Centre Universitaire d'Informatique

2022

Activity Report

CUI UNI GE

Adopt a skill event, Battelle, October 2022

UNIVERSITÉ DE GENÈVE

Foreword

We live in an era of digital transformation with a tremendous impact on our societies. The mission of the Centre Universitaire d'Informatique (CUI), funded in 1975, is more than ever essential, relevant and in line with the actuality. Our mission at CUI, as scientists, is to be pioneers of technology, to stimulate the digitalization of services in order to promote the progression of society, while keeping in mind key elements and important values such as: digital responsibility, respect for users and a user-centered view or ethics. As teachers, our mission is to transmit these values and knowledge to our students so that they can develop the digital services of tomorrow with full knowledge of the facts and in compliance with these principles. Such an approach is necessarily interdisciplinary in that the digital transformation and digitization of services is necessarily done for the benefit of another field or profession (e.g. health, environment, mobility, energy, education).

CUI federates research and teaching activities at the University of Geneva. We have seen an increase of 25% of the number of BSc and MSc students enrolled at CUI. In 2021, we observed the biggest growth in terms of students of the whole University. This is also the result of a new program started in 2019: the MSc in digital systems and services, a research-oriented program with various specialisations (e.g. Digital transformation, Knowledge engineering, Smart cities, User experience, Information security). A new version of the MSc in Mathematics and computer science led jointly with our colleagues of Mathematics also attracts additional students. Continuous education is also very present at CUI with programs covering various domains from data protection, information security, blockchain, information systems management, or data science.

With more than 200 members of staff, of which approximatively 60 PhD students enrolled in our various doctoral programs, we develop key research competences in several areas, particularly on: Artificial Intelligence, Virtual and Augmented Reality, Services for Smart Cities, Modelling and Simulation, Information Security, E-Health and Quality of Life, Natural Language Processing, or Computational Diplomacy. This research is supported by more than 4.3 MCHF of externally funded money (76% of our total budget). As proof of this vibrant research activity, the Prof. Dimitri Konstantas has been awarded the H2020 ULTIMO project of an amount 55M Euro project. This project aims at investigating sustainable mobility, human-centered, exploiting autonomous vehicles, and is carried in partnership with Geneva public transport (TPG). As an additional aspect, CUI hosts two new professors carrying our research in the new field of Computational Diplomacy aiming at understanding international institutions complexity and modelling social behaviour. Finally, another novelty of this year concerns our involvement in the University's membership and founding member of the Bloxberg association, the blockchain for the academy.

In addition to research, we developed reach out activities. Started in 2018, the Infoscope offers now 6 workshops for Geneva's school primary and secondary classes. It also regularly goes outside our walls, meeting its public on various places or events, such as La Nuit de la Science or Tecdays.

In 2019, CUI established the Digital Innovation Hub of the University of Geneva. Part of the University's digital strategy the Digital innovation hub has 3 main missions: (1) developing innovative services for the University community, (2) reaching out to the public, private, international sector with innovation activities or proof-of-concepts, (3) supporting students and researchers with digital projects that lead to commercial exploitation or social impact. The novelty of 2022 lies in the establishment of a programming club, "Coding Dojo", addressing three public: high-school students, University students, and researchers. This activity is held in collaboration with the HEG. We already hosted a group of high-school students who learned about programming, cryptography and chatbots. We also awarded to two of them 3 ECTS they can validate in CUI or HEG programs. Together with our students we develop innovative services for the University, first as proof-of-concepts, and second as actual services provided to the whole community. Among our success stories, we can mention Cultura, the chatbot of the Cultural service that can answer varied questions on the cultural offer and the corresponding courses.

I seize this opportunity to thank all CUI members of staff, students and researchers for their hard
work, commitment, innovation, reach out and research activities, all participating to our national and international visibility and excellence.

The coming years will see the development of interdisciplinary partnerships with other disciplines of the University of Geneva, the establishment of links with the local industry and administration, and a series of digital innovations for the University community.

Prof. Giovanna Di Marzo Serugendo
Director of the CUI
University of Geneva

Organisation

Centre Universitaire d'Informatique

Department of Computer Science

Director:
- **Bastien Chopard**

Academic Advisor:
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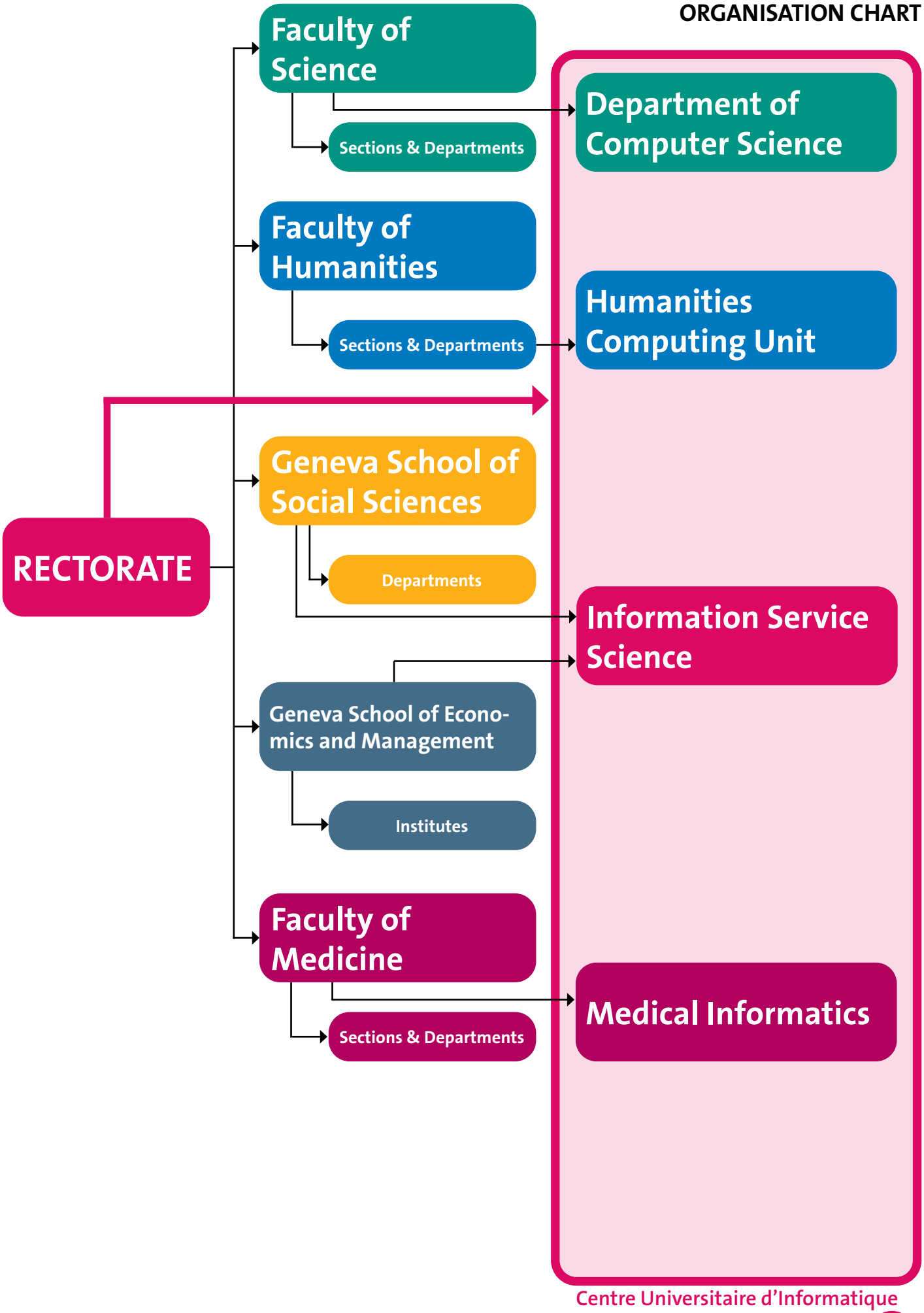
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Information Service Science
Geneva School of Economics and Management
Institutes
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CCL

Citizen Cyberlab

Domain Activities

At Citizen Cyberlab, we are developing methods and studying motivations for new forms of public participation in research. We are researchers from a diversity of backgrounds – history, informatics, learning, linguistics, medicine, physics, psychology and more. Jointly, we initiate projects and organise events that encourage citizens and scientists to collaborate in new ways to solve big challenges. From online crowdsourcing to in-person hackathons, we are exploring and expanding the limits of citizen science and human computation.

Citizen Cyberlab is based on a partnership between the **European Particle Physics Laboratory, CERN**, the **UN Institute for Training and Research, UNITAR**, and the **University of Geneva**, where several teams in different faculties contribute to the lab's activity. In the following, we report activities, events and publications by or involving CUI members of the Cyberlab team.

Co-Directors
François Grey
Associate professor
H-index: 37

Prof. Bruno Strasser

Prof. Basile Zimmermann

clcl.unige.ch

CLCL

Computational Learning and Computational Linguistics

Domain activities

All speakers can understand a sentence never heard before, or derive the meaning of a word or a sentence from its parts. And yet, these basic linguistic skills have proven very hard to reach by computational models. The Computational Linguistics and Computational Learning (CLCL) Research Group (http://clcl.unige.ch/) is concerned with interdisciplinary research combining linguistic modeling with machine learning techniques. We study the notion of similarity and association in the human mono-lingual and bilingual lexicon and compare it to current vectorial representations; we study the learning and the complexity of morphologically complex systems; we study the properties of events and clauses as an expression of their local and non-local compositionality; we address the problem of how to induce the rules and representations in language by automatic learning techniques.

We continue our participation in the NCCR Evolving Language, where we are studying the basic mechanisms that structure communicative expressions, i.e. the mechanisms of combination and division that distinguish a given expression from a holistic signal.

The Swiss National Centre of Competence in Research (NCCR) Evolving Language is a nationwide interdisciplinary research consortium bringing together research groups from the humanities, from language and computer science, the social sciences, and the natural sciences at an unprecedented level. Together, we aim at solving one of humanity's great mysteries: How did our species develop the capacity for linguistic expression, for processing language in the brain, and for consistently passing down new variations to the next generation? How will our capacity for language change in the face of digital communication and neuroengineering? Over 38 research groups across Switzerland are taking part in this NCCR, from 9 different institutions as well as partners in industry (Google AI, Sonova) and public organizations.

Director
Paola Merlo
Associate professor
H-index: 23

CVML

Computer Vision and Multimedia Laboratory

Domain activities

The **Computer Vision and Multimedia Laboratory** (CVML, http://cvml.unige.ch), divided into three groups, carries out research in multimedia data processing, multimedia data management and security, as well as in multimodal human-machine interaction. Research applies to media such as text, audio tracks, sounds, images and videos, and to physiological signals.

Information Retrieval and Machine Learning group (Viper, Prof. S. Marchand-Maillet, Prof. A. Kalousis, http://viper.unige.ch): develops strategies for the efficient modeling, indexing, retrieval and exploration of large-scale datasets. The group studies fundamental machine learning strategies to provide efficient and accurate understanding and access to large-scale collections of complex data. Research themes include information retrieval, recommendation systems, data analytics and exploration, learning over sequential and temporal data, structured and kernel learning, regularization techniques for neural networks. Applications are considered in the fields of data visualization, forecasting, IoT, chemoinformatics, biomedicine.

Stochastic Information Processing group (SIP, Prof. S. Voloshynovskiy, http://sip.unige.ch): studies various aspects of information-theoretic machine learning. The applications mostly cover several domains : physical object security, generative models and anomaly detection in high energy physics, astrophysics and next generation imaging techniques for the radio-astronomy.

Social Intelligence and Multi-Sensing group (SIMS, Dr. G. Chanel, http://sims.unige.ch): conducts research in artificial intelligence, socio-affective computing, multi-sensing, human machine interaction, entertainment and games. Our objective is to better understand human behaviors in their day to day environment particularly when interacting with machines and multimedia. Our approach is based on multi-modal sensing and artificial intelligence to make meaning out of several measures including audio, videos, eye-movements, physiological signals such as EEGs (electroencephalograms), EMG (electromyograms), blood pressure, galvanic skin resistance (GSR) and skin temperature, breathing rate. Member of the Swiss Center for Affective Sciences. Strong cooperation with faculties of psychology, literature and medicine.

Co-Directors

Sviatoslav Voloshynovskiy
Full professor
H-index: 35

Stéphane Marchand-Maillet
Associate professor
H-index: 27

Alexandros Kalousis
Full professor
University of Applied Studies, Geneva School of Business Administration
H-index: 33

Guillaume Chanel
Senior Lecturer and Researcher (also affiliated with the Swiss Center for Affective Science)
H-index: 27

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ISS

Institute of Information Service Science

Collective Adaptive Systems

Director
Giovanna Di Marzo
Serugendo
Full professor
H-index: 30

Domain activities

Collective Adaptive Systems refer to a form of complex systems where a large number of heterogeneous entities interact without specific external or internal central control, adapt their behaviour to environmental settings in pursuit of an individual or collective goal. Actual behaviour arises as an emergent property through swarm or collective intelligence.
Examples include understanding emergence and social behaviour of natural life (e.g. bacteria self-organising to overcome shortage of food), engineering swarm robotics, developing socio-technical systems and more generally developing services for smart and sustainable cities.

We lead and develop research in three main areas:

- Studying natural systems (e.g. biological, social, human ones) and identifying essential models, mechanisms and interactions at work at the heart of those systems, mostly through agent-based models, simulations and design patterns.
- Designing and developing artificial collective adaptive systems and different forms of emergent behaviour (e.g. swarm robotics, ecosystems of spatial services for smart cities, higher-order emergence)
- Verifying the reliability and trustworthiness of those systems prior to their deployment in real-life settings.

Since several years we also investigate: (1) semantic-based multi-agents systems for service composition; (2) semantic-based analysis of geo-spatial application data and interoperability issues; (3) artificial intelligence techniques for geo-spatial applications.

Recently we started new research aiming at developing innovative services in the academic field. We experiment various innovations leveraging students projects, set up an accelerator of science and services (LINK) to devise prototypes, as well as an R&D unit to continue the pipeline of innovation into proper industrialization of innovative services. We are pioneer in Switzerland in this field for the academic sector. We complete our hands-on experiments with building up of an academic community through workshops and hackathons.

http://unige.ch/cui/cas/

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Institute of Information Service Science

Digital Trust, from Decentralized Finance to Augmented Human & Metaverse

Director
Jean-Marc Seigneur
MER
H-index: 20

Domain activities

For ages, humans have used the human notion of trust as a means to cope with uncertainty, to engage in an action in spite of the risk of a harmful outcome. More recently, computational models of this human notion of trust have been researched in order to be able to use trust in the digital world as well, between computers and/or digital accounts controlled by remote humans, from direct observations to recommendations and online reputation. Technical decentralized trust solutions such as blockchains are revolutionizing many business domains from finance to supply chain certification. In the near future, it is even envisioned that humans and computers merge together, possibly creating a metaverse. We have contributed to this trend with the organization since 2010 of the augmented human international conferences focusing on scientific contributions towards augmenting or retrieving human capabilities through technology. We are researching how these augmented human technologies can improve computational trust assessment not only of machines but also of humans.

https://www.linkedin.com/in/jmseigneur/

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Institute of Information Service Science

Digital Rights & Policy

Domain activities

As our society and economy continues to move towards interwoven digital services and systems, blending the real and the artificial world, our research activities continue to investigate some of the complex challenges and issues towards a more sustainable and responsible digital society. Information Protection and Control (IPC) in general and the growing need for Data Protection have become recognized area where increased research is needed. We continue our work in those areas with a particular look at distributed ledger technologies (blockchain) as a mechanism to support new services and designs to support increasingly complex requirements. Major examples of these research issues we are currently working on include data marketplace ecosystems, dispute resolution and arbitration, data protection and digital rights and policy management.
From July 2016 to July 2017, Jean-Henry Morin is on sabbatical leave in South Korea where he is Invited Professor at Korea University Business School and Yonsei School of Business. During this time, he is also invited researcher at Fasoo.com where he investigates blockchain technologies in Information Security.

Director
Jean-Henry Morin
Associate professor

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ISS

Institute of Information Service Science

Digital Transformation

Director
Jolita Ralyté
MER
H-index: 22

Domain activities

Digital transformation is not just the adoption of new information technologies and the computerization of human activities. It embraces much broader strategic ambitions and involves fundamental changes in the activities, structure and even culture of the organization, with the primary goal of innovating and creating value. Service Science plays a driving role in digital transformation by providing key concepts, such as information service and service system, that facilitate business innovation through the integration of digital technologies. The approach for information service and system engineering must be necessarily exploratory, agile, and contributory, as the implementation of new services transforms the daily life of many people, and affects the organisation's activity and even its position in the ecosystem. Such transformation has to be understood, assessed and accepted by all parties. To be successful, it must be value-driven and ensure the involvement of all stakeholders by making them responsible co-creators. The transdisciplinary is another dimension to be considered in service co-creation as it allows to cross the borders of the conventional information system engineering and create new capabilities and new values. To make the approach holistic, we need to consider many other service-related aspects, such as ethics, accountability, compliance to the regulatory framework, and risks. The robustness and sustainability of services will depend not only on the quality but also on the situational-fitness of the approach. Indeed, the context and requirements of each organisation facing the digital transformation challenge is different, and therefore requires a situation-specific approach. We apply situational Method Engineering principles and techniques for developing our approach and defining contextual criteria for its configuration and application.

https://cui.unige.ch/~ralyte/
https://matis.unige.ch
https://www.linkedin.com/in/jolitaralyte/
https://scholar.google.ch/citations?hl=fr&user=g-eCFB4AAAAJ&view_op=list_works&sortby=pubdate
https://www.researchgate.net/profile/Jolita-Ralyte

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Information Security Group (I-SEC)

Director
Niels Alexander Nijdam
MER
H-index: 11

Domain activities

I-Sec aims to translate the complex nature of Cyber Security into an easily comprehensible way to understand, monitor and control the risks of employing current and future technologies. With a strong commitment to co-designed solutions with the end-users, we research new ways on how to expose and present the raised implications on privacy, risk, security and safety.

Applied research in the domains of:
- Internet of things
- Connected (autonomous) vehicles
- Smart Cities and infrastructure

With a strong focus on Cyber Security:
- Risk assessment
- Threat identification
- Anomaly detection
- Privacy preservation
- Usability in security and privacy
- Mitigation advisory

iss.unige.ch

ISS

Institute of Information Service Science

Knowledge Engineering

Domain activities

Knowledge Engineering @ ISS is a research laboratory of the Institute for Information Service Science (ISS) within the Center for Computing (CUI) at the University of Geneva. KE@ISS is conducting research on knowledge engineering: knowledge representation, knowledge-based information systems, and interfaces to access knowledge, with an emphasis on ontologies, semantic web, information extraction, and space-related applications.

The main results obtained in 2020 relate to:

- The contextualization of knowledge graphs: a model for representing context types in Wikidata ; many-sorted logic and algebraic specifications to express semantic rules ;
- Representing subsurface geospatial objects: integrating different types of geospatial models ; expressing completion and conformance rules for subsurface objects
- The development of a model for the adaptation of health-related applications based on user psychological profiles

Directors
Gilles Falquet
Associate professor
H-index: 18

Claudine Métral
MER

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Institute of Information Service Science

MIRALab

Domain activities

MIRALab was founded in 1989 by Professor Nadia Magnenat-Thalmann and has brought together PhD students and researchers from different fields, such as computer science, 3D graphics, 3D simulation, social robotics, 3D fashion design, and cognitive science. This truly interdisciplinary group continues to work in the field of cultural heritage , virtual worlds, and virtual humans.

Since 1992, MIRALab has participated into more than 50 European Projects and contributes to chair two International Conferences, CASA and CGI. In 2021, MIRALab was working mainly on the simulation of dancers and 3D, Cultural heritage.

http://www.miralab.ch/

Director
Nadia Magnenat-Thalmann
Honorary professor
H-index: 93

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CUI UNI GE

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Mobile Services

Domain activities

Mobile services and applications are today an indispensable part of our daily life. We are using our smartphones to access our mail, chat with friends and colleagues, take and store photographs and videos, obtain guidance and route information, play games, access the internet and even measure our daily activities and our physical performance and obtain highly personalized services and information. In other words, smartphones are today indispensable to all our daily activities. For the past few years we have been working in the development of mobile services and applications in different domains, including services for the elderly, services for civil engineers and security applications.
Since 2009 we have been applying the results of our research in the study and development of services for the aging society and for mobile services of elderly. In this context, in 2016 we have succeeded acquiring 4 European projects in the Ambient Assisted Living (AAL) program, 2 technology transfer projects (CTI), one FNRS project (memory condition of Eldrrly) and one H2020 (Security in IoT). Our work in the domain of ageing society concentrates in the study of lifestyle of senior persons (age 65 and more) and the creation of mobile services for monitoring the activities of the users and providing them proactive information regarding activities to do (realising the basic directive for senior persons : do not stay inactive), putting them in contact with other users with similar interests (socialisation), providing them the means for getting help from formal and informal care givers, and even advising them on diet and exercise. In this projects we collaborate with local (Geneva based) industrial partners that are offering services for seniors. The research results from the AAL and H2020 projects are then transfered, via the CTI technology transfer projects, towards commercial applications and services. Our research is carried out in four specialised Laboratories, the Conscious Analytics System Laboratory (CASlab), the Quality of Life Laboratory (QoL), the Travelling and Mobility Laboratory (TaM) and the Security Laboratory (SecLab).

Director
Dimitri Konstantas
Full professor
H-index: 31

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Quality of Life Technologies (QoL)

Domain activities

The QoL lab research interests revolve around the fundamental and algorithmic problems as well as human-centric challenges of the systems enabling an assessment and improvement of human behavior, well-being, health, and quality of life in the long term.

qol.unige.ch
https://**twitter**.com/katewac
https://www.**youtube**.com/channel/UCohpE4xXEDXLcoT_IIcl-7g
http://j.mp/**GoogleScholar**_Wac
http://www.**slideshare**.net/KatarzynaWac

Director
Katarzyna Wac
Full professor
H-index: 27

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Travelling and Mobility (TaM)

Domain activities

Welcome to TaM, the Travelling and Mobility R&D team from the University of Geneva. We are specialized on indoor positioning as well as on processing data coming from smartphone or wearable's sensors. Most of our innovative solutions are developed on Android phones. To understand the users' needs and deploy our solutions in the market, we benefit from strong links with industrial partners.
The TaM group is a member of the Institute of Services Science (ISS) and belongs to the Computer Science Centre (CUI, for Centre Universitaire d'Informatique) from the University of Geneva. Our team is today composed of PhD candidates, scientists and developers. Some of us are used to work in private companies. We have the know-how to cover the complete lifecycle of a R&D project, from its initial idea to a fully operational prototype. By using agile development methods, we combine the advantages of fast prototyping, early involvement of users, and high-quality products.

tam.unige.ch

Director
Michel Deriaz
MER
H-index: 13

latl.unige.ch

LATL

Laboratory for the Analysis and Technology of Language

Domain activities

LATL (http://www.latl.unige.ch) has been active in the field of natural language processing since the early 1990's. Its main research focus is the development of a multilingual syntactic parsing model (the Fips parser), as well as the development of large lexicons and dictionaries.

The Fips parser is currently available for several of the main European languages (English, French, German, Italian and Spanish), with several other languages at various stages of development (Romanian, Greek, Japanese). In 2021 the LATL continued the development of the parsers for the above languages. It is based on a grammatical model inspired by Chomsky's generative grammar and on an object-oriented design for its implementation. The parser and its rich lexical database (Figure 1) are used in a number of applications, including machine translation, terminology extraction, speech-to-speech translation, and computer-assisted language learning.

The LATL works on a project of digital edition of Ferdinand de Saussure's manuscripts in collaboration with the Knowledge Engineering group. In 2021 the LATL continued its effort on the automatic transcription of manuscripts. In this task the LATL benefited from two advanced computer science student labour force, under the form of Bachelor's research work. This work was done with the collaboration of the central computer sciences services of the University of Geneva, in the framework of the Digital Humanities portal project.

The LATL was also involved in many collaborations with various University of Geneva Faculties through advanced student's Information and Communication Technologies projects in collaboration with the Department of east Asian studies, the Department of linguistics and the University Geneva Hospital among others. These projects end with some remarkable results, e.g. a website for Chinese language learning, the Petit Prince website, the flashcard system for pronunciation learning of L2 languages, the HbVar project in collaboration with the HUG, etc (Figures 2 to 6).

Directors
Luka Nerima
Senior researcher

Eric Wehrli
Honorary professor
H-index: 24

mlg.unige.ch

MLG

Machine Learning Group

Domain activities

The Machine Learning Group of the computer science department investigates the development of novel machine learning methods with a particular interest for their algorithmic cost and sample efficiency.

Learning from data is a key element in modern techniques of artificial intelligence and has demonstrated remarkable performance for real-world tasks that require to deal with complex large dimension signals such as images.

The first downside of these methods is the requirement for very large training sets, recorded sensor data accompanied with a human-generated «ground truth» that specifies the ideal response an AI system should generate. Such ground truth is difficult to generate and often suffers from undesirable and problematic biases. The second downside of high-performance leaning-based AI methods is their computational requirements, that often translate to tens of thousands of computer hours, with the associated financial cost and environmental impact.

We aim at mitigating both to allow a wider use and lesser impact of AI.

Director
François Fleuret
Full professor
H-index: 43

PIG

Proteome Informatics Group

Director
Frédérique Lisacek
MER
H-index: 41

Domain activities

The Proteome Informatics Group (PIG) is involved in bioinformatics. Bioinformatics is a recently created discipline in which computer technology is applied to the understanding and effective use of biological data (see http://www.sib.swiss/bioinformatics-for-all/what-is-bioinformatics). At PIG, we concentrate on the study of proteins that are the active molecules of the cell. Extracting and studying proteins from a cell or a tissue requires the use of sophisticated experimental methods which generate large datasets. The analysis of this experimental data entails the identification and quantification of proteins, the determination of their cellular location, modifications, interactions and, ultimately, their function. This information is crucial to decipher cellular processes. This strongly motivates our group to develop software and databases that support data analysis and knowledge discovery in cooperation with Life scientists. These resources are made available through the ExPASy server (http://www.expasy.org). Our software tools mainly support experimental mass spectrometry data analysis, focused on the detection of post-translational modifications. Our databases store knowledge of carbohydrates (sugars) attached to proteins as well as protein-carbohydrate interactions.

In 2020, the group has been actively involved in collecting carbohydrate-related information describing the Sars-Cov-2 surface protein known as the main target of vaccines (spike protein). It provides a striking example of a phenomenon called the «sugar shield» which helps the virus escape the vigilance of the immune system. The figure below illustrates a 3D model of the bare protein on the left and the shielded protein on the right. Collected data on the sugar shield is made available to the scientific community through our resources.

http://www. sib.swiss/lisacek-frederique

unige.ch/sml

SML

Understanding solar and stellar flares with machine learning

Domain activities

Our group focuses on synergies between machine learning and astronomical research. Funded by a PRIMA grant from the SNSF, we investigate solar eruptions («flares») and how methods from computer science can help predicting and understanding them. Astronomy is a big-data domain: terabytes of data are taken every day, making it impossible to analyze all data manually. Our group develops sophisticated methods for statistical studies and applies them to solar data. In particular, we aim to answer the following research questions: When and where will the next flare occur? How is flare energy dissipated? What are the origins and mechanisms of stellar "superflares", which are thousands of times more powerful than the strongest recorded solar flares?

Director
Lucia Kleint
Professor

smv.unige.ch

SMV

Software Modeling and Verification

Director
Didier Buchs
Full professor
H-index: 20

Domain activities

Symbolic Model Checking was developed with the idea of verifying complex high level models with a reasonable amount of work for the user. In particular we propose to separate the model to the informations for performing eficiently model checking (clustering, anonymization, partial unfolding). The introduction of new kind of decision diagrams (∑ -DD) based on a generalization of the Shannon decomposition principles allow us to perform model checking for models with huge combinatorial explosion of states (around 10E4500 symbolic states). We are currently exploring the systematic use of rewriting of set of terms principles based on decision diagrams and operational control based on strategies as a metalevel in model checkers.

We currently develop several tools such as StrataGEM for the set rewriting principles, Stew as an abstraction over StrataGEM and Ardoises a meta-environment for managing formalisms and their veri cation tools. We also continue to organize a model checking contest in the conference Petri Nets in order to be able to compare existing model checkers on significant benchmarks. We also study programming language construction that check that the use of memory is alias safe. This language SafeScript is extending JavaScript in an elegant way. We also develop methods to adapt our formalisms (CREST) to the domain of modeling and verification of cyber-physical systems.

Several application domain have been covered by the team such as the development of a domain specific language for computing on sets (Trexmo Tool for the SECO). This language is applied successfully for expressing various models of toxicology analysis in the context of health in the workplace.

spc.unige.ch

SPC

Scientific and Parallel Computing

Domain activities

The Scientific and Parallel Computing laboratory (SPC, https://spc.unige.ch/en/), divided into two groups, dedicates its research to the fields of computational science and high performance computing, with a special focus on the study of complex systems and modelling approaches based on cellular automata, lattice Boltzmann, and multi-agent techniques. Massively parallel programs and algorithms are developed, capable to explain or reproduce natural phenomena with the help of computer simulations executed on CPU and GPU-based supercomputers. The SPC lab develops and maintains the open-source software Palabos (www.palabos.org), which is widely used and acknowledged by the simulation community and has been used as a tool for more than 300 publications by universities world-wide. Palabos is used as a tool to spread the research of the UNIGE internationally, establish collaborations, and assess the expert position of the UNIGE in the field of lattice Boltzmann modeling.

Directors

Bastien Chopard
Full professor
H-index: 46

Jonas Lätt
Professor
H-index: 22

tcs.unige.ch

TCS

Theoretical Computer Science

Director
José Rolim
Full professor
H-index: 25

Domain activities

Experimental driven research on Topology Control Protocols for Wireless Sensor Networks (WSN) using transmission power and throughput rate feedback schemes. The goals include link qualification in terms of symmetry and coherence and link quantification. Transmission power constitutes the link «generator» and throughput rate the link «regulator» to meet the qualitative and quantitative criteria for links between WSN nodes .

Research on designing a geographic routing algorithm for large scale networks, which is an extension to the Virtual Raw Anchor Coordinate localization based geographic routing. The goal is to perform routing in wireless ad-hoc network in a hierarchical manner, where in the top level routing is done between two geographic regions and in the bottom level performing routing to the exact node. A randomized protocol is designed and evaluated with simulations.

Design of a distributed publish/subscribe algorithm for an ubiquitous sensing scenario. We consider unstructured and free-geocoordinates sensing networks in which no network protocol is provided. Our solution, which avoids implying all the nodes of the network in the dissemination process, uses a distributed notification service defined by Directional Random Walks (DRW). A DRW is a probabilistic technique able to go forward into the network following a loop-free path. The principle assumed in our research is that two lines in a plane cross.

Also research on Future Networks, Internet of Things and Crowdsensing. Our efforts focus on problem modeling aspects and incentive formulation regarding the crowd participation in tasks that aim at optimizing spatial and temporal coverage issues.

Also, research on radiation aware wireless networking; studying the cumulative impact on ERM caused by multiple wireless sources in terms of numbers, topology, protocol, etc.

Thesis completed

Evangelia Baka

Doctor ès Sciences, mention Computer Science

9th June, 2022

Directors: Prof. Nadia Magnenat-Thalmann, Prof. José Rolim

A Multimodal Approach for Identification, Analysis, and Comparison of Human Emotional and Behavioral Patterns between Human – Human and Human – Technology Interaction

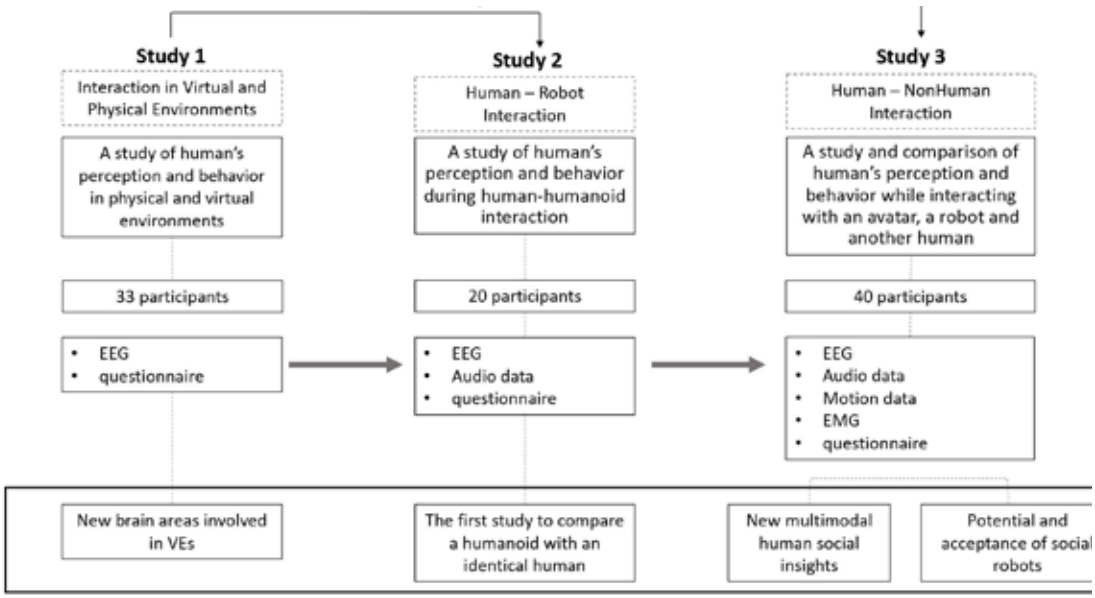
Our everyday life includes more than one social interaction, which are based mainly on human communication. The latter consists of human emotional and behavioral informations, expressed by voice, facial expressions or body movements. However, a social interaction is not limited between humans and thus, Human-Computer and Human-Robot Interactions (HRI) are meeting their golden point of research. The multidisciplinary area of computer graphics, neuroscience, psychology, and artificial intelligence is trying to explore, decipher, decode and model the human emotional behaviors and expressions to enhance the field of social interactions between humans and technology. Toward this direction, the goal of this research is to delve deeper into the features and the nature of Human –Human (H-H) and Human – NonHuman (H-NH) social interactions, providing a detailed validated assessment of how humans react towards technology but also how the latter affects humans.

In the first place, we examined the effect of the well-used virtual environments in the brain, identifying possible differences in perception between the virtual and the real world. An EEG device was used to capture participants' brain activity in different brain areas examining motor, cognitive and other function of the users and a questionnaire was used to evaluate psychological factors and the sense of presence. Our results enhanced the current literature by revealing new brain states involved in virtual environments, like frontal theta state and centra alpha state and they highlighted the importance of the graphics content revealing a difference in the occipital area.

The second part of our work is concentrated on the broad area of HRI, consisting of two different experiments. The first one concerned the identification of the effects human-humanoid interaction can have on human emotional states and behaviors, through a physical interaction with a robot, an identical human and a human. This research was supported by EEG and audio recordings as well as a questionnaire indicating that the human brain does understand visually and auditorily the difference between a robot and an identical human but the levels of concentration and motivation remain higher during HRI.

The second experiment led us to multidisciplinary in-depth documentation, analysis, and comparison between H-H and H-NH interactions recording brain activity, muscles activity, body movements, voice, and emotional states. A dataset was created with 40 participants interacting with three different agents (human, virtual human and a robot) under the same scenario. The robot was also tested under four different roles. Human emotional and behavioral patterns were extracted and compared, providing valuable insights regarding the role of robots and the effort for humanization. The role of physical presence was also assessed. Up-to-date researches show us that the need is focused on designing social agents in a more human-like way behaviorwise and not in terms of appearance and our study complemented the above concluding that it is the reactions of the agents that trigger the different human responses and not the appearance alone. Lastly, we developed a model that can recognize and classify the human voice based on the nature of the interlocutor with a score of 82%.

This thesis bridge the gap among studies that have examined the role of human – likeness in nonhuman agents, studies that have examined human-human interactions alone and the ones that have analyzed and compared human reactions during nonhuman social interactions. Further research with more extended studies is required to shed more light to this broad area of H-NH interaction, revealing human reactions that can guide the design of nonhuman agents, can elicit better cognitive and emotional responses and ensure a higher level of engagement, respecting the human needs.



Doctorat thesis: Univ. Genève, 2022 - Sc. 5660 - xxxx/xx/xx
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Anastasija Collen

Doctor ès Economy and Management, mention Information Systems

25nd April, 2022

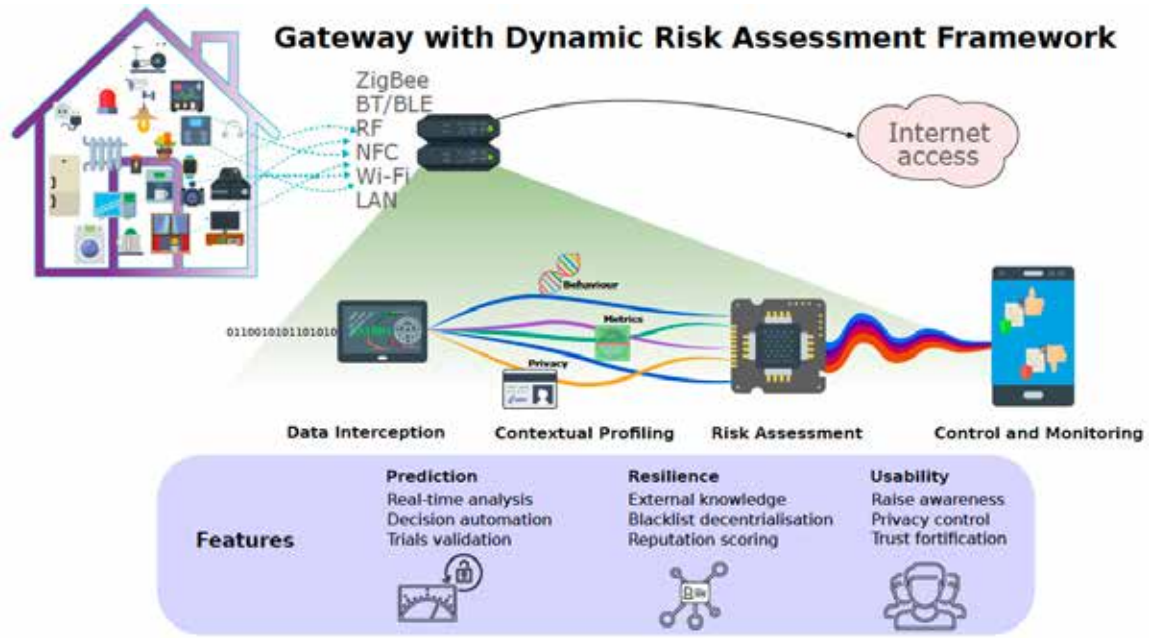
Directors: Dr. Niels Nijdam, Prof. Dimitri Konstantas

Automated Risk Assessment for Cyber Threats Identification in IoT Environments

Internet of Things (IoT) enabled systems are steadily expanding their presence in all facets of industry and consumer lives. They enable regular citizens, consumers and manufacturers to easily interact with the digital world. A plethora of composing IoT objects is gradually employed in almost every domain. As their normal operation is becoming critical for society, abnormal behaviour of such system's composing elements poses significant implications – cyber risks – for their end-users, related to financial loss, privacy violation, critical services' outage or even human lives endangering. This is where a well established field of the Risk Assessment (RA) becomes indispensable. It studies various aspects of the identification of hazards and threats, analysis of their causes and consequences, and representation of the corresponding risks for further decision-making based on derived probabilities of encountered uncertainties. RA in Information Security shares a common notion of a future prediction, necessary to be equipped with, to understand the risk in a given situation. While traditionally performed in a static way, where analysis operates on historical and snapshot data of today, it is widely accepted that the future of RA relies on the Dynamic Risk Assessment (DRA) with conditions monitoring.

In this work, a complete framework on the DRA is applied to one of the most prominent examples of conjunction of physical and digital worlds – smarthomes. Stipulated by the studies on the challenges associated with the mobile properties of the IoT objects, we have conceptualised the representation of the generic object model – IoT Stack – and applied it to the DRA. On this side, our work began with the definition of the theoretical foundation for the establishment of the RA and its application in IoT environments through the evolution of the reference architecture from conceptualisation to deployment in real settings. Governed by the constantly evolving user and functional requirements, we have designed a complete workflow from data capture and network analysis to anomaly detection and operational DRA. It was further extended with the usability focused visualisation of the user interfaces for control and monitoring to support the decision-making process. Constant evolution of those requirements also shaped the input and output interfacing of the DRA, shifting the initial focus of behaviour comparison to anomaly processing integration into the RA process. We have integrated support of the real-time adjustment of the deployment infrastructure for a stronger system-level resilience. Finally, this work explored the possibilities to eliminate human interference in the RA process, aiming to develop a high level of automation for the decision-making to mitigate the confronted risks.

Bound by operating in the IoT environment, we faced the associated constraints and limitations on hardware and software level of the IoT objects. Automation, not always being possible or even desirable by lay users due to their risk perception, proved to be of crucial importance in the decision-making process. The DRA framework provides the tools for understanding, monitoring and addressing the risks encountered in the digital arena of our lives.



Doctorat thesis: Univ. Genève, 2022 - GSEM 107 - 2022/05/13
https://archive-ouverte.unige.ch/unige:161003

Raphaël Conradin

Doctor ès Sciences, mention Interdisciplinary

7th September, 2022

Directors: Prof. Bastien Chopard,
Prof. Jonas Latt,
Prof. Jean-Pierre Wolf

Cell-based simulation of tissue morphogenesis

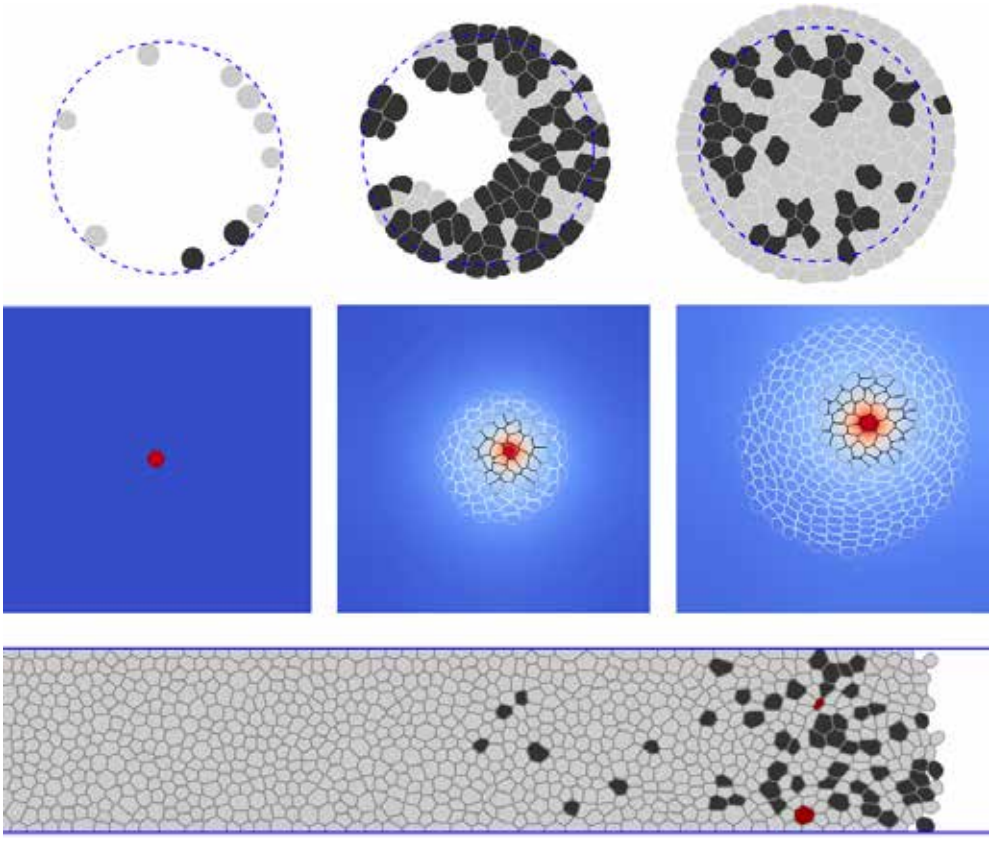
Numerical simulations have become essential in many fields to understand and solve complex problems, for example, in biology, where experiments can be long and complex to set up. Once set up, a numerical model allows to quickly test many parameters or hypotheses while having a controlled and reproducible environment. Moreover, a numerical simulation can give access to data that would otherwise be complicated to obtain because the measurement is complex or available resources are limited. In the case we are interested in, the morphogenesis of biological tissues, one of the complexities comes from the fact that many biochemical and mechanical mechanisms are involved in the process. Nevertheless, to be helpful, a numerical model must be tested and validated beforehand.

This thesis presents the model we have developed for 2D cell simulations. Unlike other types of cell models, such as «vertex models», it uses a detailed description of the cell membrane discretized into a hundred points. They follow Newtonian dynamics, with a membrane force accounting for cell deformation, an internal pressure force replacing the cell's internal structure, and adhesion and contract pressure forces between the cells. Thus only the cell's membrane is modeled but not the cell's internal structures, simplifying the model description. Biological processes are either dependent on the simulated experiment, such as the cell cycle, or fixed by the model, like the cell state evolution. The latter uses the internal pressure variation by changing the cell mass to simulate a growth or apoptosis state. Since the cell cycle may depend on the diffusion of chemical species, the cell model can be coupled to a Lattice Boltzmann Method (LBM) model simulating this diffusion.

This model has been implemented in C++ based on the Palabos library [67], especially for managing parallelism and LBM simulations. Parallelism in Palabos is done according to a spatial domain division, so the model's different mechanisms have been implemented to be spatially parallelized. Nevertheless, the parallelization efficiency depends strongly on the simulation's spatial distribution of the cells. When the distribution is homogeneous, the parallelization works rather well. On the contrary, the inhomogeneous cell distribution of the threads does not have a very interesting speedup.

Biological validation of the model was performed in two steps; first, the single-cell properties, then the cell distribution in growing tissue. The viscoelastic-incompressible properties of a single cell were well recovered, and the neighbors' number distribution was similar to data from biological experiments.

The model was then used to reproduce two recent biological experiments, one by Di Meglio et al. [26], the other by Gauquelin et al. [36]. The first studied the impact of the pressure exerted on the cells on their proliferation, showing that there is a maximum pressure at which cell proliferation stops abruptly. The simulations reproduce well experiment behavior using a pressure-based cell cycle. Furthermore, by testing different functions for the relationship with pressure, we find that a linear function shows the closest results to the experimental results. The second explored the tissue displacement inside a strip by comparing experiments with normal cell proliferation and blocked cell mitosis. It showed the same velocity for the cell front in both cases but a difference in the velocity profile within the strip. By adding a simple model for cell motility and the ability of cells to undergo apoptosis, the simulations captured the change in profile structure. However, they failed to recover a comparable front velocity. The latter was most likely due to the used cell motility model, which must be too simple.



Doctorat thesis: Univ. Genève, 2022 - Sc. 5677 - 2022/09/20
https://archive-ouverte.unige.ch/unige:166037

Jörn Erbguth

Doctor ès Social Sciences, mention Information Systems

21th February, 2022

Director: Prof. Jean-Henry Morin

A Framework for Long-Term Revocable Credentials

Long-term credentials like academic titles are increasingly being used in a digital format. Often, paper diplomas, secured by special paper and seals are used as unsecured scans when communicating online. However, forging unsecured scans of paper diplomas is easy and an increasing problem. A range of different approaches are being discussed in scientific literature and are also partially available on the market. These approaches to secure long-term credentials by cryptographic means offer different strengths and weaknesses regarding a range of requirements like authenticity and usability.

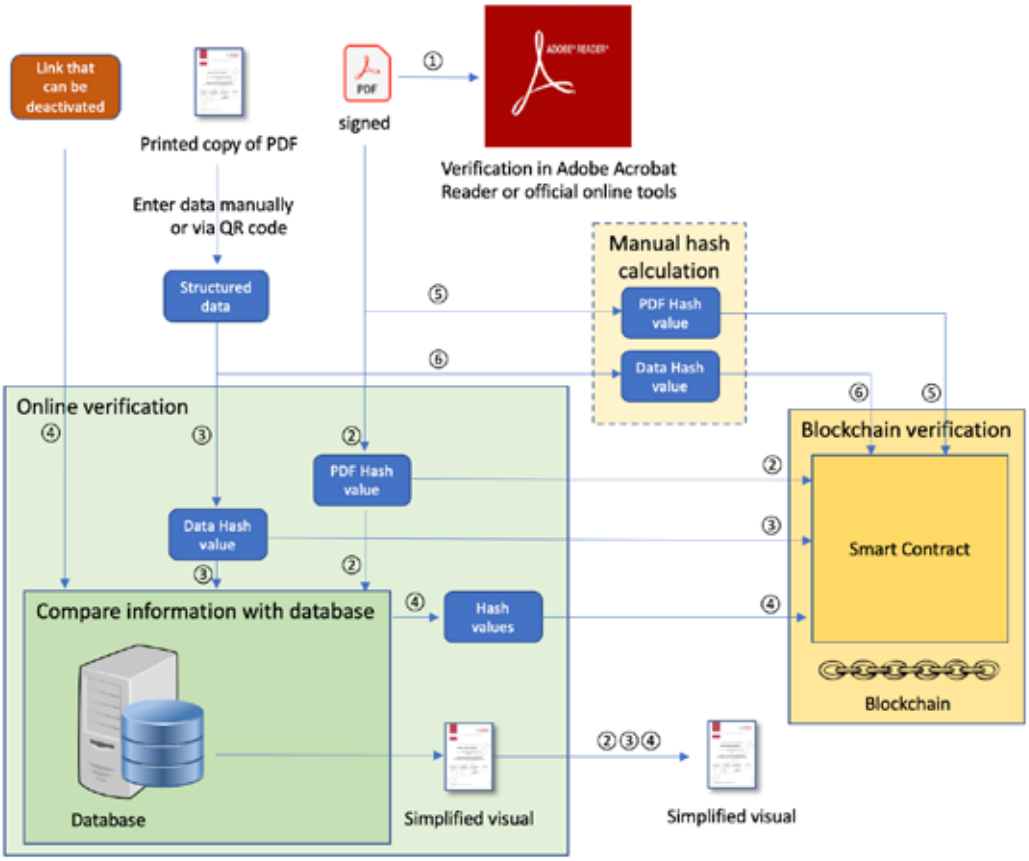
However, revocable long-term credentials like university diplomas face a specific challenge: Credentials remain valid even when the institution ceases to exist. Therefore, credentials need to be verifiable even when the institution no longer exists, but they also need to be revocable by the issuing institution in case of error or plagiarism. At the same time, data protection laws provide the credential holders with the right to be forgotten. How can a credential be verifiable independently from the institution and at the same time revocable? How can it be ensured that the revocation notice cannot get lost when the institution might cease to exist? At the same time, access to the credential and possibly its revocation notice needs to be limited.

In the first part, this thesis evaluates existing open and proprietary approaches ranging from qualified electronic signatures and e-apostilles to verified credentials for self-sovereign identities.

The second part discusses and defines a set of requirements for a framework to support revocable long-term credentials. A design proposes a framework based on a combination of qualified electronic seals, a smart contract on a blockchain and an online server. A prototype is being built according to that specification. Finally, the chosen approach is evaluated by presenting and discussing it at several conferences at government hearings, standards organizations, and academic institutions. A range of questions occurred in that context and are discussed in the third part of this study.

It is concluded that decentralized ledger technology can be a useful tool to verify long-term credentials that remain valid even when the issuing institution does not exist anymore. Determining who should have access to the revocation information depends on the specific use-case and the retroactive effect of revocations. The legitimate interest of those who should be informed about a revocation needs to be balanced with the right to be forgotten by the credential holder of the revoked credential that is no longer used. Smart contracts on a blockchain can model a good balance here, provide the revocation information where justified and hide it in other cases. Self-sovereign identity (SSI) could – in theory – support some rights of the credential holder further. A credential holder could prove a credential without disclosing her name, for example. However, SSI wallets have less usability and are not widely used yet. Particularly they do not yet ensure reliable identification of the credential holder without the disclosure of the name of the credential holder.

The proposed solution is an open solution that can be adopted by many issuing institutions by sharing a smart contract and can provide the possibility of cross-verification of credentials with a minimal decentralized governance structure as being found, for example, at the Bloxberg academic blockchain.



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Jonathan Lemus

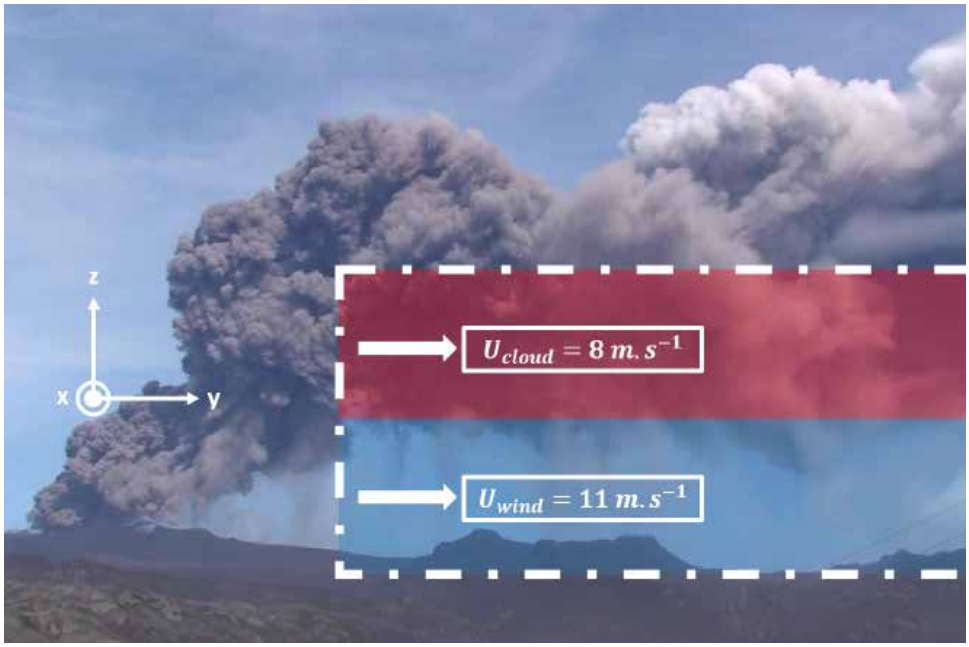
Doctor ès Sciences, mention Earth Sciences

26th April, 2022

Director: Prof. Constanza Bonadonna

Modelling Settling-Driven Gravitational Instabilities at the Base of Volcanic Clouds

Explosive volcanic eruptions inject large quantities of magma fragments (tephra) into the atmosphere. Dispersion and sedimentation of tephra particles can cause significant impact such as damage to infrastructure, pollution of the ecosystem and paralysis of economic and transport sectors. Recent eruptions (e.g., 2010 Eyjaf-jallajökull, Iceland; 2021 Cumbre Vieja, Spain) have shown that even moderate events can significantly impact our society. Also, significant effort has been involved to improve Volcanic Ash Transport and Dispersal Models (VATDMs) used for the forecasting necessary to emergency management during volcanic crises.
Field observations and laboratory experiments have shown that tephra sedimen-tation can be significantly affected by collective settling mechanisms that promote premature ash deposition (i.e., deposition of particles < 2 mm). This has important implications for dispersal and associated impacts. Indeed, the amount of ash in the atmosphere may be overestimated by VATDMs that do not take in account the pro-cesses that promote premature sedimentation. These mechanisms include particle aggregation and settling-driven gravitational instabilities (SDGIs) taking the form of downward moving ash fingers. Volcanic ash aggregation has been documented over the past decades while SDGIs remain poorly described as well as the combi-nation of both processes. The main objectives of this thesis include to: i) develop an accurate numerical model able to simulate the dynamics of SDGIs; ii) use this model alongside field and experimental studies in order to constrain the parame-ters controlling the formation of SDGIs; and iii) combine the modelling of both ash aggregation and SDGIs to better interpret their associated roles in premature ash sedimentation.



First, a single-phase model has been developed using a novel approach involving a Lattice Boltzmann model in order to solve the fluid motion, while a Weighted Essentially Non Oscillatory (WENO) finite difference scheme is employed to solve the particle transport. The model is then validated thanks to comparison with ex periments and theoretical works. Second, the model is applied to experimental and natural configurations in order to study the effect of controlling parameters such as the particle concentration and size. I found that increasing the particle concentra-tion enhances the development of SDGIs while increasing the particle size beyond a threshold prohibits the formation of fingers. The study also revealed that the critical Grashof number usually used to characterise such instabilities is about ten times larger than the value suggested by previous studies. The addition of shear has also confirmed that SDGIs are able to produce similar ground signature as ash aggregation. Third, a numerical scheme has been integrated in order to include the aggregation process, the goal being the study of possible effects of aggregation on SDGIs. Simulations showed that aggregation enhances all the sedimentation modes including individual settling and SDGIs. Conversely, the turbulence gener-ated within SDGIs can also promote ash aggregation. Finally, a two-phase model has also been developed. This model solves the motion of individual particles but, given the numerical cost, the use of this model is limited to the study of small scale processes involving only a reasonable number of particles.
My numerical investigations have demonstrated that the triggering of SDGIs at the base of volcanic clouds is controlled by several parameters such as the particle concentration, the particle size and the shear induced by the wind. Volcanic ash aggregation and SDGIs present the same ground signature and the two processes enhance each other. However, further work is needed regarding the effect of turbu-lence, the analytical scaling of the fingers vertical velocity and the development of a comprehensive parametrisation of SDGIs to model the loss of fine ash in the cloud due to SDGIs.

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Julien Mariethoz

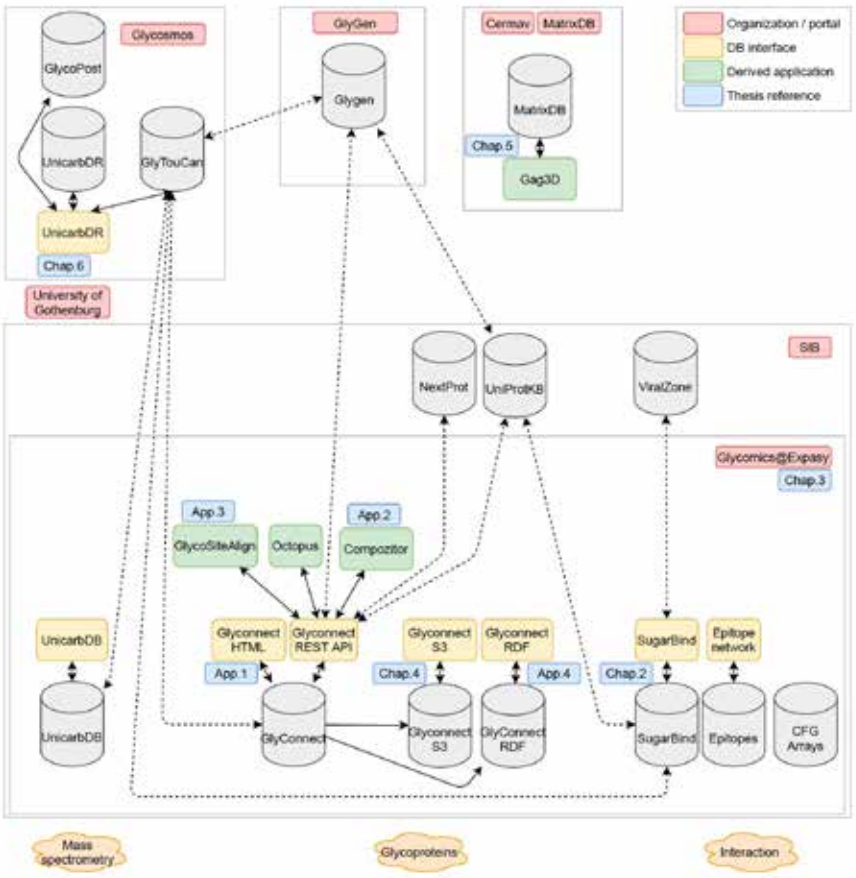
Doctor ès Sciences, mention Bioinformatics

4th March, 2022

Director: Prof. Frédérique Lisacek

Heterogeneous Data Processing for Information and Knowledge Management in Glycomics and Glycoproteomics

Glycans or carbohydrates represent a major class of biomolecules. They are also the observable result of the most common Post-Translational Modification, known to play a crucial role in the host-pathogen interactions as well as in signaling processes or disease states, among others.
Glycoinformatics is the dedicated bioinformatics field supporting glycobiology and its experimental parts, including glycomics and glycoproteomics and any other glycan-oriented studies. The generated data and resulting information drive the disci-pline.
Glycans molecules have tree structures with a characterized topology. This struc-tural complexity induces glycoinformatics problems relative to their representation, encoding formats, processing, and interpretation. Furthermore, the lack of consen-sus in this respect significantly limits reproducibility and comparability in glyco-biology. We suggest that common descriptions, application guidelines, and best practices are solutions to overcome these issues.
Over the recent years, Findability, Accessibility, Interoperability, and Reusability (FAIR) principles and minimum information required for a glycomics experiment (MIRAGE) initiatives have driven and ruled data standardization processes. Sub-sequently, adopting these principles and guidelines improves reproducibility, inter-operability, and data reuse, increasing its value.
Based on published articles, this thesis globally covers different specificities of gly-cans, their representation, and current field knowledge, where a common approach is needed.
Several glycoinformatics resources are presented. SugarBindDB provides a glycan functional viewpoint. It is a curated database storing information extracted from the scientific literature on host-pathogen interaction through the pathogen glycan-binding protein.
Glycomics@Expasy is the global initiative on covering glycoinformatics resources at SIB. It includes databases and software tools integrated as a platform on various structural and functional topics such as interaction, glycosylation, and experimental measurements.
Information and knowledge representation issues were further explored in two data modeling approaches. First, as graph database technologies are fit for knowledge representation of the glycan structural properties, Neo4j and RDF were short-listed and evaluated for that purpose. Second, glycosaminoglycans (GAGs), a distinct class of linear glycans with a minimal set of building units, have provided another testing ground for mapping diversity. The vast variety of GAG molecules results from multiple sulfation patterns or variable numbers of repeated units. A pipeline converts the GlycoCT text-based representation of the GAG structure to a three-dimensional representation using knowledge on low energy conformation.
Finally, Unicarb-DR is a repository initiative on storing experimental results simi-larly to Unicarb-DB, a curated glycan MS database also hosted at SIB. Experimen-talists can submit their pre-publication experimental result information based on templates and ensure MIRAGE compliance. This process enforces an early adop-tion of guidelines, eases the later curation process, and increases the reliability, reproducibility, and overall data value.
With high-throughput experiments in glycomics and glycoproteomics, glycoinfor-matics is entering into a big-data era where formal and standard data representa-tion are essential to build new knowledge and move towards prediction.



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Francesco Marson

Doctor ès Sciences, mention Computer Science

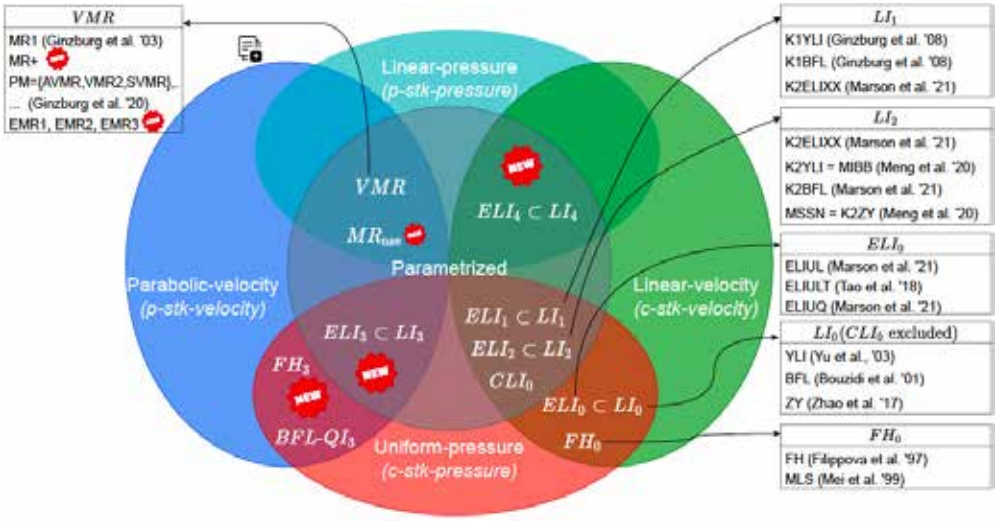
31th January, 2022

Directors: Prof. Bastien Chopard
Prof. Jonas Latt

Directional lattice Boltzmann boundary conditions

The main goal of the thesis is the proposition of highly accurate curved boundary conditions aiming to reduce the need for grid refinement or non-Cartesian grids mean-while maintaining highly favorable characteristics for massive parallel deployments on CPU or GPU systems. This proposition is the nonunique outcome of a broad work of analysis, unification, and improvement of the directional boundary conditions of the lattice Boltzmann method (LBM).

Directional or link-wise boundary conditions (DBC) constitute one of the three principal families of boundary conditions that have the characteristic of applying in-dependently along with the different lattice directions. The others are, namely, the node-based and the immersed boundaries. The present dissertation will demonstrate how to describe the DBC family as a unified method, reducing, in this way, the confu-sion among the zoo of possible schemes for the LBM. Also, it will show how this group can be tuned to produce local single-node methods with parabolic exactness, previ-ously an exclusive feature of advanced multi-reflections schemes that require access to information in multiple nodes to operate. The other families generally need access to information outside the boundary nodes, still leading to non-parabolic exactness (with few specific exceptions).



Three decades after its birth, the LBM has proven to be a robust numerical ap-proach. It is currently a widespread tool, not only in the academic context but also in industrial applications. Its regular Cartesian computational grid is equally one of its main assets and one of its main limitations. On the one hand, it guarantees a simple implementation and effective domain decomposition for parallel computing. On the other hand, it limits its geometrical flexibility and accuracy when dealing with com-plex geometries. Therefore, the challenge is to increase the LBM geometrical flexibility without affecting its overall accuracy and its excellent amenability to parallel comput-ing. To meet this hurdle beyond the techniques available in the literature, we followed three policies: increase accuracy, reduce communication, and preserve simplicity and uniformity.

The first matter comprises three distinct subtopics: convergence order, accuracy at under-resolved scales, and parametrization. An efficacious curved boundary condition firstly preserves the order of convergence of the bulk to avoid costly grid-refinement procedures before their time: one should avoid using first-order methods. Additionally, it should provide high accuracy at the coarsest scales. It means securing the same level of exactness of the LBM bulk, also in the boundaries. If, for example, the bulk can exactly reproduce at steady-state a linear velocity profile, the boundary condition must not spoil this characteristic. Finally, a desirable characteristic is a parametric behavior. Roughly speaking, considering the steady-state solution, the accuracy should only depend on the spatial resolution and the non-dimensional number characterizing the flow.

The second policy concerns maintaining the parallel performances of LBM. If a boundary condition is accurate, it is often at the cost of nonlocal computations that spoil the favorable compute to communication ratio of the LBM. Then, it is desirable to construct boundary schemes that can be applied locally in a single node without accessing further information outside the time step and boundary node where they act. It is an infrequent characteristic; for example, immersed boundary methods need large kernels, and node-oriented methods based on macroscopic interpolation (through multiscale expansions) are also nonlocal.

The third twofold theme is the simplicity and uniformity of the boundary scheme. The first aspect relates to preserving the user-friendliness of the numerical method. The second regards the suitability of the boundary schemes to the single-thread-multiple-data GPU paradigm. Furthermore, simplicity and uniformity facilitate the load balancing procedure in parallel computing systems.

To summarize, following our main three goals, we propose a novel family of directional boundaries, named ELI (for Enhanced Local Interpolation, or Enhanced LInear scheme), and a set of new corrections to DBC. These corrections grant advanced accu-racy, especially in low Reynolds number flows (a common condition in the proximity of boundaries). The development followed two successive steps. In the first one, a generalized geometric understanding of the interpolated "bounce-back" rule allowed the discovery of ELI, a family of schemes that use ghost populations located on the wall. In the second, the numerical analysis of all existing directional schemes unveiled the standardized ELI formulation leading to a generic class that encloses all existing DBC into a unique expression supported by new accuracy improvements. In detail, one of the newly introduced corrections provides parabolic accuracy to many families of DBC: it allows for exact modeling of a Stokes Poiseuille flow in an arbitrary inclined channel. Theoretical analysis and numerical investigations in elementary and complex flows support these assertions. Therefore, the ELI schemes in their improved and cor-rected version can sometimes be a cheaper alternative to the more expensive grid refinement or body-fitted meshes approaches. Further, they are local both from the algorithmic and the physical viewpoint: they do not need to recover information out-side the boundary node and can model narrow gaps where only a single computational node is present.

To conclude, we expect that the newly proposed schemes will provide a valuable tool to improve accuracy and scalability, especially in large-scale biological simulations, the main inspiration for this research.

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Behrooz Razeghi

Doctor ès Sciences, mention Computer Science

23nd November, 2022

Director: Prof. Svyatoslav Voloshynovskiy

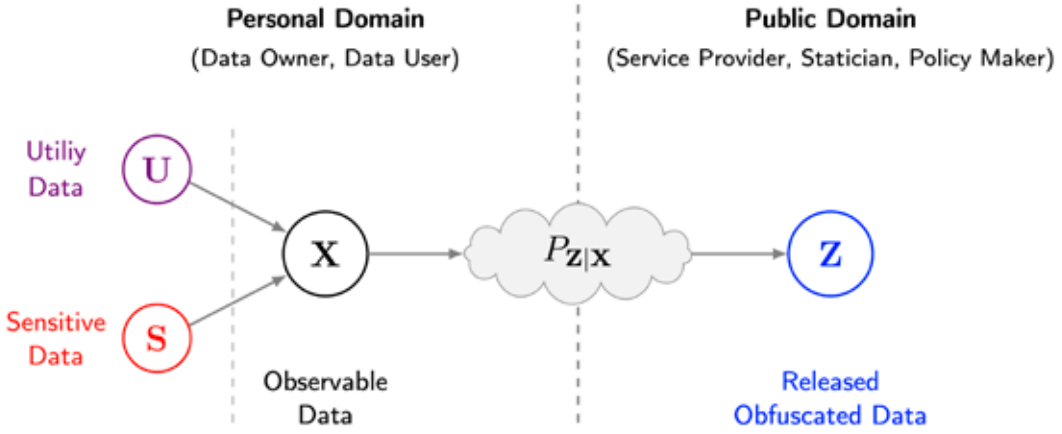
Bottlenecks CLUB: Unifying Information-Theoretic Trade-offs Among Complexity, Leakage, and Utility

Bottleneck problems are an important class of optimization problems that have recently gained increasing attention in the domain of machine learning and information theory. They are widely used in generative models, fair machine learning algorithms, design of privacy-assuring mechanisms, and appear as information-theoretic performance bounds in various multi-user communication problems. In this dissertation, we propose a general family of optimization problems, termed as complexity-leakage-utility bottleneck (CLUB) model, which (i) provides a unified theoretical framework that generalizes most of the state-of-the-art literature for the information-theoretic privacy models, (ii) establishes a new interpretation of the popular generative and discriminative models, (iii) constructs new insights to the generative compression models, and (iv) can be used in the fair generative models.

We first formulate the CLUB model as a complexity-constrained privacy-utility optimization problem. We then connect it with the closely related bottleneck problems, namely information bottleneck (IB), privacy funnel (PF), deterministic IB (DIB), conditional entropy bottleneck (CEB), and conditional PF (CPF). We show that the CLUB model generalizes all these problems as well as most other information-theoretic privacy models. Then, we construct the deep variational CLUB (DVCLUB) models by employing neural networks to parameterize variational approximations of the associated information quantities. Building upon these information quantities, we present unified objectives of the supervised and unsupervised DVCLUB models. Leveraging the DVCLUB model in an unsupervised setup, we then connect it with state-of-the-art generative models, such as variational auto-encoders (VAEs), generative adversarial networks (GANs), as well as the Wasserstein GAN (WGAN), Wasserstein auto-encoder (WAE), and adversarial auto-encoder (AAE) models through the optimal transport (OT) problem. We then show that the DVCLUB model can also be used in fair representation learning problems, where the goal is to mitigate the undesired bias during the training phase of a machine learning model. We conduct extensive quantitative experiments on colored-MNIST and CelebA datasets, with a public implementation available, to evaluate and analyze the CLUB model.

Focusing on the finite alphabets and considering local information geometry analysis, we develop the notion of perfect obfuscation based on $\chi 2$-divergence and Kullback–Leibler (KL) divergence in the Euclidean information space. Under this analysis, we establish the necessary and sufficient condition to obtain representation Z of the original data X that maximizes the mutual information between utility attribute U and released representation Z, while simultaneously revealing no information about sensitive attribute S. We decompose statistical dependence between random variables U, S, X and Z by decomposing the corresponding mutual information I(X; Z), I(U; Z), and I(S; Z) into orthogonal modes.

We also propose a new computationally efficient privacy-assuring mechanism, namely Sparse Coding with Ambiguation (SCA), and address various characterizations and applications for our model. The SCA is a generalization of randomization techniques that integrates 'sparse lossy coding' with 'ambiguization'. The idea of ambiguation is to add (pseudo) random noise to the orthogonal complement, i.e., non-informative components of the sparse code.



Using the SCA mechanism we introduce two practical identification frameworks. We then propose a practical framework to address the problem of privacy-aware image sharing in large-scale setups. We, therefore, encode images, such that, on one hand, representations are stored in the public domain without paying the huge cost of privacy protection, but ambiguated and hence leaking no discernible content from the images, unless a combinatorially-expensive guessing mechanism is available for the attacker. On the other hand, authorized users are provided with very compact keys that can easily be kept secure. This can be used to disambiguate and reconstruct faithfully the corresponding access-granted images. We achieve this with a convolutional autoencoder of our design, where feature maps are passed independently through sparsifying transformations, pro- viding multiple compact codes, each responsible for reconstructing different attributes of the image. The framework is tested on a large-scale database of images with a public implementation available.

Doctorat thesis: Univ. Genève, 2022 - Sc. xxxx - xxxx/xx/xx

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Shideh Rezaeifar

Doctor ès Sciences, mention Computer Science

10th October, 2022

Director: Prof. Svyatoslav Voloshynovskiy

Variational methods in privacy protection and offline reinforcement learning

This thesis considers variational methods in privacy protection and reinforcement learn-ing. In recent years, companies have relied more on MLaaS (Machine Learning as a Service) providers with a wide range of services, from data storage to model deployment and evaluation. Nevertheless, using such services requires sharing vast amounts of data with the third-party provider, which raises many privacy concerns. In this thesis, the main focus is on a classification task where the users send their original data or feature representation of their data to a service provider.

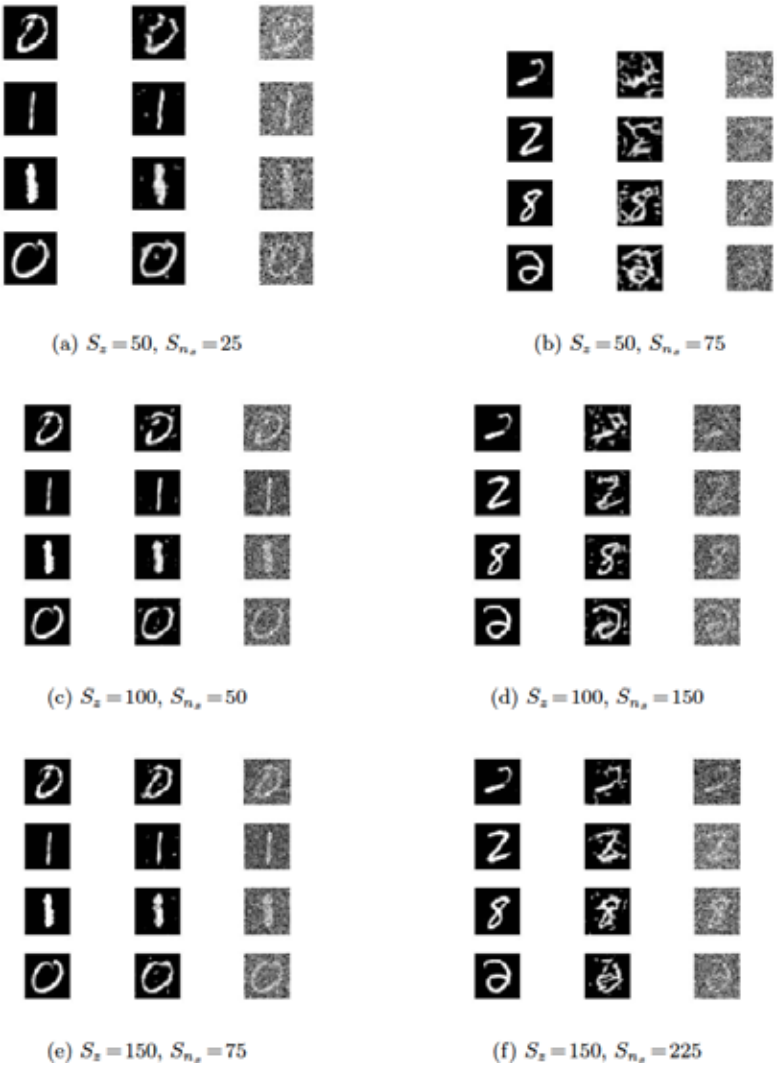
Basic notations regarding privacy concerns in MLaaS are first presented. Then, we review the main ideas and attempts from the literature in the defense against privacy attacks. This overview allows us to formulate our primary problem in a broad spectrum of privacy concerns in an MLaaS framework. This thesis focuses on the privacy of users' data during the training phase.

First, a highly distributed setting with minimal privacy leakage is considered. In such a distributed scheme, each user trains its own model locally on its private data and only shares the trained model outputs with the server. By keeping both the model and data locally, the risk of privacy leakage is highly minimized. It is also assumed that each user has one class's data as an extreme case of non-IID data. Our main intuition is to exploit the benefits of deep generative models in learning a class-specific manifold representation. We propose two schemes based on variational autoencoder (VAE) and bounded information bottleneck autoencoder (BIB-AE). We show that both models are successful in the distributed setting, considering that each user only has access to its own data.

The privacy leakage is minimized in the distributed setting as the users' data are kept locally and private. However, we notice the limitation of distributed frameworks in achieving high classification performance as an extreme case of utility-privacy trade-off. Other than that, the assumption of having samples of only one class per user might not hold. Therefore, an essential step is to relax these assumptions and consider a general case where users share protected representations of their original data with the central service provider. To better understand the privacy vulnerabilities of such a setting, we impose the following research question: How reliably can an adversary reconstruct or identify attributes of original data while having access to only the protected templates?To answer this research question, we consider an obfuscation technique based on sparse ternary codes with ambiguization (STCA) with a fixed or learned encoder. We analyze the privacy vulnerabilities of this defense strategy against deep reconstruction attacks. Our results highlight the weakness of this defense strategy and impose the following research question: How can we develop a more carefully designed obfuscation scheme for better protection against deep reconstruction attacks?

Therefore, we introduce a new framework based on contrastive learning to defend against reconstruction and attribute inference attacks. For defense against the reconstruction attack, we directly minimize the correlation of encoded features with the original data. Furthermore, training an encoder with the supervised contrastive loss removes redundant information about the original image; thereby, a better utility-privacy trade-off can be achieved. In the attribute inference attack, we proposed an encoder trained with the supervised and private contrastive loss. Meanwhile, an obfuscator module is trained in an adversarial manner to preserve the privacy of private attributes while maintaining a high classification performance.

Finally, we consider an application of decentralized classification based on variational autoencoders in the context of offline reinforcement learning. First, the distribution mismatch issue in offline reinforcement learning is addressed where an agent erroneously overestimates out-of-distribution actions. Then, we develop an anti-exploration bonus based on a variational autoencoder to restrict the agent. Finally, we show the effective-ness of the proposed method in guiding the agent in an offline setting.



(a) $S_z = 50$, $S_{n_z} = 25$ (b) $S_z = 50$, $S_{n_z} = 75$

(c) $S_z = 100$, $S_{n_z} = 50$ (d) $S_z = 100$, $S_{n_z} = 150$

(e) $S_z = 150$, $S_{n_z} = 75$ (f) $S_z = 150$, $S_{n_z} = 225$

Doctorat thesis: Univ. Genève, 2022 - Sc. 5684 - 2022/10/10
https://archive-ouverte.unige.ch/unige:168739

Arbër Salihi

Doctor ès Social Sciences, mention Information Systems

6th April, 2022

Director: Prof. Jean-Henry Morin

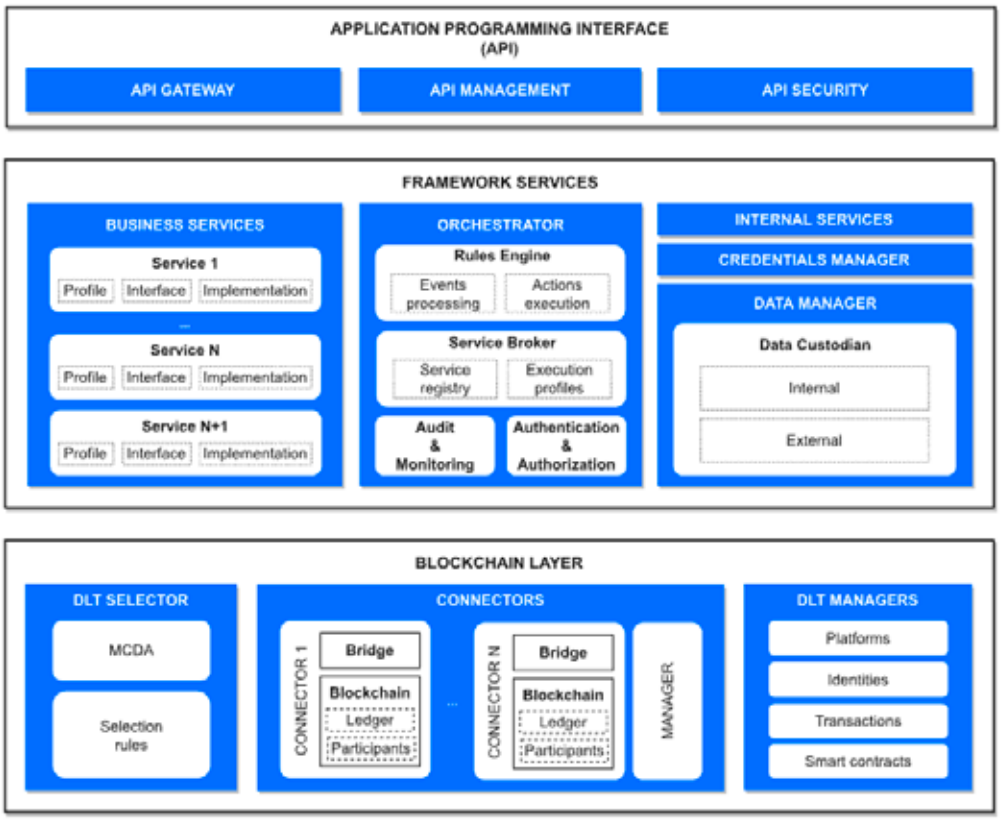
Abstracting Distributed Ledger Technology (DLT): A Service based Framework enabling Distributed Trust Application Design and Integration

While trust plays a fundamental role in the stability of our economy and society, it has been under heavy pressure over the past few decades. Distributed ledger technology is an emerging protocol-based socio-technical paradigm enabling decentralized trust among a network of participants. By challenging the traditional approaches based on trusted third parties, distributed ledger technology holds the potential of a drastic change in many areas where trust needs to be informed rather than blindly accepted. However, as with many emerging technologies, limitations and problems limit its broad adoption.

Research and industry initiatives address several of these issues, but often with varying objectives. In this context, the problem of abstracting distributed ledger technology represents today a major challenge that should be addressed in priority. The inherent complexity of the technology related to its underlying components, combined with the proliferation of heterogeneous platforms, lies at the heart of this research. In practice, this complexity results in increased difficulty for users to understand the constituents of the technology, reduced interoperability with existing information systems, high maintenance costs and, more generally, in an increase in business and technical risks associated with the use of blockchain platforms. Ultimately, these problems represent a real technology rejection risk in the long run.

This dissertation addresses the question of abstracting the technical complexity and platform heterogeneity of distributed ledger technology to enable better design and integration of applications based on distributed trust. Three particular aspects are considered. First, what are the key elements of distributed ledger technology that should be part of a generic abstraction. Second, assuming such an abstraction, what challenges and requirements must be met to reduce complexity and strengthen technology adoption. Finally, how does a service-oriented approach to a blockchain based framework enable better integration in organizations and in enterprise information systems in particular.

The design of a framework is proposed in the form of a service-oriented architecture coupled with an abstraction and complexity reduction layer dedicated to distributed ledger technology. In order to demonstrate the approach of the proposed conceptual model and the designed framework, a prototype is provided as a reference implementation. It is instantiated in the context of audit and control professions within a research project funded by the Swiss National Science Foundation. Ultimately, this work is part of an effort to help stabilize and sustain distributed ledger technology towards broader adoption in organizations and in particular within enterprise information systems. Finally, technology agnostic, distributed trust blockchain based business process reengineering represents a promising opportunity to be further investigated and confirmed based on this framework.



Doctorat thesis: Univ. Genève, 2022- SdS 193 - 2022/04/25
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pin.unige.ch

CUI UNI GE

Digital Innovation Hub

DIGITAL INNOVATION HUB
University of Geneva

As part of the University's digital strategy, the **Digital Innovation Hub** (https://pin.unige.ch) active since March 2019, hosts creativity and innovation activities in the field of digital services. The purpose of the hub is to be transverse to the University and to reach the City, i.e. Geneva State as well as companies and organizations of the Geneva area. It is part of the network of innovation hubs of the University (https://www.unige.ch/collaborateurs/innovation/).

The Digital Innovation Hub has the following missions:

1. Support students and researchers with digital projects that lead to commercial exploitation or social impact;
2. Provide a meeting place and collaboration with the public and private sector in the region;
3. Develop innovative services for the university community.

To carry out its missions, the Digital Innovation Center has developed a series of tools.

Accelerator of digital sciences and services

The Accelerator of digital sciences and services (https://cui.unige.ch/fr/pin/accelerateur/) is born from the joint effort of two entities of the University: (1) the Information Systems Division (DISTIC) providing expertise in developing professional digital services to the whole University community, and (2) the Computer Science Center (CUI), providing innovative technologies arising from research.

Through the Accelerator and a joint coaching (from DISTIC and CUI), students' or institutional projects undergo an innovation process, going from ideation up to a fully working service prototype. The final user or stakeholder interested by the service takes over the final stages of deployment and maintenance. The Accelerator contributes to the third mission of the Digital Innovation Hub.

Managed by a dedicated team, the accelerator regularly offers new initiatives and innovative projects for the university community. Concretely these projects are put into practice in the form of bachelor's work, internship, research project in coordination with the DISTIC, the CUI, and final users of stakeholders. Since the start, there have been 10 finalised projects, of which 3 have been deployed and made available to the university community, 11 projects in progress and 7 projects starting in 2021. The 2020 novelties concern the development of conversational agents, in particular the «GSEM Chatbot» helping future GSEM students in their registration process for the masters of the GSEM faculty, according to their study situation (https://www.cui.unige.ch/fr/nouvelles/chatbotgsem/).

In 2021, the accelerator developed/accelerated 6 projects and deployed 1 project.

https://www.unige.ch/stic/innovation

FacLab

The FacLab is a fabrication laboratory (FabLab) anchored in an academic environment which supports the different actors of the Digital Innovation Hub from ideation to prototyping. It draws on the set of techniques and methods traditionally used in these settings to develop learning and research based on fabrication and prototyping to learn and understand. Fabrication is broadly understood and is not just limited to physical or digital artifacts. It can also be about making economic models, public policies, laws, models, etc. Anchored in the heart of the university, the FacLab is an internal and external network available to the entire academic community. The FacLab participates in the three missions of the Digital Innovation Hub.

The capabilities offered by tangible fabrication include vinyl cutting, laser cutting, 3D printing, CNC milling, an electronics workbench, a large toolbox. The capabilities offered by the intangible fabrication include the Parkour methodology

Figure 1: Nuit de la science, July 2022, Geneva

and pretotyping (or ultra-rapid prototyping) equipment.

Five ephemeral residencies are active at the FacLab: Real-time crowd-mapping urban air quality with open-hardware (with the Logair association); Education and practical tools to better explain the personal data environment to individuals (with the MyData Geneva association); Redesigning how talents and companies match and grow (with the startup Tungxten); Learning and teaching by making for all (with the startup Eduka3D); Study the benefits of the Beekee Box during study trips (with the startup Beekee).

In 2021, the FacLab hosted 2 hackathons and organized 26 training/workshop sessions with over 140 participants from academia and the general public.

Innovation clinic

The Innovation Clinic supports innovative student projects, whatever the field, from ideation to actual impact. These projects benefit from a personalized guidance process, visibility and the opportunity to connect with other interested students. The process is based on proven methods for carrying out innovation and transformation projects. Members of the project team learn while participating in the innovation process, in a spirit of empowerment. The Innovation Clinic allows students to learn how to innovate by actually doing it. The Innovation Clinic participates to the first and third missions of the Digital Innovation Hub.

The development of the Innovation Clinic began in 2019 and involves the establishment of processes and partnerships such as, for example, with the student association Innovation Time, whose members will operate the desk of the Innovation Clinic", i.e. the first contact point for the Innovation Clinic (starting in 2021).

From November to December, the Innovation Help Desk held regular sessions on 7 occasions in public locations at Uni Mail and Battelle.

Coding Dojo

In September 2021, the PIN launched a programming club called the Coding Dojo, which is a collaboration between UNIGE, HEPIA, and HEG. The Coding Dojo, based at the FacLab, has a dual mission: to provide coaching, tutoring, and mutual support for students (learning new programming languages, tools, or paradigms, and helping with specific programming problems), and to promote programming awareness among secondary school and vocational training center students. Since the start of the academic year in September, 9 Coding Dojo sessions have been held on various topics such as cryptography, Python, Git, Linux, Chatbot, and Java.

Figure 2: Nuit de la science, July 2022, Geneva

Digital forge

The digital forge is a laboratory of scientific and technical expertise that forges ideas into products. The digital forge is directed towards the technical realization of proof-of-concepts (POC) and rapid prototyping of digital project ideas. Strongly anchored between digital scientific research and the Swiss economic fabric, the forge joins forces with companies or organizations to support and help them in their phases of ideation, validation and production of prototypes.

The digital forge brings scientific expertise in IoT, Blockchain, IA, Big data, Machine Learning and covers various fields such as smart city, digital health, fintech, cybersecurity, etc. The Digital Forge contributes to the second mission of the Digital Innovation Hub.

In 2021, the Digital Forge developed and accelerated 5 projects and deployed 1 project. The Digital Forge also strengthened the team of the Cantonal Physician for computational needs related to pandemic management.

SciCoS (Scientific Computing Support)

SciCoS is a team of experts in scientific informatics, dedicated to supporting researchers from the University of Geneva and the Applied Universities of Geneva (HES-GE). The services provided include: operational support for high performance computing (HPC) and data processing, development of scientific applications, consulting and training for researchers. SciCoS contributes to the third mission of the Digital Innovation Hub. SciCoS is a new tool from the Digital Innovation Center which will offer its services from March 1, 2021. The project was initially funded by the State of Geneva (PL12146).

Digital Innovators

Digital Innovators is a series of monthly seminars, starting in February 2021, describing a digital innovation and its application in a use case.

In 2022, 8 online seminars were organized.

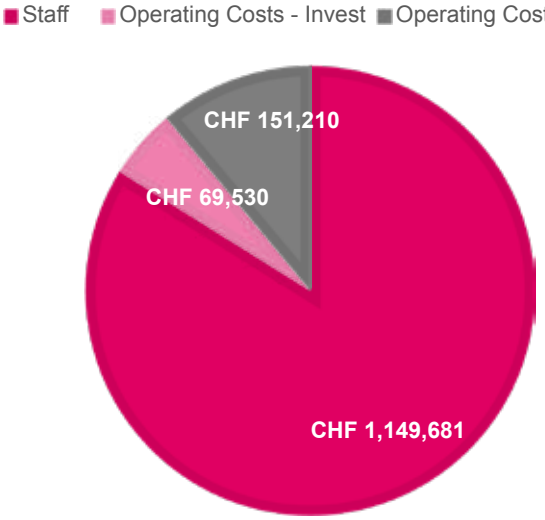
Cellule R&D

The recently created Cellule R&D within the Information Systems and Technology Directorate (DISTIC), under the functional domain of «Research and Scientific Information» (RISE), aims to transform innovative prototypes that address essential digital needs into services for the university community and beyond. These prototypes are developed within the Pôle Innovation Numérique (PIN). The R&D Unit aligns perfectly with the digital strategy of UNIGE, especially with the emergence of promising technologies, such as artificial intelligence applied in the academic field and more broadly in public services.

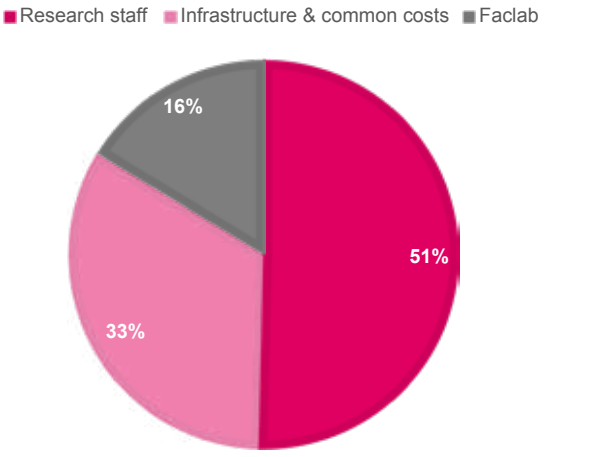
Financial Report

Financial Resources State of Geneva (DIP)

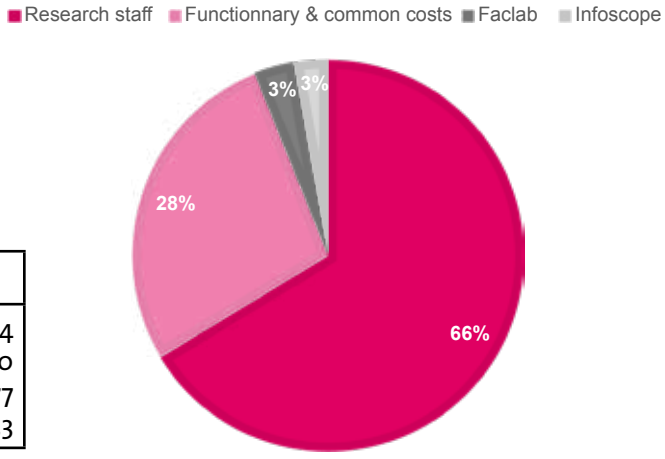
	Budget
Staff • Academic • Administrative and Technical • Employer's social contributions	CHF 1'149'681 CHF 379'800 CHF 543'932 CHF 225'949
Operating costs - Investment	CHF 69'530
Operating costs - Others	CHF 151'210
Total Budget 2022	**CHF 1'370'421**



Main operating costs - Investment	**Budget**
• Research staff • Infrastructure & common costs • Faclab	CHF 36'307 CHF 24'021 CHF 11'725



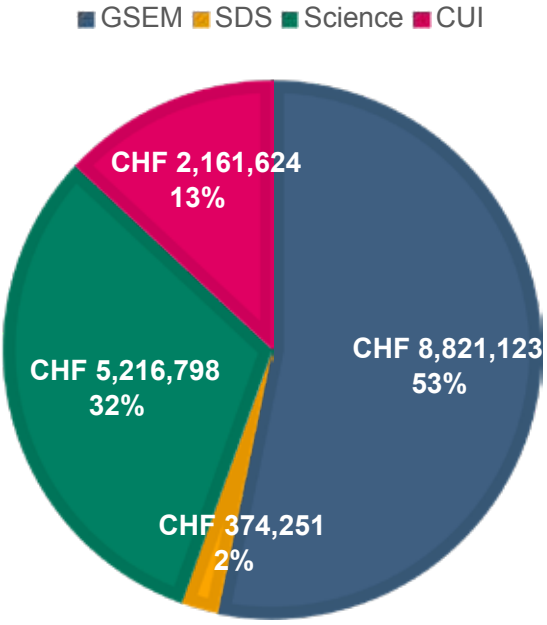
Main operating costs - Others	**Budget**
• Research staff • Functionnary & common costs • Faclab • Infoscope	CHF 84'084 CHF 35'000 CHF 4'177 CHF 3'533



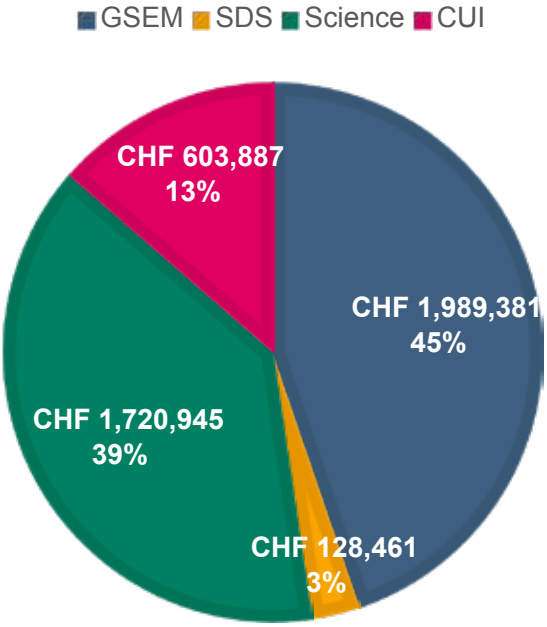
Funds with administrative workload on CUI (Contrats, Finances, Accounting)

	Total allocation for the projects	2022 allocation
GSEM registered projects	CHF 8'821'123	CHF 1'989'381
Science registered projects	CHF 5'216'798	CHF 1'720'945
SDS registered projects	CHF 374'251	CHF 128'461
CUI registered projects	CHF 2'161'624	CHF 603'887
Total Credit	**CHF 16'257'404**	**CHF 4'442'674**

Total allocation for the projects



2022 allocation



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