gamification emerged as another thematic area within our research, as our SNF project supports this area. We explored how spatial design and gamified elements contribute to user engagement and overall experience in HCI [SSNS23]. This focus highlighted the potential for innovative approaches to enhance user interactions in virtual spaces.

[19] https://www.alexandria.unisg.ch/bitstreams/0b897417-af18-45d8-9227-a9532383e8b0/download

Lastly, our papers addressed the theme of accessibility in virtual reality (VR) [SSK+23, KS23, SSF+22]. Recognising the importance of ensuring technology is accessible to all, we provided recommendations for designing inclusive interfaces and promoting diversity within the HCI research community. Lessons from Second Life inform accessibility considerations [KS23], while inclusive design for children with ADHD [SSRN23]. Additional studies focus on emotion regulation in VR and fostering intergenerational connectedness through smart toy bricks [SDB+23], collectively emphasising inclusivity in virtual environments [WSRN23, WNRS22].

Our research contributes to the overarching themes of emerging technologies in HCI, human-computer interaction and social impact, spatial exploration and gamification, accessibility and inclusivity in VR. Collectively, these themes underscore the need for a comprehensive understanding of technology's impact on human experiences and the necessity of considering diverse perspectives in the design and development of interactive systems.

Teaching

The HCI group has contributed to courses on both bachelor and master levels. They taught mandatory courses in HCI at both master's and bachelor's levels. They offered master projects for their students and began supervising their first master's thesis in computer science and in other programs such as the MBI.

Outreach

The HCI group regularly hosts events throughout the year to foster interdisciplinary collaboration among PhD students, postdocs, and professors from various academic disciplines. In 2023, we organized a summer meeting to develop relevant publications for submission to the ACM CHI conference.

Johannes Schöning serves as the president of the ACM SIGCHI chapter in Switzerland, overseeing the organization of multiple events annually. Collaborating with the School of Computer Science, the HCI group coordinates the Computer Science Insights St. Gallen (CSI St. Gallen) talk series. This series has featured nearly 40 speakers from industry and academia who shared insights into computer science and presented their research findings and best practices.

Software Systems Programming and Development, Barbara Weber

The chair deals with the development of adaptive software systems. This includes the integration of process-oriented information systems with the Internet of Things as well as the development of neuro-adaptive software systems. Furthermore, the chair conducts research on human and cognitive aspects of software and process engineering. Moreover, *Process Mining* is an overarching research area at the chair.

Team

The "Software Systems Programming and Development" chair began operations in February 2019. The team includes five researchers with PhDs in 2023. Dr. Francesca Zerbato works on the topic of process mining. Dr. Marco Franceschetti is researching the interface between Internet of Things (IoT) and Business Process Management (BPM) in the newly launched SNSF-funded research project *ProAmbiTion*. Dr. Amine Abbad Andaloussi is strengthening research—funded by an International PostDoc Fellowship—in the area of human and cognitive aspects in software engineering. Dr. Hagen Völzer supports the team as Senior Project Manager since 2022 and works in the area of Business Rule Mining. Prof. Dr. Ronny Seiger, former Post-Doc, continues to research aspects in IoT, BPM and Software Engineering as an Assistant Professor. In addition, there are two PhD students on the team. In addition to Thierry Sorg, who has already been researching the development of neuro-adaptive software systems since 2020, Lisa Zimmermann continues her work in the area of process mining, which she started in 2021.

Teaching

Our teaching activities included the development and teaching of a mandatory course (*Advanced Software and System Engineering*) in the Master of Computer Science (since 2021 together with the chair Interaction- and Communication-based Systems), the two elective courses "Event-driven and Process-oriented Architectures" and "Software Assessment: From Planning to Experimentation"

as well as a PhD-level course together with the Programming chair. In 2023, we additionally developed and successfully established the new course "Entwurf von Softwaresystemen" (Design of Software Systems) taught to 3rd semester Bachelor of Computer Science students.

In addition, our teaching portfolio includes a course in the Master of Business Innovation (*Event-driven and process-oriented applications for the IoT*) in the Spring 2023 semester and a course in the Entrepreneurial Informatics profile area of the Bachelor of Business Administration (*Accelerating Digital Transformation with Process Modeling, Automation, and Mining*) in the Fall 2023 semester. Furthermore, the chair is active in the computer science courses (*Fundamentals of Computer Science*) (since HS19) together with the chair Interaction- and Communication-based Systems. Since 2021, the chair also teaches the elective *Coding for Executives* in the EMBA and IEMBA together with the chair Artificial Intelligence and Machine Learning as part of the Executive Education.

Research

Our research is currently focused on the development and evaluation of software artifacts. The research covers topics in process mining, Internet of Things, and source code analysis to develop event-driven software systems that adapt to the user's behavior and context and is supported by the Swiss National Science Foundation (SNSF) with two projects *ProMiSE*[20] and *ProAmbitIon*[21].

Process Mining. In 2023, we were able to further strengthen our research in the field of process mining. Together with international partners, we continued working on the **process of process mining** as part of *ProMiSE* (started in November 2020), which we presented at the Int. Conf. on Advanced Information Systems Engineering (CAiSE 2023) [ZZVW23]. Process mining has developed into a mature discipline in recent years. Process mining involves several exploratory analysis tasks that are knowledge intensive and require analysts to rely on their own experience to extract insights from the data. To date, however, little attention has been paid to understanding the behavior of analysts during process mining, including the challenges they face. In our research, we focus on gaining a comprehensive understanding of how analysts perform process mining in practice (the "process of process mining"), including patterns of effective and non-

[20] https://data.snf.ch/grants/grant/197032
[21] https://data.snf.ch/grants/grant/208497

effective behavior, common analysis strategies, and typical challenges. Here we worked closely with partners from the University of Haifa and the University of Queensland. Building on this, we plan to develop methodological guidance and software-based operational support to assist (inexperienced) process analysts in their work. Based on the data collected in 2021, we continued to work on understanding the practices of process analysts, completing our examination of the challenges faced by individual process analysts [ZZW23b] and the specific challenges associated with using metadata to assess the quality of repurposed event logs [ZZW+23a]. We also contributed to developing PEM4PPM, a model for the analysis of the cognitive processes of process analysts [SSH+23].

In addition to the empirical results described earlier, we have identified areas where additional methodological support is lacking and software-based operational support is needed. One of them - the problem of fixed granularity in process mining logs - was published along with other major BPM challenges as "The biggest business process management problems to solve before we die" in the journal Computers in Industry [BDCR+23].

Also, based on our insights into the process of process mining, we have already achieved a first milestone in the development of tool support for the process of process mining [ZBV+23]. Our work includes requirements, design, and initial evaluation results of a system aimed at enhancing the rigor of exploratory analysis for process analysts by recording provenance information about their analysis and results. Also, we proposed an interactive approach, based on novel visualizations and rule induction techniques to support analysts in finding explanations for process outcomes [VZSW23]. This work is based on the open-source software package *rulelearn* for rule induction to which we contributed and which was released in 2023. At last, we continued our collaboration with the University of Utrecht, and presented a tutorial "Task Support for Process Mining: From Formulating Questions to Evaluating Results" at the Int. Conf. on Business Process Management (BPM 2023). Our focus for the upcoming year will shift more and more towards developing support for process mining analysts.

Business Process Management and Internet of Things. Our research related to the combination of BPM with the Internet of Things (IoT) focused in 2023 on the SNSF basic research project *ProAmbitIon*. We were able to present results on the detection of process activities from low-level IoT data [SFW23b] including a framework for automatically generating activity detection services [SFW23a]. Additionally, we developed together with our partners from

Kantonsspital St.Gallen a new lab setup related to activity monitoring in smart healthcare [FSG+23]. Further research activities in the context of this project included the development of an event-centric metamodel for IoT-driven process monitoring and conformance checking [FSW23] and a characterisation of ambiguity in BPM [FSL+23]. We also strengthened our collaborations with international research partners from other universities discussing, among others, the integration of IoT-driven events into business processes [KGSR23] and an object-centric approach to handling concurrency in IoT-aware processes [GKSR23]. We are actively participating in an ongoing working group on *Internet of Things and Processes* to strengthen our research collaborations on BPM and IoT and gain international visibility. Here we are actively contributing to discussions and publicly available datasets[22].

Human and Cognitive Aspects in Software and Process Engineering. Our research within this stream focuses on investigating how users interact with software design artifacts, such as process models and source code during various tasks. This research follows a multi-granular approach, combining both coarse-grained analyses of cognitive load at the task level and fine-grained explorations of users' visual behavior and its evolving dynamics over time.

Over the last year, we have conducted extensive research covering different facets of the human and cognitive aspects in software and process engineering, from innovative software development to advanced empirical studies. Notably, our data collection and empirical investigation framework, *EyeMind*, has evolved into a stable software system supporting the design of experiments on process models, the collection of eye-tracking data on dynamic stimuli [HNA+11], the automated mapping of the collected gaze data to the underlying process model elements, and the analysis of this data to extract meaningful insights on users' cognitive and behavioral states. The approach underlying EyeMind was published in [AALW23]. The software has been successfully used in several studies examining various factors affecting the comprehension of process models. Furthermore, with collaborators from the Technical University of Denmark (DTU) and KU Leuven in Belgium, EyeMind is being extended to support other types of experiments (e.g., investigating simulations of process models) on different process model notations (e.g., Dynamic Condition Response – DCR Graphs).

On the empirical front, we have proposed new complexity metrics and advanced the community's understanding of several factors affecting the comprehension

[22] https://zenodo.org/communities/iopt

of process models. Specifically, we have established a set of metrics for declarative (constraint-based) process models and evaluated the impact of these metrics on users' cognitive load [AABS+23]. Furthermore, we have delved into how varying types of tasks impact users' cognitive load and behavior in a work that received the Best Student Paper Award at the BPM Conference 2023 [SAAW23].

Our work this year also resulted in fruitful collaborations, particularly with researchers at DTU, with whom we investigated the notion of semantic transparency in visual notations of process models and proposed a new, more semantically transparent visual notation for DCR Graphs [TAAL23]. This work was complemented by an open-source modeling editor implementing the new visual notation [TAATLA23]. The tool received the best demonstration award at the Cooperative Information Systems (CoopIS) 2023.

Lastly, our collaboration with researchers at RheinMain University of Applied Sciences on assessing the quality of source code identifiers has led to the development and evaluation of a new approach powered by language models capable of detecting naming guideline violations in identifiers [VCP+23].

Outreach and Academic Citizenship

The Chair not only contributed to the development of HSG with Barbara Weber serving as the dean of the School of Computer Science, but was again able to achieve great visibility in 2023 and make an important contribution to St. Gallen gaining (international) visibility as a computer science location.

Barbara Weber was co-organizer of the Doctoral Consortium at the BPM conference and co-organizer of the Dagstuhl seminar "Humans in the Process Mines"[23] and Francesca Zerbato was co-organizer of the International Workshop "Education meets Process Mining" (EduPM 2023), which was held in conjunction with the ICPM conference. Barbara Weber was also invited as keynote speaker at the ENASE 2023 and ICEIS 2023 conferences on "Leveraging Digital Trace Data to Investigate and Support Human-Centered Work Processes".

Since 2022 Barbara Weber is elected to the evaluation panel "Postdoc.Mobility Mathematics and Engineering (STEM-T)" of the SNSF. It is very gratifying that with Barbara Weber, the computer science of the HSG is thus not only represented in

[23] https://drops.dagstuhl.de/entities/document/10.4230/DagRep.13.7.1

the HSG-internal research commission, but is also allowed to set accents on a national level after such a short time.

Barbara Weber is now part of the Editorial Board of the journal “Software and Systems Modeling”[24]. Further, she is an Associate Editor part of the Editorial Board of the journal “Business & Information Systems Engineering (BISE)” for the “Business Process Management”[25], a member of the Editorial Board of the journal “Computers in Industry”[26], part of the Editorial Advisory Board of the journal “Information Systems”, and Associate Editor of the journal “Computing”. Moreover, since 2023 she is member of the editorial board of “Process Science”. In addition, Francesca Zerbato is an Associate Editor of the “Journal of Data and Information Quality” and a member of the Editorial Board of the journal “Artificial Intelligence in Medicine”, where she also served as leading guest editor for the special issue on “Knowledge Representation and Reasoning for Healthcare Processes”.

Barbara Weber and Hagen Völzer are Senior Program Committee Members of the International Conference of Business Process Management.

In 2023 we had the pleasure to host several researchers for a research stay and work together on topics of joint interest. This included Clemens Schreiber from the Karlsruhe Institute of Technology, Mauricio Jacobo Gonzales from the Tecnologico de Monterrey in Mexico, researchers from the University of Utrecht (Hajo Reijers and Iris Beerepoot), professor Pnina Soffer from the University of Haifa, professor Manuel Resinas from the University of Seville, and Victoria Torres Bosch and Manoli Albert from the Valencia Politechnic University.

[24] https://www.springer.com/journal/10270/editors
[25] https://www.bise-journal.com/?page_id=20
[26] https://www.journals.elsevier.com/computers-in-industry/editorial-board

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