

Institute of Computer Science (ICS-HSG)

Annual report 2022

D. Borth, S. Handschuh, A. Horlemann, S. Mayer, K. Mitrokotsa, G. Salvaneschi, J. Schöning, B. Weber

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Institute of Computer Science



University of St.Gallen

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 our board (Geschäftsleitender Ausschuss GLA in German) that is presided by *Prof. Ernst Mohr* and comprises by *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 continued commitment to the institute's ideals and its projects!

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Introduction

The Institute of Computer Science (ICS-HSG) consist of eight different 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 2022, the respective full professors (Borth, Handschuh, Mayer, Mitrokotsa, Schöning, Weber) 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. It should be noted that the role of the Managing Director is a coordinating one and does not involve any authority to issue directives to other members of the management team.

Since 2019, the board (GLA) of ICS-HSG, chaired by *Prof. Dr. Ernst Mohr*, consisted of the following members: *Doris Albisser*, *Markus Bänziger*, *Prof. Dr. Elgar Fleisch*, *Prof. Dr. Dietmar Grichnik*, *Prof. Dr. Manfred Hauswirth* and *Stephanie Schoss*.

The chairs of the ICS-HSG are jointly committed to the establishment of the **Bildungsoffensive des Kantons St. Gallen** (ITBO) for the *Master and Bachelor Computer Science Study Program* at the HSG. This initiative is focused on the development and implementation of the Master and Bachelor Computer Science Study Programs at HSG, with the overarching aim of fostering a strong and innovative technology-driven academic environment in the Canton of St. Gallen.

In 2022, we proudly welcomed the first cohort of students in the **Bachelor of Computer Science** program. At the same time, we were delighted to welcome the second cohort of students to the **Master's program in Computer Science**. This continuation demonstrates our commitment to providing quality education in computer science and fostering a vibrant learning environment for students at various stages of their academic journey.

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

In addition to our joint *teaching and research activities* at the ICS-HSG, 2022 has seen a large number of joint activities with other institutes of the HSG, national and international universities and with companies at home and abroad; we have also set the course for further growth of the ICS-HSG.

With this annual report, we provide an overview of the activities of the ICS-HSG and its chairs in 2022. 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 2022, the lab was able to keep its high research velocity and extend its teaching portfolio towards the new Master of Science in Computer Science (MCS). Highlights of 2022 were (i) the *Google Research Scholar Award* handed over for the work on Hyper-Representation Learning¹, (ii) the *Best Student Paper Award* for the work on self-supervised learning for earth observation at the CVPR Earthvision workshop, (iii) the successful SNF project acquisitions of the project “*Self-Supervised Learning for Earth Observation: Leveraging a wealth of multi-modal data*” co-lead by Prof. Michael Mommert and Prof. Damian Borth, and (iv) the election of Prof. Michael Mommert to the “*Schweizer Kommission für Fernerkundung (SKF)*” representing the University of St.Gallen in this domain.

Team Members

The chair of Artificial Intelligence and Machine Learning consists of 10 members including Prof. Michael Mommert, who is the newly appointed Assistant Professor in Computer Vision to the School of Computer Science (SCS) and is affiliated with the lab. Additionally, with Prof. Adrian Ulges the lab did host its first guest researcher in the spring semester of 2022.

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**. While in 2021, multiple members of the lab went through the PhD proposal defense, in 2022 they were able to continue with their research and

¹<https://www.unisg.ch/en/newsdetail/news/google-research-scholar-award-for-hsg-research-on-trust>

successfully publish their work in international journals, conferences, and workshops.

In the research area “Representation Learning of Deep Neural Networks”, the lab was awarded a Google Research Scholar Award in the category Machine Learning and Data Mining about “*Hyper-Representations: Learning from Populations of Neural Networks*”. In context of this topic, the lab was able to repeat its previous success in publishing two milestone publications at Neural Information Processing Systems (NeurIPS) conference and one workshop publication at Int. Conference on Machine Learning (ICML). One line of research did focus on the generative process of a large-scale population of neural networks coined “Model Zoo” containing over 3,844,360 collected model states. This model zoo served as foundation for the generative use to sample unseen neural network models with desired performance characteristics.

The area “Remote Sensing and Earth Observation” experiences a shift in research direction towards self-supervised learning. Self-supervised learning (SSL) is able to utilize the vast amounts of earth observation data without the need for equal amounts of label data. This way, task agnostic models can be trained to perform multiple independent downstream task such as classification or segmentation with the same pretrained encoder model. Most of the published work in this area was centered around pioneering work in SSL for earth observation from which one publication was awarded the “Best Student Paper Award” at the IEEE Computer Vision and Pattern Recognition (CVPR)’s Earthvision workshop 2022. Additionally to the SSL work, the lab was able to publish its first work at the IEEE Transaction of Geoscience and Remote Sensing (TGRS). This work, an extension and improvement of the previous work on NO_2 monitoring, allows to quantify uncertainty in out-of-distribution scenarios, which is important in remote sensing and earth observation setups.

In “Text-to-Speech Synthesis”, the lab did publish two individual works in voice conversion and speech emotion recognition at top conferences in audio and speech procession. This work proposes a novel machine learning approach to train models for low-resource languages in an efficient and performant way. Finally, in the research area “Financial Audit and Fraud Detection”, the lab was very prominently visible with its publications at the ACM AI in Finance conference, the only computer science conference on machine learning targeting the financial domain. One topic covered the labs research in “federated and privacy preserving learning” of financial data and the other topic was about “explainability” in anomaly detection setups.

Finally, with Marco Schreyer, one of the members of the lab started his nine-month visiting stay with Prof. Miklos Vasarhelyi at Rutgers University in the US to pursue independent research in representation learning of accounting and audit data. The visit was financially supported by the Mobi.Doc program of the University of St.Gallen.

Summarizing, the lab was able to publish 16 publications, including four journal publications, nine conference publications and three workshop papers in top venues such as NeurIPS, ICML, IEEE CVPR, IEEE IGRASS, ACM ICAIF, Interspeech and TGSRS. These publications were written in collaboration with authors of University of Polytechnic Catalonia in Barcelona, Reykjavik University, Rutgers University, Nestle, Samsung AI, 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 platform². As in the previous year, members of the lab were serving as technical program committee, area chairs, and reviewers of international conferences, journals, and governmental funding programs.

Projects

In 2022, the lab was able to successfully acquire an SNF funded project titled: *“Self-Supervised Learning for Earth Observation: Leveraging a wealth of multi-modal data”*. This four-year-project will focus on novel methods for self-supervised learning on satellite data and combine these methods with a multimodal input stream of data. Additionally, in the scope of this project, novel transformer-based approaches will be developed as underlying backbones for self-supervised learning in earth observation.

Additionally, with *“HumAIIn – A Human Rights Approach to AI”*, a development grant from the Botnar foundation was successfully acquired in collaboration with Prof. Florian Wettstein, Prof. Veronica Barassi and the Economist group, UK. This project focuses on the investigation of potential negative impact of AI on children with special focus on generative AI.

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

Teaching

In 2022, 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 2022 for its first time. This course is part of the data science specialization, teaches theoretical foundations in machine learning, and combines the theoretical knowledge with a novel coding challenge, where students are competing on a classification task hosted by the popular Kaggle platform. Further, the newly developed course in “*Deep Learning*” at the MCS was also held for the first time in fall 2022. This course extends the previously acquired knowledge in machine learning with state-of-the-art learning methods such as contrastive learning, multi-task learning, meta-learning, continual learning, and federated learning. Finally, on PhD level, the Advanced Topics in Deep Learning course was continued in the DCS program.

Additionally, several service teaching courses were held by lab members. These were the Bachelor BWL “Machine Learning” course, the Bachelor BWL “Unternehmerische Informatik Capstone Projekt”, 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 2022 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 the TH Nürnberg, Germany.

With regard to bachelor and master thesis work, in 2022, the lab has supervised five bachelor theses and five master theses. Out of these, two theses lead to publications at IEEE IGRASS and ACM ICAIF conferences. Finally, for the first time, two MCS master projects were supervised at the lab supervised by Prof. Michael Mommert and/or Prof. Damian Borth.

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.

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 2022 was the panel discussion about Space Exploration with ESA's director general Josef Aschbacher, former NASA astronaut Franklin Chang-Diaz and space law expert Alyssa Goessler. Another highlight was the invitation by European Space Agency (ESA) for the keynote at the Machine Learning workshop organized by the European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, UK. Over 800 participants joined, either in person or watching the livestream online³. Finally, the lab was able to successfully present their work at the Swiss Remote Sensing Days in Ascona organized by ETH and EPFL.

In 2022, multiple invited lectures or seminars at universities such as ETH Zurich, Rutgers University, TU Darmstadt, TU Munich, LMU Munich, Uni Lichtenstein have been held. Additionally, lab members have given keynote at event invited by e.g., Eidgenössische Finanzkontrolle (EFK), European Union, Roman Herzog Institute, Deutscher Akademischer Austauschdienst (DAAD) and the Jugendparlament SG/AI/AG. Similarly, lab members were involved in multiple University of St.Gallen events such as HSG-Zukunftstag, Infoday Woman@HSG, Open Day BCS/MCS giving talk or lectures. In total the AIML lab was able to communicate its research in 26 invited keynotes, lectures, and seminars.

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 and the scientific advisory board of the Roman Herzog Institute.

³<https://vimeo.com/770757594/4545f61370>

Data Science and Natural Language Processing, Siegfried Handschuh

In 2022, our research efforts in the field of **Natural Language Processing** continued with a particular emphasis on **Large Language Models** (LLMs). 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.

The PhD students who began their academic journey at the University of Passau and followed us to Switzerland are now approaching the completion of their programs. We have successfully secured multiple projects, and our collaboration within HSG, particularly with IBB-HSG, was further strengthened.

Team

Christina Niklaus successfully defended her dissertation with the highest honors (**Summa Cum Laude**) at the University of Passau. Her dissertation was also submitted for the GI Dissertation Prize 2022, which recognizes the best dissertation of the year 2022 from the Computer Science Faculty at the University of Passau. The prize selection and award ceremony will be held in 2023.

Matthias Cetto left our chair in 2022 and returned to Passau due to personal reasons and to start a family. He is now working as a data scientist at ONE LOGIC GmbH in Passau. One of our last joint projects was the co-authoring of a textbook on Data Science (see later). Matthias has been a highly valuable member of our team, and we are grateful to have had the opportunity to work with him.

By the second half of 2022 Reto Gubelmann has started a part-time position as a postdoctoral researcher at the chair. He will continue his research on exploring the linguistic and logical capabilities of Large Language Models, as well as providing support for project management.

During the autumn semester of 2022, Prof Handschuh took a half-sabbatical.

He set two primary objectives for his research semester. The first goal was to work on a **comprehensive textbook** about the mathematical underpinnings of Data Science. The second objective focused on conducting meticulous, in-depth research on the subject of **Large Language Models**.

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 the **powerful 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.

Projects

In 2022, several new and exciting projects were successfully started and executed:

- **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)”. The project is being carried out in cooperation with IBB-HSG and Mahidol University in Thailand.
- **Swissuniversities:** P-8 “Stärkung von Digital Skills in der Lehre”. Teilprojekt 4, Ananda - Data Analytics und automatische Assessments. Zusammen mit dem IBB-HSG
- **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 is led by Dr Reto Gubel-

mann.

Industrial projects were carried out with the companies Service-Ocean⁴ and ValueFocus⁵. In partnership with Service-Ocean, we conducted a Data Science project aimed at optimizing service center capacity. We tackled the challenge of maximizing service center staff availability using cutting-edge algorithms and data analysis techniques. Additionally, we worked on a project outline concerning an intelligent skills database in collaboration with SIP-Ost⁶. The objective is to facilitate connections between companies, research partners, and organizations within the global ecosystem.

Publication

This year we again succeeded in publishing at the **renowned ACL conference**⁷ with a pragmatic study on LLMs' negation understanding.

Siegfried Handschuh, along with team members Tomas Hrycej, Bernhard Bermeitinger, and Matthias Cetto, authored a textbook titled "Mathematical Foundation of Data Science" (refer to Figure 1). This work is set to be published by the prestigious Springer Verlag and will be accessible starting April 2023.

This textbook's objective is to highlight the critical mathematical principles underpinning data analysis. It specifically delves into the essential principles required to comprehend the implications of an application and the conditions for the success of employed methods. The theoretical aspect is presented to the extent necessary for proper application, maintaining a balance between excessive complexity and oversimplification. The primary focus lies on the principles vital for the success of applications. Although this core textbook targets computer science and data science students primarily, it also appeals to researchers in the field who wish to gain a solid understanding of the mathematical foundations that extend beyond their computing experience alone.

⁴<https://www.serviceocean.com/>

⁵<https://valuefocus.ch>

⁶<https://innovationspark-ost.ch/>

⁷Association for Computational Linguistics: A* conference: 14.9 % acceptance rate

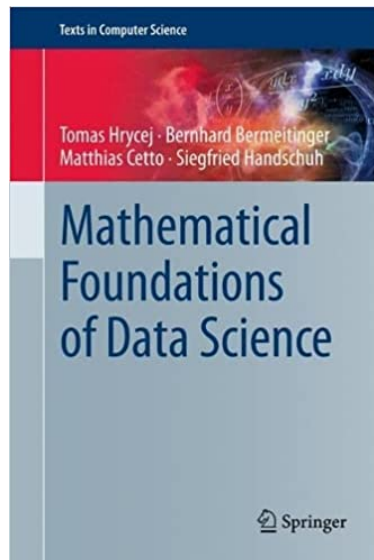


Figure 1: Mathematical Foundations of Data Science. Springer Verlag. Serie: Texts in Computer Science

Community & Outreach

Siegfried Handschuh has taken on the honourable task of **GLA President** for the newly founded Institute for Educational Management and Technologies (IBB-HSG).

During his sabbatical, Siegfried Handschuh had the opportunity to visit the prestigious University of Queensland in Australia, where he engaged in fruitful collaborations and knowledge exchange with fellow researchers. Additionally, he was invited as a **keynote speaker** at the IEEE CSDE Data Science Conference 2022⁸ held in Australia, where he delivered an insightful presentation on Large Language Models, sharing his expertise and discussing the latest advancements, challenges, and future directions in this rapidly evolving field of research.

⁸<https://ieee-csde.org/csde2022>

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

In February 2022 the group joined the Institute of Computer Science. At this time, the group consisted of the head of the chair, as well as the doctoral researchers Marc Newman and Nadja Willenborg. In April, Adrien Pasquereau, also a doctoral researcher, joined the team. Additionally, Dr. Habibul Islam has been a part of the group since 2021, financed through the International Postdoc Fellowship (IPF) of the University of St.Gallen.

Research

In the area of Coding Theory we could achieve several results on the number of optimal error-correcting codes in different metric spaces. This allows us to predict properties of random codes with high probability, which is extremely important for the design of code-based cryptosystems. We presented these results at four international conferences. Two of the presentations took place as plenary lectures. In a second project, we set up new error-correcting codes for quantum computers that work with entanglement assistance.

In the area of cryptography, we have initiated a project on zero-knowledge proofs, which are built on general linear codes. We have also started a collaboration with Dr. Karan Khathuria of Cambridge Quantum in which we analyze lattices in the Manhattan norm (or L_1 norm). The expected results will have an impact on both lattice-based and code-based cryptography.

In the summer of 2022, we were part of the international organizing team for the conference "Coding theory and cryptography - a conference in honor of Joachim Rosenthal's 60th birthday", which took place for one week in Zurich and had 70 participants from all over the world.

Teaching

In 2022 the group taught several courses in various degree programmes of the University of St.Gallen. These include *Fundamentals of Computer Science* 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 an *Integrative Master Project* on "Machine Learning Based Attacks on Post-Quantum Cryptosystems" at the School of Computer Science, as well as several undergraduate theses at the School of Economics and Political Science (SEPS).

Interactions Research, Simon Mayer

The team at the Chair for Interaction- and Communication-based Systems⁹ consists of 16 individuals who, together with our partners at the University of St.Gallen and beyond, explore interactions among devices and people in ubiquitous computing environments. Our group's focus is on increasing the autonomy of cyber-physical systems and their intelligibility for people and on making the interaction with ubiquitous computing environments more enjoyable.



Figure 2: Members of the Interactions Research Team

Team Members

Early in the year 2022, our team celebrated the appointment of Prof. Dr. Andrei Ciortea as *Assistant Professor for Web-based Systems* at the University of St.Gallen. In his new role, and in addition to his successful research agenda on Hypermedia Multi-agent Systems, Prof. Ciortea is taking over teaching responsibility for several courses at the School of Computer science, including prominently the course on *Web-based Autonomous Systems* in the Master of Computer Science program and the course on *Distributed Systems* in the school's Bachelor of Computer Science program. Congratulations, Andrei! The Interactions Research Team furthermore grew by two persons: Jérémy Lemée, who had already been working on his Master's Thesis on the topic of *Signifiers as a First-Class Design Abstraction in Hypermedia Agent Environments* in our group, decided to

⁹<https://interactions.ics.unisg.ch>

continue his research and work towards a PhD in Computer Science. In his new role, Jérémy also joined the subgroup working on our EU H2020-funded research project on Intelligent, distributed, human-centered and trustworthy IoT environments (IntelloT)¹⁰. And finally, in September 2022, Lukas Eichelberger joined the team to start working in his newly created role of *Research Entrepreneur*, looking at possibilities where we might push our research to find broader application.

At the end of the year 2022, our team comprised 16 members, including eight PhD students, four postdoctoral researchers, and a software engineer.

Teaching

Our Chair 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 and to Computer Science. In the year 2022, our Chair's teaching comprised 13 courses that were attended by more than 1050 students in total. Overall, we are active in seven different degree programs at the University of St.Gallen and, despite our core Computer Science contents, several of our courses are open to all students of the university.

In autumn 2022, we were highly motivated to start teaching in the newly created Bachelor program in Computer Science (BCS), where we contributed a fundamentals course on *Computer Systems and Computer Engineering* (taught by Simon with exercise support by Iori and Sanjiv). At that point in the year, our teaching for the Master of Computer Science program was already in full swing with the mandatory course on *Advanced Software and Systems Engineering* (taught by Simon and Andrei in collaboration with Prof. Barbara Weber and Prof. Ronny Seiger at the Chair of Software Systems Programming and Development), the *Ubiquitous Computing* course (taught by Simon with exercise support by Janis, Kimberly, Kenan, Andres, and Ganesh), the *Web-based Autonomous Systems* course (taught by Andrei with exercise support by Danai and Simon), and the *Integrative Master's Project* (taught by Kimberly, Sanjiv, Andrei, and Simon). Simon furthermore taught a course on *Advanced Topics in Pervasive Computing* for the PhD program in Computer Science.

In terms of courses that were offered for non-Computer Science degree programs at the University of St.Gallen, we engaged in teaching the *Fundamentals*

¹⁰<https://cordis.europa.eu/project/id/957218>

and *Methods of Computer Science for Business Studies* (EN and DE) as well as the *Fundamentals of Computer Science* course that is open to all students at the university. In the Bachelor of Business Administration, we furthermore taught a course on *Computer Networks and Distributed Systems* and – together with Prof. Johannes Schöning at the Chair for Human-Computer Interaction – advised five student groups as part of the *Capstone Project in Entrepreneurial Informatics*. We furthermore offered an *Introduction to Computer Systems and Networks* (taught by Andres and Simon) as well as a foundational course on *Ubiquitous Computing and the Internet of Things* (taught by Simon) to students in the Master of Business Innovation (MBI) program. Finally, together with Prof. Tanja Schneider from the School of Humanities and Social Studies and with Prof. Aurelia Tamò-Larrieux, we offered *Cross-Disciplinary Perspectives on Privacy-Invasive Technologies* to students in the Contextual Studies program.

Across all our courses, we again received very good student evaluations, where specifically our BCS and MBI courses stand 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 2022, we deepened our expertise, consolidated our team, 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). With the FoodCoach¹¹ system and application, we furthermore significantly increased our capacity to provide pervasive nutrition and health support, and started our first own large-scale study in this field. Finally, we continued our investigation of the legal context of ubiquitous computing, which is driven by Clement and together with Aurelia Tamò-Larrieux at Maastricht University.

Our second major area of interest are *World-Wide Autonomous Systems*. In this field, Andrei is driving our group's research on Hypermedia Multi-Agent Systems, and we are investigating interactions of autonomous agents with each other and their environment, where we developed a specific interest in the application of

¹¹<https://foodcoa.ch>

concepts from ecological psychology – specifically, Affordance Theory – beyond interactions of animals and to interactions of *artificial* agents. Bridging with ubiquitous computing, we furthermore investigate the possibility to deploy autonomous agents to embedded and low-power systems, and 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 2022 published more than 30 peer-reviewed research articles at international journals, conferences, and workshops.

Cyber Security, Katerina Mitrokotsa

The **Chair of Cybersecurity** 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

At the end of 2022 the Cybersecurity group at the University of St. Gallen consisted of three Doctoral Researchers and two Post-doctoral Researchers. Additionally, one Doctoral and one Postdoctoral Researcher, affiliated with the Chalmers University of Technology, Gothenburg, Sweden, still performed research under the supervision of Prof. Dr. Katerina Mitrokotsa. To support our research group in implementation tasks, a Research Engineer was hired for a duration of four months from Nov. 2021 End of Feb. 2022. As a part of the EU-funded Marie Skłodowska-Curie Actions project Trespass-ETN, a doctoral researcher from EURECOM, France, visited the group from April until June for her secondment. Her visit was fruitful both for the TReSPasS-ETN project as well as the group's research. Furthermore, one PhD student Georgia Tsaloli of our group (affiliated with Chalmers Univ. of Technology) defended her PhD thesis and graduated. Congratulations Dr. Tsaloli!

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 algorithm. 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 2022, we were involved in two main externally funded research projects: the EU-project TReSPAS-ETN and the GFF project Decent-IoT.

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- The EU-Project TReSPAsS-ETN¹² (TRaining in Secure and PrivAcy-preserving biometricS) funded by the Marie-Sklodowska-Curie Innovative Training Network entered into its second year and continued to be an important part of the group's research in 2022. As part of this project, we design 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 have been submitted to top research venues in cybeseurity and have recently been accepted.
 - The GFF-project Decent-IoT: Decentralised, Secure and Private Internet of Things was finalized in 2022. This project aimed at providing research foundations that help to build decentralised IoT ecosystems as well as providing service-oriented IoT systems that guarantee security and privacy. The challenge that lied ahead was how to construct an efficient fundamental system that can be used in the IoT setting where many IoT devices collect private information and send them to service-providing servers. This setting can be seen as one of the examples of secret-shared settings, where computing servers obtain encoded/shared data and need to operate data analysis with the private information without knowing the original data.

During 2022, our group published research papers that appeared in well-known venues in cybersecurity and cryptography including ACM CCS 2022, AsiaCCS 2022, PETS 2022, ACM SACMAT 2022, while some additional papers submitted in 2022 were recently accepted at the Journal of Cryptology and ACNS. 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.

¹²<https://www.trespass-etn.eu>

Teaching

Our Chair offers multiple courses in the area of Cybersecurity and Applied Cryptography. During 2022 the cybersecurity chair offered four courses for the master level and two PhD courses. The courses were taught at the Computer Science master program, the Master in Business Innovation (MBI) program as well as one course at the Contextual Studies of the Univ. of St. Gallen. More precisely, the mandatory course in *Cyber Security* was taught to the Master in Computer Science students for the second time. The group also supervised a student performing her *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* in the Skills-section of the Contextual Studies at the University of St.Gallen. During 2022, 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.

Outreach

Since November 2022, Katerina Mitrokotsa is a member of the Sounding Board Researchers of the Swiss National Open Research Data Strategy¹³. 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.

Furthermore, she has served in the program committees of multiple top conferences in the field of cybersecurity e.g. ACM CCS 2022 as well as as member on the evaluation of multiple Research Evaluation Proposals (e.g., FWO (in Belgium) and Academy of Finland). In addition, Katerina Mitrokotsa was invited to participate at the Dagstuhl seminar *Security of Machine Learning*¹⁴ which took place in July 2022. The seminar brought together researchers from machine learning

¹³<https://akademien-schweiz.ch/en/themen/scientific-culture/open-science/>

¹⁴<https://www.dagstuhl.de/22281>

and security communities, and its goal was to generate new ideas for security assessment and design in the field of machine learning.

In addition the Chair of Cybersecurity, has established a collaboration with the Cyber Defence (CYD) Campus of Switzerland. During 2022, the director of the CYD campus has visited the School of Computer Science at the University of St. Gallen as part of the CSI seminar and correspondingly Katerina Mitrokotsa gave an invited lecture at the CYD seminar, while a research collaboration is currently in progress. Furthermore, we disseminated our research results to the media by giving interviews to the press (e.g. Leader magazine) and locally at the Univ. of St. Gallen.

Finally, throughout 2022, 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.

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 two Ph.D. students and a Postdoc. 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 for distributed software applications. The other Ph.D. student is active on the research line on languages and systems for infrastructure as code.

Three additional Ph.D. students supervised by Prof. Guido Salvaneschi are 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 2022, the group offered a total of 6 courses. Overall, the group is active in a number of programs, at the university of St.Gallen.

In Spring 2022 the group offered the course *Engineering Software Systems* in the MBI program. In Fall 2022, the team has offered a course in the Context Studies *Emerging Trends in Information Technology* which provides students with a non-technical background an overview of selected significant areas in Computer Science. 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.

Autumn 2022 has also been an important milestone for the group with the start of the Bachelor program in Computer Science 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.

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 the design of programming languages 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.

A second research line is about the problem of deploying software systems into production after their development. Over the last few years, various organizations have started accomplishing this task using general-purpose programming languages. This trend has created a new class of software applications that aim to configure 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 results of these research lines have been published, respectively in ECOOP and ICSE, two highly prestigious venues in programming and software systems.

Human-Computer Interaction, Johannes Schöning

The HCI Group at the Institute of Computer Science at HSG is committed to advancing research in the field of 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 one PostDoc at HSG in St. Gallen. In addition, four 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 as well as within HSG. Their summer meeting, "CHI Together", has promoted (inter)disciplinary exchange between PhD students, postdocs, and professors across different schools.

Team

At the end of 2022, the team consisted of 7 researchers. Dr. Jasmin Niess left the group to take over an associate professorship at the University of Oslo, Norway. Gian-Luca Savino finished his PhD, becoming the first PhD of Science in the 125-year-long history of HSG. Gian-Luca Savino is now a Postdoc in the group.

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 approach. Their research resulted in various high-quality publications in 2022. For example, the team published at ACM CHI, Mobile HCI (the paper was awarded an Honorable Mention Award), ACM Interactions, and other high-quality outlets. Additionally, the group acquired an SNF project on the impact of novel navigation technologies, which runs for four years and finances a PostDoc and a PhD. They also received a 75K USD grant from Microsoft research to investigate novel technologies for hybrid work.

Our research papers published in 2002 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 ¹⁵.

For example, the team researched how the As-the-crow-flies (ATCF) navigation method as an alternative to turn-by-turn navigation for cyclists, which utilizes the least-angle strategy by providing the shortest possible path to the destination [SKS22]. However, previous research has identified weaknesses of ATCF navigation, such as running into dead ends, which can affect the user experience. They investigate how the street network attributes to the experience of the navigation method by analyzing the feature importance and comparing different city types across 1633 cities. The study identifies the characteristics of the perfect ATCF-city, such as long streets, many options to turn at decision points, few dead ends, and a grid-like structure, which are primarily found in East Asia and North America. The team also found that previous ATCF studies were conducted mainly in Western Europe, which features the least-suited street networks for the navigation method. The paper concludes with design implications for future ATCF implementations and emphasizes the importance of diverse study locations in future research [SKS22].

In addition, the research group tackled the challenge of providing users with a realistic haptic weight sensation of virtual objects in VR due to the limitations of current consumer VR controllers and software-based approaches. To address this issue, they developed a haptic VR controller named Triggermuscle [SBKS22]. that adjusts its trigger resistance according to the weight of a virtual object. The

¹⁵http://www.alexandria.unisg.ch/269342/1/HCI_2022.pdf

group conducted two user studies to evaluate the effectiveness of Triggermuscle. The results showed that participants had varying abilities to sense changes in trigger resistance and discriminate virtual weights, which may have implications for the design of future haptic VR controllers [SBKS22]. The team also researched how VR can promote mindfulness practice and presence [WAS⁺22]. They conducted a user study to explore the impact of different multimodal feedback, such as passive haptic feedback by artificial grass and auditory feedback at the feet level, on mindfulness and presence. They found that passive haptic feedback significantly improved presence and mindfulness, while auditory feedback did not significantly affect it. The study also revealed that footstep sound disrupted both presence and mindfulness. Based on these findings, design recommendations for multimodal VR applications that support mindfulness practice were derived [WAS⁺22].

The SNF Project *Understanding and Improving Society-level Effects of Navigation Technologies (SENT)* seeks to address the negative externalities associated with navigation technologies like Google Maps and “SatNavs” by conducting research to understand the algorithmic mechanisms behind these externalities and developing design implications to reduce them. The research will be conducted in two phases in the next 3.5 years - the first phase will focus on analyzing catastrophic incidents associated with navigation technologies and the behaviour of routing algorithms to gain a deeper understanding of the society-level effects (i.e., negative externalities) of existing navigation technologies. The second phase will involve developing proof-of-concept solutions, including developing datasets and technologies that will facilitate the consideration of externalities by navigation technology researchers. The goal is to produce a new generation of navigation technologies that minimize negative externalities while maintaining good trip-by-trip experiences, using mixed-methods approaches situated at the intersection of Human-Computer Interaction and Geographic Information Science.

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. Additionally, the team got involved in teaching HCI content in the MBI and provided courses on novel technologies in space for the context studies program.

Outreach

The HCI group organizes events throughout the year to promote interdisciplinary exchange between PhD students, postdocs, and professors across different schools. They organized a summer meeting called "Cto jointly developed developing relevant publications for the ACM CHI submitting manuscripts. The group invited 13 young scientists in HCI from leading HCI Labs to St. Gallen to conduct research and present their work at the ACM CHI conference. There were 13 visitors (1 Master, 10 PhDs, 1 PostDoc, 1 Prof) from 5 countries coming from 6 universities. The group also organized an HCI winter workshop in December.

Johannes Schöning is also the president of the ACM SIGCHI chapter in Switzerland, organizing several events yearly. The local "Mensch und Computer" conference will also take place in the canton of St. Gallen in September 2023, allowing the HCI group to showcase their work and network with other researchers in the field. Together with the School of Computer Science, the Computer Science Insights St. Gallen (CSI St. Gallen) talk series is organized. Nearly 20 speakers from industry and academy learned about the ICS and the SCS and presented their research 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 four researchers with PhDs in 2022. 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 2 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 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 2022 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 2022 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. Furthermore, the supervision of six bachelor theses in Entrepreneurial Computer Science was successfully completed in 2022. Since 2021, the chair also teaches the elective *Coding for Executives* in the EMBA 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*¹⁶ and *ProAmbitlon*¹⁷.

Process Mining. In 2022, we were able to further strengthen our research in the field of process mining. Together with international partners, we are working intensively on the **process of process mining** as part of a project funded by the SNSF (project start was November 2020). 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 process analysts during process mining, including the challenges that analysts 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 common patterns of effective and non-effective behavior, analysis profiles, common analysis strategies, and typical challenges. Here we are working closely with partners from the University of Haifa. Building on this, we plan to develop methodological guidance and software-based operational support to

¹⁶<https://data.snf.ch/grants/grant/197032>

¹⁷<https://data.snf.ch/grants/grant/208497>

assist (inexperienced) analysts during analysis. Based on a study conducted in 2021 with 41 experienced process analysts and extremely rich data, consisting of behavioral data as well as interview data, we could publish first papers in 2022 [ZSW22, ZZW22, ZKB⁺22]. This work is intended to contribute to a better understanding of how process analysts work, as well as the challenges they face when performing process analysis. Cooperations with the University of Utrecht could be intensified and new cooperations with the University of Seville and the University of Queensland could be established. Also, a manifesto on “Process Mining in Healthcare: Characteristics and Challenges” could be published with the cooperation of the chair [MGMFL⁺22].

In addition to the empirical results described earlier, we have already been able to identify initial areas where additional methodological support has been lacking and software-based operational support is needed. For one of the identified areas we were able to present—together with partners from the Technical University of Denmark (DTU)—a first paper entitled “Granularity in Process Mining: Can We Fix It?” at the “International Workshop on BPM Problems to Solve Before We Die (PROBLEMS 2021)” at the renowned BPM conference [ZSF⁺21]. In the meantime, the open problem we identified could be published together with further challenges under the title “The biggest business process management problems to solve before we die” in the journal *Computers in Industry* [BDR⁺23]. We are currently working on initial partial solutions to the **granularity in process mining**. A successful solution to the problem would have far-reaching implications for the integration of process mining and task mining, in addition to implications for the “process of process mining” described earlier, as well as the analysis of human behavioral data and process data in the context of IoT.

Based on our insights about the process of process mining, we have already achieved a first milestone in developing tool support for the process of process mining [ZBV⁺]. This milestone includes requirements, design, and first evaluation results of a tool that supports process analysts by increasing transparency and rigor of their exploratory analysis.

Business Process Management and Internet of Things. Our research regarding the integration of Business Process Management (BPM) with the Internet of Things (IoT) continued in 2022. Numerous results can also be demonstrated here. With the successfully acquired project *ProAmbition* (Online Process Conformance Checking with Ambiguities Driven by the Internet of Things) from the SNSF SPIRIT program, our research work can be deepened with a focus on on-

line activity recognition and conformance checking based on IoT data. In the project, we are supported by renowned researchers from the Tecnológico de Monterrey in Mexico as additional Principle Investigator, as well as other associated partners from the TU Munich, University of Ulm, the Technical University of Denmark and the University of St.Gallen. In addition to the Smart Manufacturing application area, in which we are already intensively researching, the project has also added the new area of *Smart Healthcare*, in which we are working intensively with the Cantonal Hospital of St.Gallen. First work in the area of activity recognition based on IoT data could already be successfully published and presented [WSW23, SFW23]. Our existing collaborations with the University of Trier continued and resulted in another publication discussing system architectures for smart factories [SMWB22]. This was presented to an interested audience from industry in the Camunda User Groups “Rheinland” and “Ruhrgebiet”, among others. To intensify the cooperation with other renowned institutions, the University of Trier, the DFKI, the Technical University of Munich and the University of Ulm, a workshop of several days on the topic of BPM and IoT was held at the University of St.Gallen in the summer of 2022.

Human and Cognitive Aspects in Software and Process Engineering. Human and cognitive aspects in software and process engineering represent another focus of our research. Our research in this area is characterized by the fact that we often collect multi-modal data, combining subjective measurements with measurements of user behavior (e.g., user interactions), neuro-physiological measurements, and performance measurements. In particular, we are interested in how users interact with software artifacts (e.g., source code or process model).

With a particular focus on the **fine-granular measurement of cognitive load**, our initial approach to tackle this problem was accepted at the Early Research Achievement (ERA) track of the “International Conference on Software Analysis, Evolution and Reengineering (SANER’2022)” [SAAW22]. Following that, we further developed our approach and conducted a larger empirical study where the collected multi-modal users’ behavioral and physiological data were used to develop machine learning models predicting users’ cognitive load when engaging with source code and pinpointing the difficult parts of it at a high accuracy and precision levels. The findings of this study were published at the “IEEE/ACM International Conference on Program Comprehension” (ICPC) [AASW22].

Besides, we have conducted an extended tertiary review study on the relationship between source code metrics and cognitive load measurements of which

the results were published at the “Journal of Systems and Software” [AA23]. The aim of this work was to investigate the existing source code metrics and leverage their potential to estimate the cognitive load required for developers to understand a given part of source code. By correlating source code metrics with cognitive load measurements, we are aiming at developing novel machine-learning models that can pinpoint the mentally demanding parts of the source code without a constant need for using users’ behavioral and physiological data. A follow-up study is being initiated with researchers at the University of Ulm and the Technical University of Denmark to attain this objective.

Another important work was conducted together with researchers at the Rhein-Main University of Applied Sciences. Therein, we have contributed to the evaluation of a language model capable of assessing the quality of source code identifiers and pinpointing those violating existing naming conventions. The new language model is currently used as part of an empirical study investigating the support of such a technology in practice.

Our research within this stream extends also to the comprehension of process models. Therein, we have developed “Eye-Mind”¹⁸ i.e., a novel tool allowing to map users’ behavioral and physiological data, incoming from eye-tracking and click streams, with the gazed elements in a process model. Since the last quarter of 2022, Eye-Mind has been successfully used to conduct two large empirical studies investigating different types of model navigation support and comprehension tasks. These studies were conducted in collaboration with researchers at Leibniz Universität Hannover and Karlsruher Institut für Technologie. The results of these studies are intended to appear in the proceedings of highly ranked venues within the business process management field during this ongoing year.

In addition, together with colleagues from the University of Queensland in Australia intensively worked on the question how the integration of rules and business processes affects comprehensibility. The results of this collaboration appeared in the very prestigious journal *Information Systems* [WCI⁺22] in early 2022. In collaboration University of Queensland (UQ), we are investigating neurophysiological measures in the context of digital learning. A journal article on this topic has been accepted for publication in the prestigious journal “*International Journal of Artificial Intelligence in Education*” in 2022 [DKSW22]. We are also working with colleagues at the University of Innsbruck and the University of Haifa on the question of how the layout of process models affects their compre-

¹⁸See <https://github.com/aminobest/EyeMind>

hensibility, and we are using eye-tracking to illuminate the underlying cognitive processes.

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 2022 and make an important contribution to St. Gallen gaining (international) visibility as a computer science location.

With Barbara Weber as PC Chair, the Chair was significantly involved in the organization of the “International Conference of Process Mining (ICPM 2022)”, the leading conference in this topic area. In addition, Barbara Weber was co-organizer of the Doctoral Consortium at the CAiSE conference and Francesca Zerbato was co-organizer of the International Workshop “Education meets Process Mining” (EduPM 2022), which was held in conjunction with the ICPM conference.

Barbara Weber was also invited as keynote speaker at the renowned CAiSE conference on “The Power of Events for IS Engineering”. Together with colleagues from the BPM Steering Committee, Barbara Weber also co-organized a series of BPM Association BPM Expert Forums with business process management thought leaders in 2022 to promote the exchange of ideas between academics and practitioners worldwide¹⁹.

In 2022, Barbara Weber was 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 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”²⁰. Further, she is an Associate Editor part of the Editorial Board of the journal “Business & Information Systems Engineering (BISE)” for the “Business Process Management”²¹, a member of the Editorial Board of the

¹⁹<https://bpm-conference.org/bpma/expert-forum>

²⁰<https://www.springer.com/journal/10270/editors>

²¹https://www.bise-journal.com/?page_id=20

journal “Computers in Industry”²², part of the Editorial Advisory Board of the journal “Information Systems”, and Associate Editor of the journal “Computing”. In addition, Francesca Zerbato serves as Lead Guest Editor of a Special Issue on “Knowledge Representation and Reasoning for Healthcare Processes” in the journal “Artificial Intelligence in Medicine”.

In 2022 we had the pleasure to host several doctoral researchers for a research stay and work together on topics of joint interest. This included researchers from the University of Queensland, Karlsruhe Institute of Technology, University of Seville and TU Dresden.

²²<https://www.journals.elsevier.com/computers-in-industry/editorial-board>

Publications

A full publications list of the Institute of Computer Science is available at the Alexandria platform of the University of St. Gallen: https://www.alexandria.unisg.ch/view/pub_institute/IIT/2022.html.



Universität St. Gallen
Institut für Informatik (ICS-HSG)
Rosenbergstrasse 30
9000 St.Gallen
<https://ics.unisg.ch>

Institute Members

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- Prof. Dr. Siegfried Handschuh (Director)
- Prof. Dr. Anna-Lena Horlemann
- Prof. Dr. Simon Mayer (Director)
- Prof. Dr. Katerina Mitrokotsa (Director)
- Prof. Dr. Guido Salvaneschi
- Prof. Dr. Johannes Schöning (Director)
- Prof. Dr. Barbara Weber (Director)

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