University *of Ljubljana*
Faculty *of Computer and Information Science*

2018
Research Review

University of Ljubljana
Faculty of Computer and Information Science

2018
Research Review

Remarks by the Dean

Dear reader,

it has been another successful year, with the Faculty of Computer and Information Science at the University of Ljubljana leading top research projects and achieving some significant breakthroughs.

The progress in all fields of computer and information science worldwide has been, again, enormous, and we are proud that our researchers have made important contributions in several areas, such as deep learning with neural networks on different biometrical data, creating the largest open-access dictionary of modern Slovene synonyms, predicting preterm birth, changing the paradigm of the tourism sector, using machine learning for the prediction of cognitive diseases, and applying our own data mining suite, Orange, to new use cases, from DNA analysis in bioinformatics to text mining in ethnographic studies.

We have expanded our network of international partners to more than 200 universities, research institutions and companies. This enables us to share knowledge and join resources to tackle bigger challenges. We therefore started a collaboration with CERN on visualisation and high performance computing research, and with the Chinese Academy of Sciences we established a joint Chinese-Slovenian virtual laboratory for high performance computing. With the Joint Research Centre of the European Commission we began to work on machine learning and IoT security, and are working closely with several industrial partners to transfer new scientific discoveries into practice.

Besides our research work, we are the largest Slovenian faculty offering programs in computer science, with 1300 active students at the bachelor, masters and doctoral levels. Our research-oriented doctoral study programme is conducted in English and open to international students.

We invite you to explore the contents of this booklet that presents highlights from the past year and lists our ongoing research projects, laboratories and researchers.

Assoc. Prof. dr. Mojca Ciglarič
Dean

University of Ljubljana

The university is among the top 3% universities in the world, according to Webonomics, Times and the Shanghai ranking.

The University of Ljubljana is an institution with a rich history. Opening its doors in 1919 on the foundations of a centuries-long educational tradition in the region, the University of Ljubljana has a reputation for impeccable quality in social sciences, physical sciences, humanities, and technical programmes, which are designed according to the stipulations of the Bologna Process. The Faculty of Computer and Information Science is a full member of the University.

Research staff and research groups at the University have proved themselves with world-renowned studies and projects in the fields of the arts, science and technology – both at home and abroad.

The University maintains close connections with the Slovenian private sector and with companies from abroad, and its partner institutions include many multinationals and some of the most successful domestic enterprises.

1757

Doctoral Students

4128

Researchers

5898

Employees

444

EU projects

427 347

Citations Scopus (2013–2018)

3270

Publications

364 647

Citations WoS (2013–2018)

60.316.252,00 €

Revenue for research and development *

* data for 2017

102

Ongoing Projects

EU: **9**
International: **9**
Industry: **30**
Slovenian Research Agency: **29**
Structural funds: **22**
Other national projects: **3**

142

Publications

SCI journals: **79**
1st quartile: **31**
Exceptional (top 5%): **9**
Conference: **63**

Faculty of Computer and Information Science

33

Doctoral Students

122

Researchers

166

Employees

The Faculty of Computer and Information Science of the University of Ljubljana is Slovenia's leading educational and research institution for computer and information science. The Faculty's main function is educating undergraduate and graduate computer science experts of various profiles, as well as engaging in research work which generates new knowledge and uncovers solutions to contemporary problems.

The Faculty also offers additional educational activities in computer and information science for several professional profiles by hosting lectures and workshops to increase the level of computer literacy in the country. Its public events also serve to popularise ideas about computers, especially among young people.

The Faculty was founded in 1996, when the Faculty of Electrical Engineering and Computer Science split into two separate faculties. The study of computer science itself began at the University of Ljubljana back in 1973, first as an elective programme after the 2nd year of electrical engineering study, and has been an independent study programme since 1982. In 2014, the Faculty moved to a new building in Brdo at the outskirts of Ljubljana.

17 070

Citations Scopus (2013–2018)

11 443

Citations WoS (2013–2018)

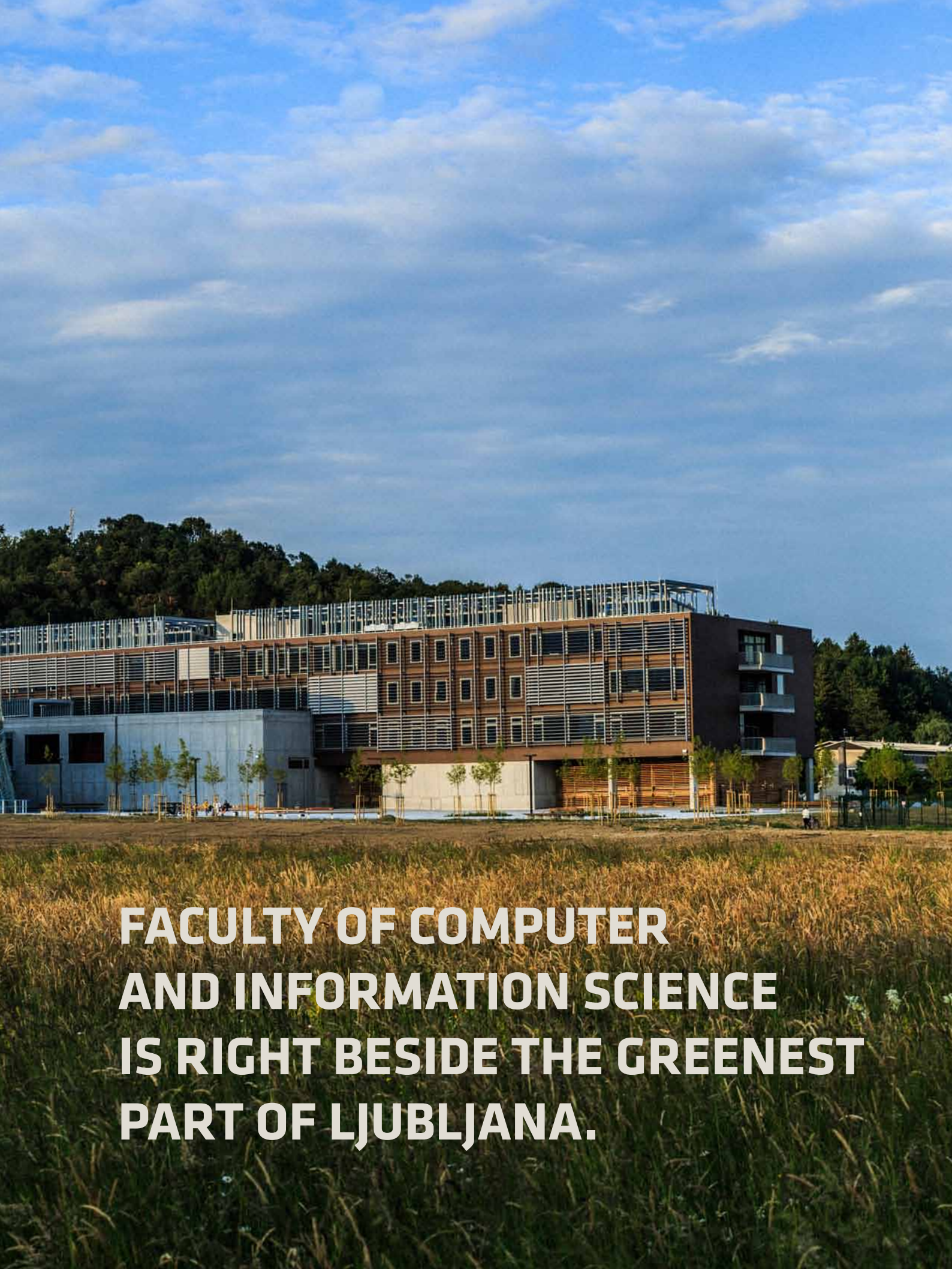
Slovenia: A Green Country

Slovenia lies in the heart of Europe, its 20,273 km2 of land ranking it among the smallest European states. The country's official language is Slovenian. Ethnic Slovenes make up the majority of the 2 million inhabitants, while there are also significant Hungarian and Italian minorities. Since 2004, Slovenia has been a full member of the EU and uses the euro as currency. Life in Slovenia, in comparison to other western countries, is fairly comfortable, and the quality of life is appropriately high.

Despite its small size, the landscape is quite diverse, from the Mediterranean coast to towering alps and the fertile Pannonian plane. A large part of the country is also marked by karstic soil, countless sources of water, and nearly endless forests. Slovenia is among the European countries with the highest percentage of forest, providing a safe haven for a whole zoo of wildlife, including bears, wolves, and lynx, which have disappeared from many other countries. Natural endowments and a safe and peaceful environment bring a number of tourists to the country each year.

Ljubljana is the capital of Slovenia and no visit to Slovenia is complete without a visit to this historic city. With a population just topping 300,000, Ljubljana ranks among medium-sized European cities. It offers everything that larger capitals do, while still giving the cosy feeling of a town, where everything is at your reach. Many of the state institutions are located in the city, as are the most important financial institutions and many major private companies, and of course the largest university in Slovenia.

Students make up a good seventh of the population, giving the city a youthful and lively atmosphere. Numerous cultural events held in the city throughout the year mark its rich tradition, as well as its modern creativeness. By day, the many tourists flocking to the capital are delighted by the cafes and bars along the Ljubljanica river, which winds its way through the heart of the city, while things heat up a bit at night.



FACULTY OF COMPUTER AND INFORMATION SCIENCE IS RIGHT BESIDE THE GREENEST PART OF LJUBLJANA.

Open to International Collaboration

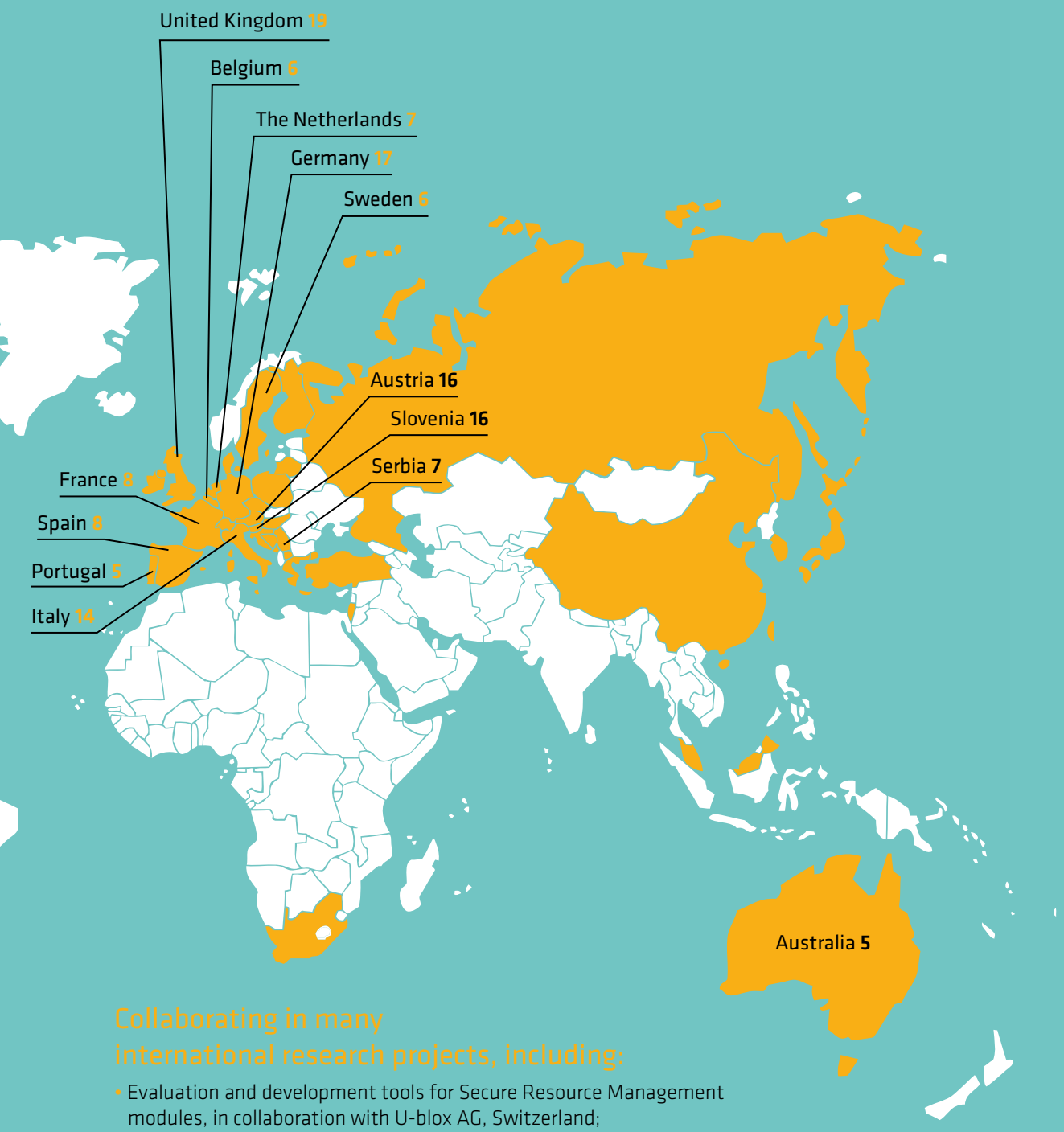
Great diversity and interdisciplinary approaches distinguish the research work of our faculty members. Our research addresses a number of research questions from a wide range of fields concerning computer and information science. Research groups at the faculty are successful in conducting a wide range of national and international projects and programmes. International studies are conducted in collaboration with world-class universities and research centres in Europe, the US and elsewhere around the world. In collaboration with the private sector, which has considered the Faculty an important partner for development, the Faculty conducts numerous applicative studies in computer science. The findings and results of research staff at the Faculty are regularly published in recognised international scientific publications, and its research staff – as world-class experts – participate in professional conferences and actively collaborate in international professional associations in all aspects of computer and information science.

Collaboration with many world-renowned institutions, including:

- Joint Research Centre – Collaborative Doctoral Partnership;
- The European Organization for Nuclear Research (CERN);
- Chinese Academy of Sciences;
- Kyungpook National University (South Korea) – joint research in computer vision and wireless computing and a double degree study programme in computer science/electronics engineering;
- University College London (UK) – joint research in bioinformatics and mobile computing;
- Baylor College of Medicine (USA) – joint research in bioinformatics;
- DFKI, Saarbrücken (Germany) – joint research in computer vision;
- Alpe-Adria University Klagenfurt (Austria) – joint research in computer compilers and algorithmics;
- University of Belgrade (Serbia) – joint research in sport statistics and computational linguistics.

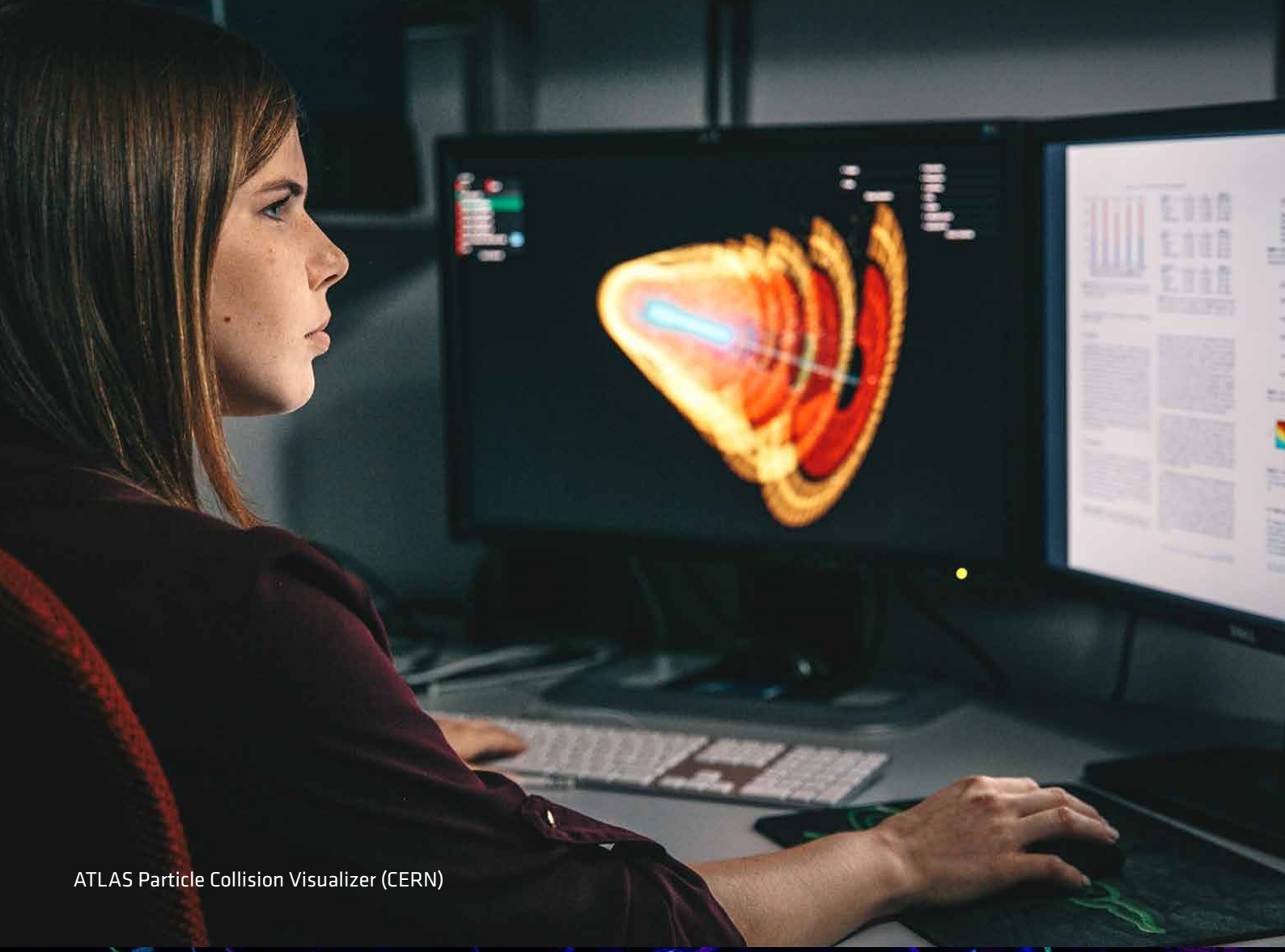
202
collaborations

Argentina • Australia • Austria • Belgium • Bosnia and Herzegovina • Canada • China • Costa Rica • Croatia • Czech Republic • Denmark • Finland • France • Germany • Greece • Hungary • Ireland • Italy • Japan • Kosovo • Lithuania • Macedonia • Montenegro • Poland • Portugal • Russia • Serbia • Slovenia • South Africa • South Korea • Spain • Sweden • Switzerland • Taiwan • The Netherlands • Turkey • United Kingdom • United States of America



Collaborating in many international research projects, including:

- Evaluation and development tools for Secure Resource Management modules, in collaboration with U-blox AG, Switzerland;
- CROSSBOW – CROSS BOrder management of variable renewable energies and storage units enabling a transnational Wholesale market, EU H2020;
- DIGITRANS – Digital Transformation in the Danube Region, Danube Transnational Programme;
- HUBLINKED – Strengthening Europe's Software Innovation Capacity, Erasmus+;
- SILICOFCM – In Silico trials for drug tracing the effects of sarcomeric protein mutations leading to familial cardiomyopathy, EU H2020.



ATLAS Particle Collision Visualizer (CERN)

Research and development of exascale computing technologies

Joint Research Centre

The Joint Research Centre (JRC) is the European Commission's service that employs scientists to carry out research in order to provide independent scientific advice and support to EU policy. A five-year Collaborative Doctoral Partnership (CDP) agreement between JRC in Ispra and UL FRI has been signed in 2018. The CDP provides fully funded doctoral studentships in the field of Machine Learning (ML) as applied to cyber-security research.

CERN

We are collaborating with European Organization for Nuclear Research (CERN) on visualization and high-performance computing research fields. We are developing algorithms for a real-time interactive rendering of large datasets obtained from CERN experiments (ATLAS, CMS, and Alice), and we are exploiting the computational power of modern GPUs for the purposes of reconstruction the events acquired from experiments.

Chinese Academy of Sciences

A three-year, tripartite collaboration agreement was signed in 2018 between the Institute of Computing Technology of the Chinese Academy of Sciences, the hardware manufacture company Sugon and UL FRI to provide funding for collaboration in 2019-2021. The joint Slovenian-Chinese laboratory for high performance computing supports research across an array of science and industrial applications, including biomedical data and image analytics. Its main goal is to train young high-performance computing talents and to promote the exchanges, research and joint development of exascale computing technologies.

Highlights

"They told me computers could only do arithmetic."

Grace Hopper

The Thesaurus of Modern Slovene: Responsive Dictionary

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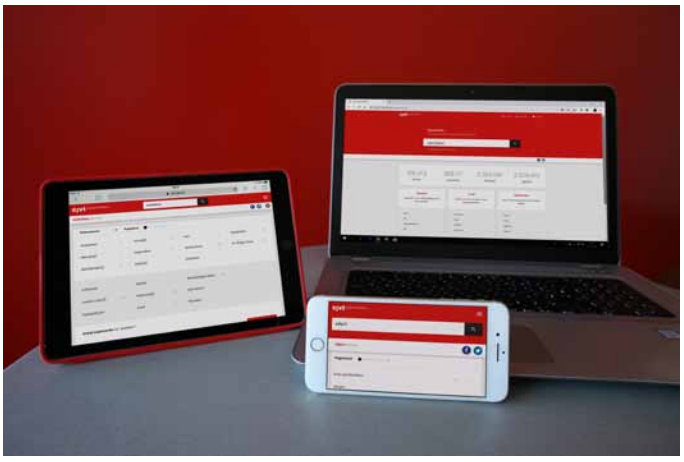
Collaborating Laboratories:
Laboratory for Cognitive Modeling
Laboratory of Computer Vision

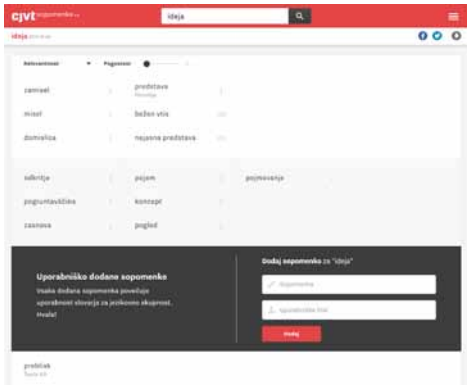
"Automatically created, free and fun, with crowdsourcing and random walks to synonyms."

The Thesaurus of Modern Slovene is the largest open-access collection of Slovene synonyms, and introduces the concept of a responsive dictionary, one that allows its data to continuously respond to both changes in the language and feedback from the language community. The thesaurus was constructed using automatic knowledge extraction from the bilingual Oxford English-Slovene dictionary and 1.2 billion words in the Gigafida monolingual corpus of modern Slovene. A random walk Personal PageRank algorithm extracted relevant synonyms from word co-occurrence graphs. The dictionary was designed with a user-friendly interface, suitable for all digital media. The thesaurus uses crowdsourcing, and encourages several types of user input and feedback. The first evaluations show that the thesaurus is succeeding in building an engaged community. This kind of dictionary is both technically and conceptually novel, and addresses user expectations in the digital age. In terms of the Slovene language, the thesaurus is an important building block in its language infrastructure.

https://viri.cjvt.si/sopomenke/eng

The thesaurus is available on many digital media.





A screenshot of the thesaurus.

Deep Learning Methods for Biometric Recognition Based on Eye Information

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Peter Rot
Dejan Štepec
Klemen Grm
Assoc. Prof. dr. Vitomir Štruc

Collaborating Laboratory:
Computer Vision Laboratory

"Taking part in the competitions held at conferences can be very productive – this not only opened a new research line for us, but we also won, twice, and received the most prestigious student award at the University of Ljubljana."

Among all ocular modalities the iris has received the most attention due to the high recognition accuracy that it enables. But new modalities, such as sclera blood vessels and the periocular region, are also used as autonomous (or iris-complementary) modalities. We built and individually evaluated three deep recognition pipelines based on different ocular modalities: sclera blood vessels, periocular region, and iris. Our main contributions in this work are as follows: we i) created a new public dataset that is currently the largest of its kind; ii) proposed and evaluated segmentation approaches that won the first place in SS(ER)BC competitions [1,2]; iii) developed and evaluated the rest of the sclera-based recognition pipeline [3]; iv) proposed and evaluated pipelines for periocular and iris recognition; and v) fused the pipelines together into a single biometric system with further improvements.

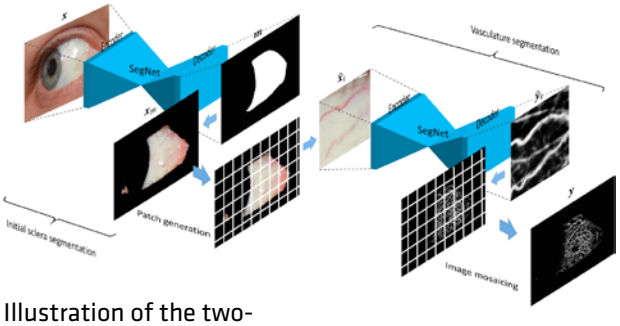
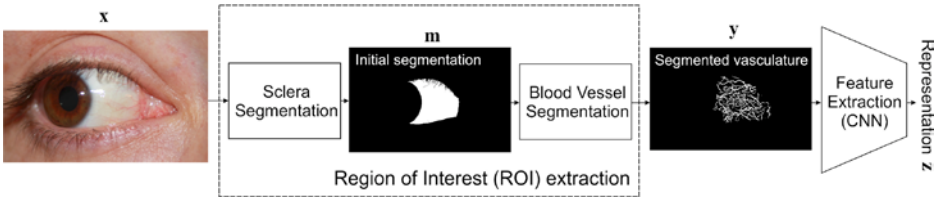


Illustration of the two-step vasculature structure segmentation procedure.

[1] Abhijit Das, Umapada Pal, Miguel A. Ferrer, Michael Blumenstein, Michael, Dejan Štepec, Peter Rot, Žiga Emeršič, Peter Peer, Vitomir Štruc, Aruna Kumar S. V., B. S. Harish (2017) SSERBC: Sclera Segmentation and Eye Recognition Benchmarking Competition, IEEE/IAPR International Joint Conference on Biometrics, 742-747.

[2] Abhijit Das, Umapada Pal, Miguel A. Ferrer, Michael Blumenstein, Michael, Dejan Štepec, Peter Rot, Žiga Emeršič, Peter Peer, Vitomir Štruc (2018) Sclera Segmentation Benchmarking Competition, IAPR International Conference on Biometrics, 303-308.

[3] Peter Rot, Klemen Grm, Žiga Emeršič, Peter Peer, Vitomir Štruc (2018) Deep Sclera Segmentation and Recognition, Handbook of Vascular Biometrics, Springer (eds.: Andreas Uhl, Christoph Busch, Sébastien Marcel, Raymond Veldhuis; currently the chapter is under review).



Block diagram of the proposed sclera recognition approach.

Ear Biometrics

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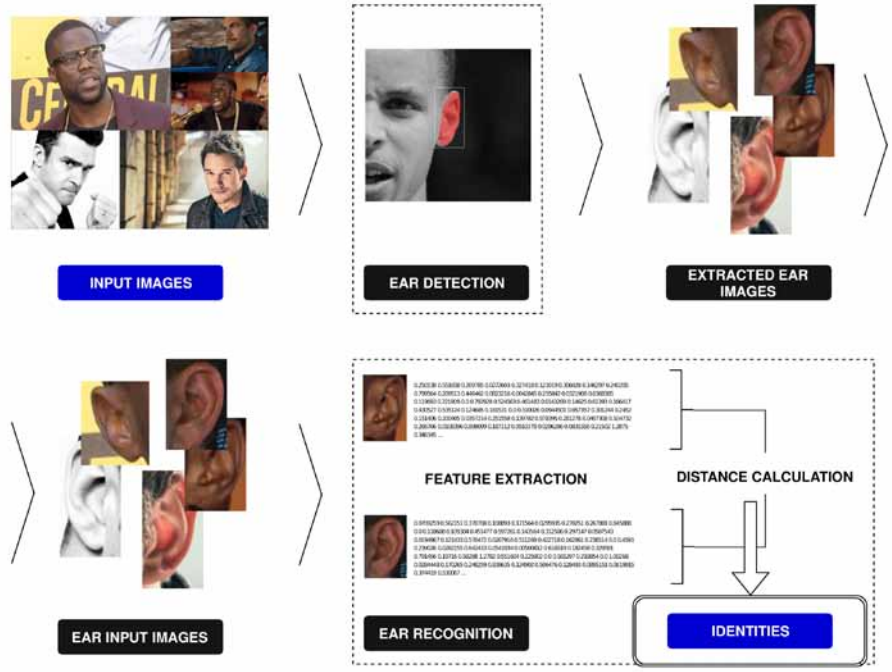
Collaborating Laboratory:
Computer Vision Laboratory

"Breakthroughs through competitions."

Ear biometrics, or recognising people based on the shapes of their ears, is becoming increasingly common. To further facilitate progress in this field we organised the first ever ear recognition competition, which established new, state-of-the-art ear recognition approaches. The Unconstrained Ear Recognition Challenge (UERC) [1], held in 2017, was organised as part of the International Joint Conference on Biometrics (IJCB). We are also currently organising the second such competition, UERC 2019, as part of the International Conference on Biometrics (ICB) 2019. However, only observing the recognition performance often does not provide enough in-depth information. To investigate ear recognition performance in more detail we thus performed covariate analysis on some of the proposed approaches, where the effects of gender, ethnicity, ear occlusions and head positions were observed [2]. Also, for the first time in ear recognition we presented a joint deep ear recognition pipeline, performing both ear detection and recognition. This enables us to recognise subjects based solely on their ears, using arbitrary photos of people, with no information regarding ear location available beforehand. The work was published as a book chapter [3], and a summary of our ear recognition research was also presented as an invited talk in Costa Rica [4].

Joint ear recognition pipeline, using convolutional neural networks for both detection and feature extraction in order to recognise people.



[1] Žiga Emeršič, Dejan Štepec, Vitomir Štruc, Peter Peer, Anjith George, Adil Ahmad, Elshibani Omar, Terrance E. Boult, Reza Safdari, Yuxiang Zhou, Stefanos Zafeiriou, Dogucan Yaman, Fevziye I. Eyiokur, Hazim Kemal Ekenel (2017) The Unconstrained Ear Recognition Challenge, International Joint Conference on Biometrics (IJCB).

[2] Žiga Emeršič, Blaž Meden, Peter Peer, Vitomir Štruc (2018) Evaluation and Analysis of Ear Recognition Models: Performance, Complexity and Resource Requirements, Neural Computing & Applications, Springer.

[3] Žiga Emeršič, Janez Križaj, Vitomir Štruc, Peter Peer (2018) Deep Ear Recognition Pipeline, Recent Advances in Computer Vision: Theories and Applications, Springer.

[4] Žiga Emeršič (2018) The Story of Ears, Invited talk at the Second International Symposium on Machine Learning Applications, Costa Rica Institute of Technology, Costa Rica.

Deidentification of Faces with Generative Neural Networks

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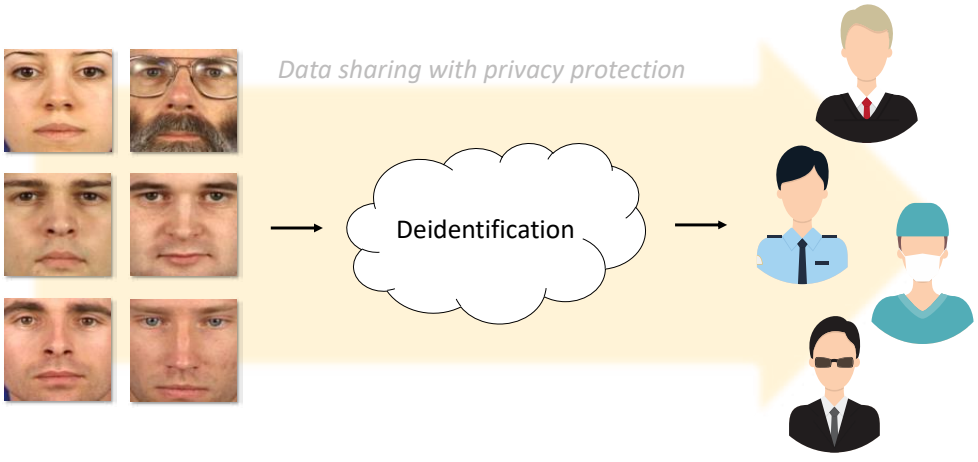
Collaborating Laboratory:
Computer Vision Laboratory

"There is growing awareness of the need to protect privacy and personally identifiable information, and we are part of the solution to such problems."

AI-based technology is nowadays driven by data, which is often provided by capturing devices and sensors monitoring the world around us. A few examples include video surveillance systems, systems for gathering and storing medical data, as well as other data banks used by government entities and/or private corporations. Information systems which deal with any kind of human activity use data which may interchangeably contain sensitive personal information and information that identified that related individuals. Unregulated disclosure of such data represents serious violation of privacy-related laws and legislation, and therefore the protection of any sensitive personal information that is collected is essential in today's extremely connected, information-driven modern world. To address these issues in the domain of computer vision and image-based biometry, we: 1) successfully employed face deidentification with a generative neural network that retains certain important characteristics (like facial expressions) of the face, even after deidentification [1]; and 2) formalised our face deidentification approach with a k-anonymity privacy protection scheme, providing a formal framework for ensuring privacy in facial imagery using generative neural networks [2].

[1] Blaž Meden, Refik Can Malli, Sebastjan Fabijan, Hazim Kemal Ekenel, Vitomir Štruc, Peter Peer (2017) Face deidentification with generative deep neural networks, IET Signal Processing, 11(9): 1046-1054.

[2] Blaž Meden, Žiga Emeršič, Vitomir Štruc, Peter Peer (2018) k-Same-Net: k-Anonymity with Generative Deep Neural Networks for Face Deidentification, Entropy, 20(1): 60.



The process of data deidentification prevents the misuse of personal information, and enable the protection of privacy before data is shared among relevant stakeholders.

A Neural Network Solution for Segmentation and Modelling of 3D Image Data

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Collaborating Laboratory:
Computer Vision Laboratory

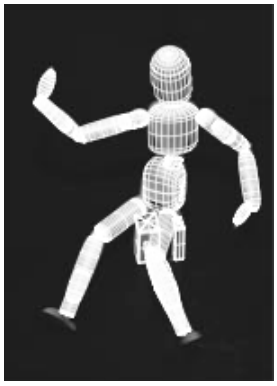
"The path to a real-time method is to use deep neural networks."

Visual perception enables intelligent interaction with the physical world. At some point, the visual information must be represented in terms of spatial or volumetric models that directly relate to actual 3D space.

We previously developed a state-of-the-art method for segmentation and reconstruction of superquadrics from range images [1]. Superquadrics are closed-surface objects: ellipsoids, cylinders, cuboids, or shapes in-between. Due to its iterative nature, the method is not suitable for real-time applications. The path to a faster method is now quite evident — use deep neural networks, which have revolutionised computer vision research.

In the framework of the project financed by the Slovenian Research Agency we are re-implementing segmentation and superquadric model recovery using CNNs. Input to CNNs are not just range images, but 3D point clouds in general. Methods and devices for the capture of 3D data have multiplied in the recent years, so that a faster approach would be beneficial in many different application domains.

Aleš Jaklič, Aleš Leonardis, Franc Solina (2000) Segmentation and recovery of superquadrics, Kluwer/Springer.



Superquadric models of a human form and the body of an amphora.

Generating Inter-dependent Data Streams for Recommender Systems

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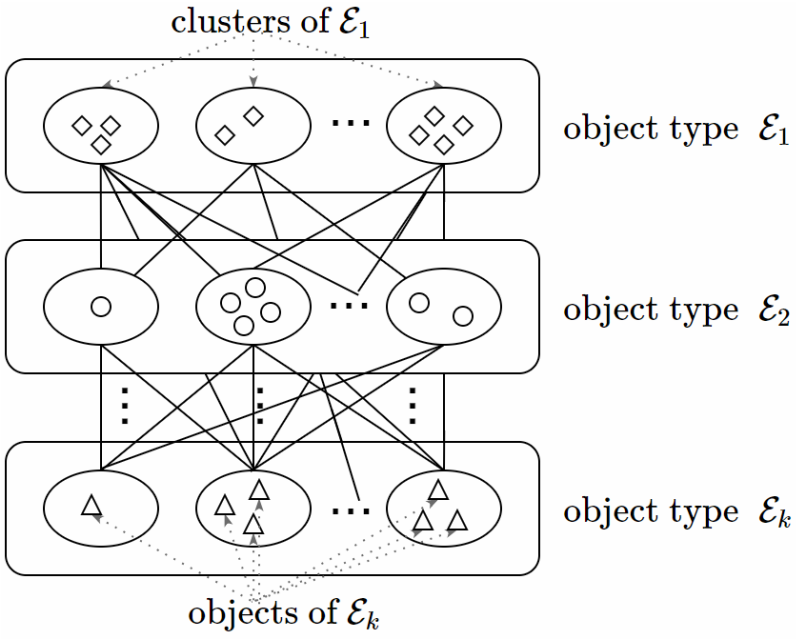
Collaborating Laboratories:
Laboratory for Cognitive Modeling
Bioinformatics Laboratory

"The generator is able to simulate a collection of time-changing data streams, helping to effectively evaluate a variety of recommender systems, data fusion algorithms and incremental algorithms."

Recommender systems are essential tools in modern e-commerce, streaming services, search engines, social networks and many other areas, including the scientific community. However, the lack of publicly available data hinders the development and evaluation of recommender algorithms. This problem gets worse when we try to collect multiple related datasets from the same domain with some meaningful connections among them. To address this problem, we have created a Generator of Inter-dependent Data Streams (GIDS), capable of generating multiple inter-dependent datasets of relational data. It can simulate a collection of time-changing data streams, providing an effective method for evaluating a variety of recommender systems, data fusion algorithms and incremental algorithms. Our evaluation showed that the generated data streams mimic real-life datasets in terms of statistical data properties, and achieve performance that is equal to that of many classic recommender systems.

Martin Jakomin, Tomaž Curk, Zoran Bosnić (2018) Generating Inter-Dependent Data Streams for Recommender Systems, Simulation Modelling Practice and Theory, 88: 1-16.

GIDS works by simulating multiple sets of clusters (groups of objects) of different object types and the connections (relations) among those clusters. In that way, it can generate multiple datasets that share mutual (hidden) information.



Detecting Concept Drift in Data Streams Using Model Explanation

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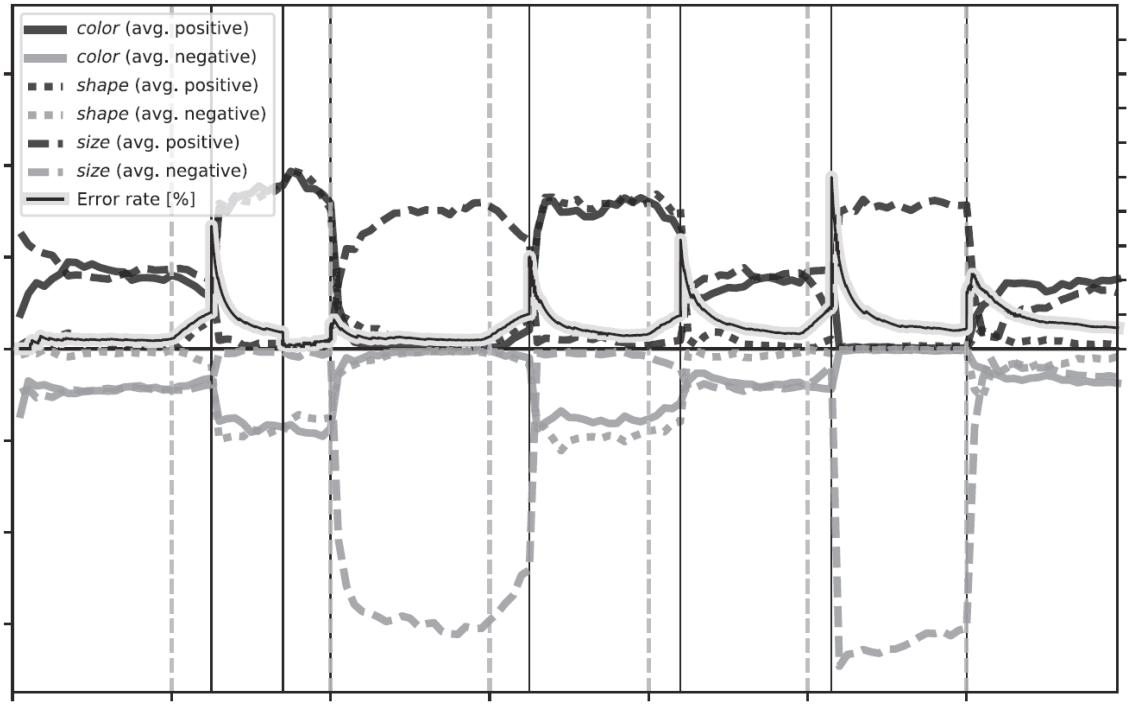
Collaborating Laboratory:
Laboratory for Cognitive Modeling

"A concept drift detector observes changes in the explanations of an arbitrary classification model."

Learning from data streams (incremental learning) is attracting increasing research focus due to the many real-world streaming problems and open challenges, among which is the detection of concept drift – a phenomenon when the data distribution changes and makes the current prediction model inaccurate or obsolete. In this work we propose a novel concept drift detector that can be combined with an arbitrary classification algorithm. The proposed concept drift detector is based on computing multiple model explanations over time and observing the magnitudes of their changes. The model explanation is computed using a methodology that yields attribute-value contributions for prediction outcomes, and thus provides insight into the model's decision-making process and enables its transparency. The evaluation reveals that the proposed approach surpasses the baseline methods in terms of concept drift detection, accuracy, robustness and sensitivity.



The detection points of concept drifts (denoted by solid vertical lines) that occurred, as indicated by dashed vertical lines. Curves in the graph show the explanations of each attribute and the classifier's error rate.

Characterisation and Automatic Classification of Preterm and Term Uterine Records

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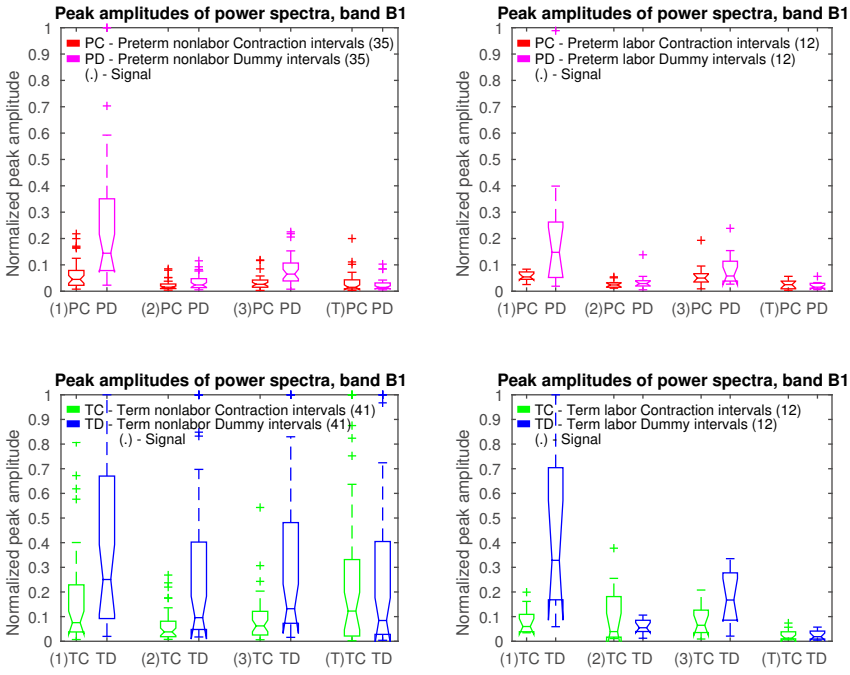
Collaborating Laboratory:
Laboratory for Biomedical Computer Systems and Imaging

"The measurable influence of the maternal heart on the uterus in an electro-mechanical sense is a predictor of preterm birth."

Current research on the non-invasive prediction of preterm birth is based on an analysis of the contraction intervals found in the electrohysterogram (EHG) signals recorded from the abdomen of pregnant women. We characterised, for the first time, the non-contraction intervals (dummy intervals) of EHG records accompanied by an external tocogram measuring mechanical uterine activity (in the form of TOCO signals), and thus developed a new method for predicting preterm birth. The peak amplitudes of the power spectra of the EHG and TOCO signals in the frequency band 1.0-2.2 Hz, carrying information on the electro-mechanical influence of the maternal heart on the uterus, are only high during term pregnancies, when the delivery is still far away (nonlabour), while they are low when delivery is close (labour). However, these peak amplitudes are also low during preterm pregnancies, when the delivery is still supposed to be far away, thus suggesting a danger of preterm birth. The newly developed method for preterm and term EHG records recorded early (around the 23rd week of pregnancy, when contractions are likely not present) achieved a 100% classification accuracy when using a publicly available TPEHG database.

Franc Jager, Sonja Libenšek, Lsenija Geršak (2018) Characterization and Automatic Classification of Preterm and Term Uterine Records, PLoS ONE, 13(8): e0202125.



Box plots of normalised peak amplitudes of power spectra in the frequency band B1 (1.0-2.2 Hz) of the EHG signals S1, S2, S3, and the TOCO signals, for preterm and term, nonlabour and labour, groups of contraction and dummy intervals. The boundary between nonlabour and labour groups is three weeks.

Machine Learning for Predicting Cognitive Diseases: Methods, Data Sources and Risk Factors

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Collaborating Laboratory:
Laboratory for Cognitive Modeling

"Much effort has been devoted to improving the diagnostics of cognitive diseases, and machine learning techniques provide one way of dealing with this problem."

Machine learning and data mining approaches have been successfully applied in many different fields of the life sciences over the past 20 years. Medicine is one of the most suitable application domains for these techniques, since they help model diagnostic information based on causal and/or statistical data, and therefore reveal hidden dependencies between symptoms and illnesses. In this paper we give a detailed overview of the recent machine learning research and its applications for predicting cognitive diseases, especially Alzheimer's disease, mild cognitive impairment and Parkinson's disease. We survey different state-of-the-art methodological approaches, data sources and public data, and provide a comparative analysis. We conclude by identifying the open problems within the field, which include early detection of cognitive diseases and inclusion of machine learning tools into diagnostic practice and the planning of therapeutic interventions.

Cognitive diseases are affecting a growing number of people. Given that they are incurable, it is critical to detect them in their early stages.

Indoor Sound Level Measurement on a Low-Power Wireless Sensor Node

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Ratko Pilipović ratko.pilipovic@fri.uni-lj.si
Sen. Lect. dr. Robert Rozman robert.rozman@fri.uni-lj.si
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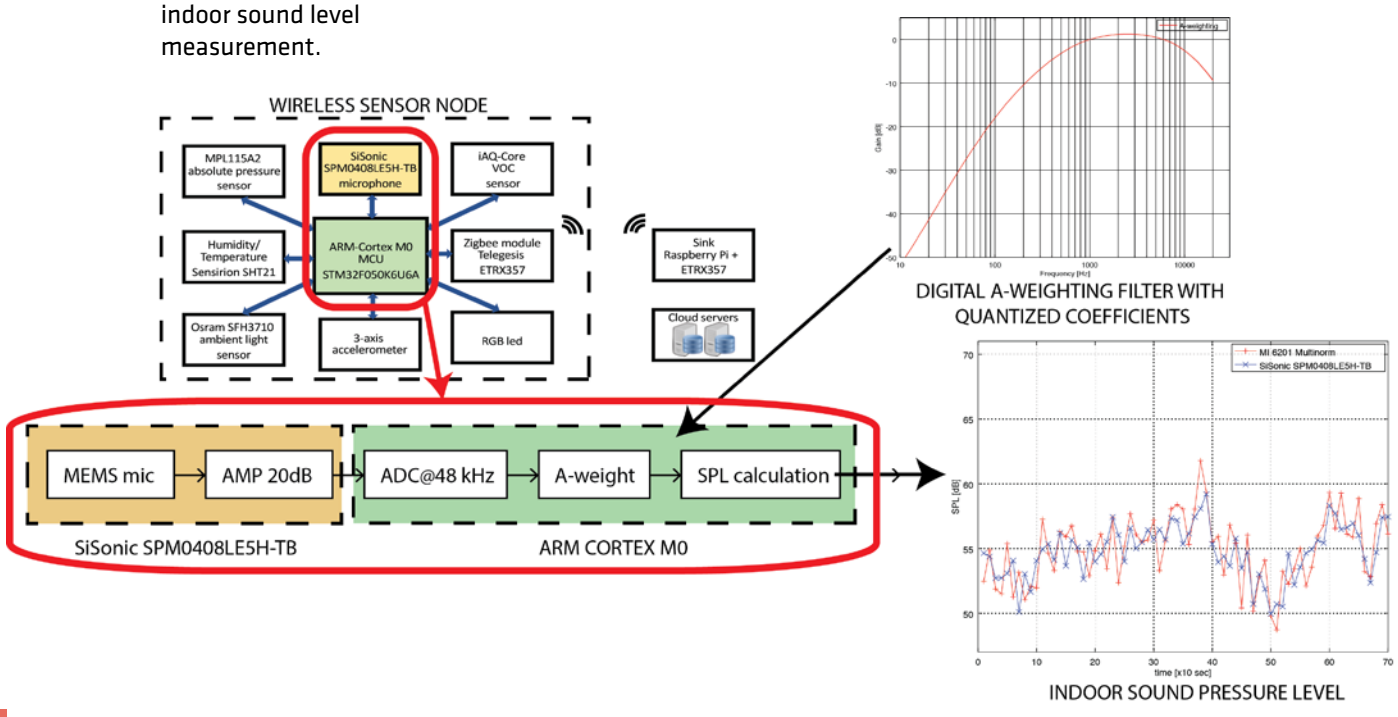
Collaborating Laboratories:
Laboratory for Adaptive Systems and Parallel Processing
Laboratory of Algorithmics

"Indoor sound levels can be accurately assessed on the smallest ARM processor core."

Noise pollution is a common problem in urban environments. It has been shown that noise pollution adversely affects people's health and cognition, and long-term exposure to high sound levels can cause hearing damage. Sound level measurement is a costly operation, because it involves complex digital signal processing (e.g. the use of an A-weighting filter). In the research we propose a low-power wireless sensor node for accurate indoor sound level measurement. The proposed node is based on the ARM Cortex-M0—the smallest and cheapest ARM processor core. As the node has limited processing abilities, we propose several simplifications to approximate a costly signal processing stage and still accurately measure the sound level at the node. The magnitude response of the proposed A-weighting filter satisfies the tolerance limits imposed by the IEC 61672-1 standard. The implemented sensor node has low power consumption, which allows battery-powered operation for several days. The mean difference between the proposed sound-level meter and the Class 1 sound-level meter is less than 2 dB.

Vladimir Risojević, Robert Rozman, Ratko Pilipović, Rok Češnovar, Patricio Bulić (2018) Accurate Indoor Sound Level Measurement on a Low-Power and Low-Cost Wireless Sensor Node, Sensors, 18 (7): 1-22.

Low-power and low-cost sensor node for accurate indoor sound level measurement.



Convex Skeletons of Complex Networks

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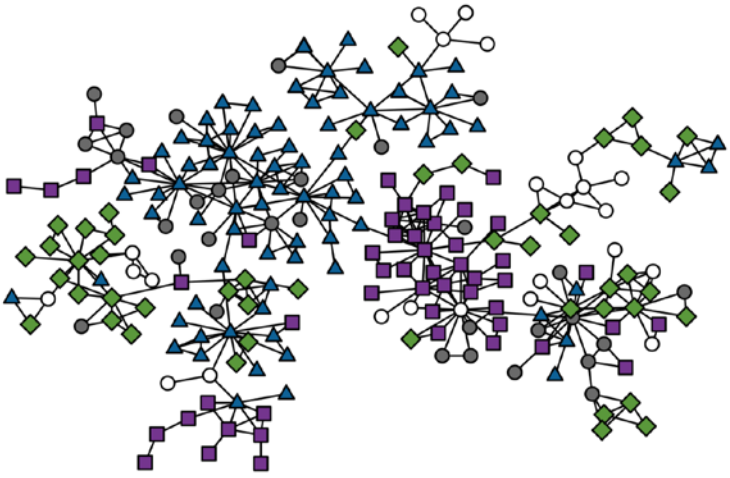
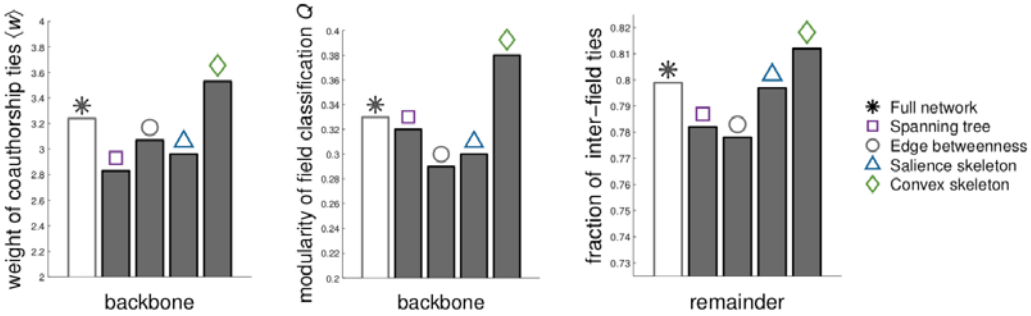
Collaborating Laboratory:
Laboratory for Data Technologies

"A convex skeleton retains the strongest collaborations among Slovenian computer scientists."

A convex network is a network such that every connected induced subgraph includes all the shortest paths among its nodes. A fully convex network would therefore be a collection of cliques stitched together in a tree. We study the largest high-convexity part of empirical networks, which we call a convex skeleton. A convex skeleton is a generalisation of a spanning tree in which each edge can be replaced by a clique of arbitrary size. We present different approaches for extracting convex skeletons and apply them to networks of various types and origins. We show that the extracted convex skeletons retain the degree distribution, clustering, connectivity, distances, node position and also community structure. Moreover, in the Slovenian computer scientists co-authorship network, a convex skeleton retains the strongest collaborations among the authors, in contrast to the state-of-the-art network backbones and skeletons (see figure). A convex skeleton thus represents a simple definition of a network backbone with applications in social collaboration networks and elsewhere.

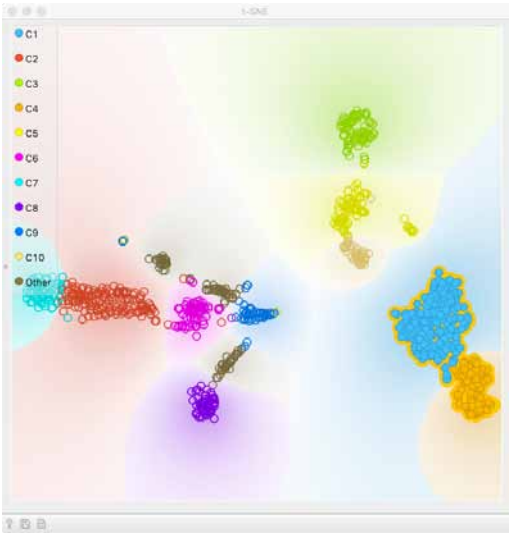
Lovro Šubelj (2018) Convex skeletons of complex networks, Journal of the Royal Society Interface, 15(145): 20180422.

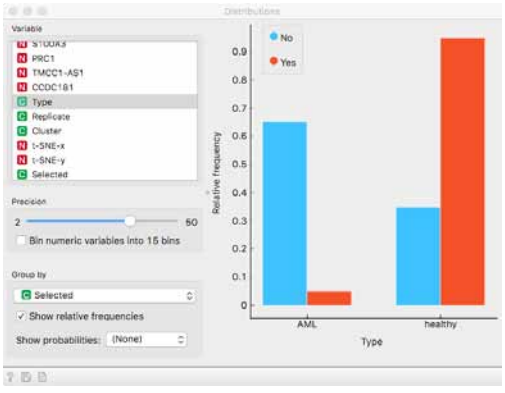




Single Cell Gene Expression Analysis in Orange

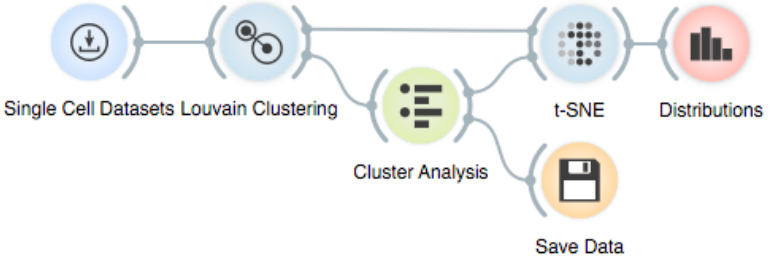
Collaborating Laboratory:
Bioinformatics Laboratory





Thanks to recent advances in biotechnology, biomedical research has become quantitative, and scientists can now study organisms and processes in the cell in great detail. One such technology that has been perfected in the past few years is single cell RNA-sequencing, which can report on the activity of every gene in a cell for thousands or even millions of cells simultaneously. Experiments with this technology can yield terabytes of data that can be analysed to discover cell types, identify cell states, trace development lineages, and reconstruct spatial organisation of cells. New software tools to help scientists sift through such data are emerging, but they often assume fluency in programming in R or Python, and deprive analysts of the joy of interactive analytics.

The flagship product of Bioinformatics Lab is Orange (*http://orange.biolab.si*), a popular data mining environment that features beautiful interactive data visualisations and visual programming for the design of data analysis workflows. Due to its intuitiveness and the simplicity of the interface, Orange can support users that are not data science experts, or wish to do data analytics without diving into the mathematical and algorithmic intricacies of machine learning and statistics. For single cell data analysis, we have extended Orange with components for data management, filtering, batch effect removal, data normalisation, cluster analysis, and cell classification. scOrange (*http://singlecell.biolab.si*) also provides simple access to single cell datasets, gene markers, gene and cell ontologies, and pathways. We are developing scOrange in close collaboration with biomedical researchers from the Baylor College of Medicine, Howard Hughes Medical Institute, and the University of Florida. Besides the laboratory staff, we have also engaged the Faculty's undergraduate and graduate students in the software development and visual design of the tool.



Spectral Orange

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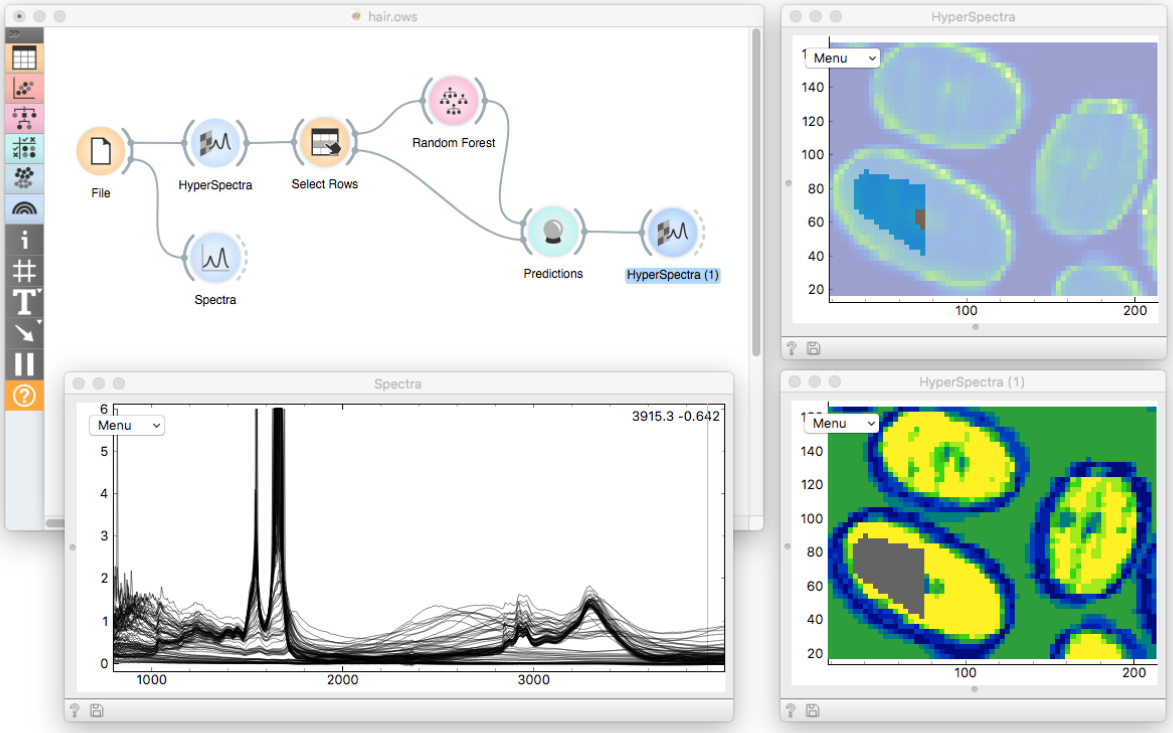
Collaborating Laboratory:
Bioinformatics Laboratory

"A user-friendly tool that can open spectral images, treat them, and apply machine learning."

Modern spectral microscopes can take an image, where each pixel is a spectrum, in under three minutes, and thus rapidly generate a lot of data. As other software, either free or commercial, lacked the data mining capabilities of Orange, we extended Orange with functionality for reading, visualising and treating spectra. Now users can open spectral images, treat them as necessary, and apply machine learning – all in a single interactive and user-friendly tool.

We are collaborating with Elettra Sincrotrone (Italy), Synchrotron Soleil (France), Canadian Light Source and NMBU (Norway).

Marko Toplak, Giovanni Birarda, S. Read, C. Sandt (2018) Infrared Orange: Connecting Hyperspectral Data with Machine Learning, Synchrotron Radiation News, 30.4: 40-45.



Classification of spectra, which describe chemical composition, with random forests. Hair cross-sections under a microscope.

Short Courses for Data Science with Orange

Collaborating Laboratory:
Bioinformatics Laboratory

"Meeting the users of our software gives us an excellent opportunity to get some quality feedback and guide its further development."

Data science is becoming an essential skill in all fields of human endeavour, from economics to academia, and from the natural to social sciences. Orange is not only a powerful tool for analysing data, but also for teaching data science to everybody. Within the past year, the Bioinformatics Laboratory has organised more than 30 workshops, courses and invited presentations for groups as diverse as linguists and biologists, physicists and government personnel, and high schoolers and graduate students. While most of these took place at our Faculty of Computer and Information Science, we also held workshops in Norway, Italy, Germany, Netherlands, France, Belgium, Portugal, USA, Russia, Australia, and Brazil.

Workshops are tailored to the target audience, which again shows the versatility of the tool. For example, the topic of the workshop in Lisbon was using Orange in ethnographic studies; in As, Melbourne, and Paris, we used Orange to analyse spectral data from synchrotrons; staff working for the Slovenian government were trained in the analysis of questionnaires, while other from the Ministry of Culture were trained in text mining; the lectures in Dagstuhl, Ghent, Hamburg, Ashburn, and Houston focused on the analysis of genetic data.

The Secret of a Hundred-year-old Cipher Postcard Revealed

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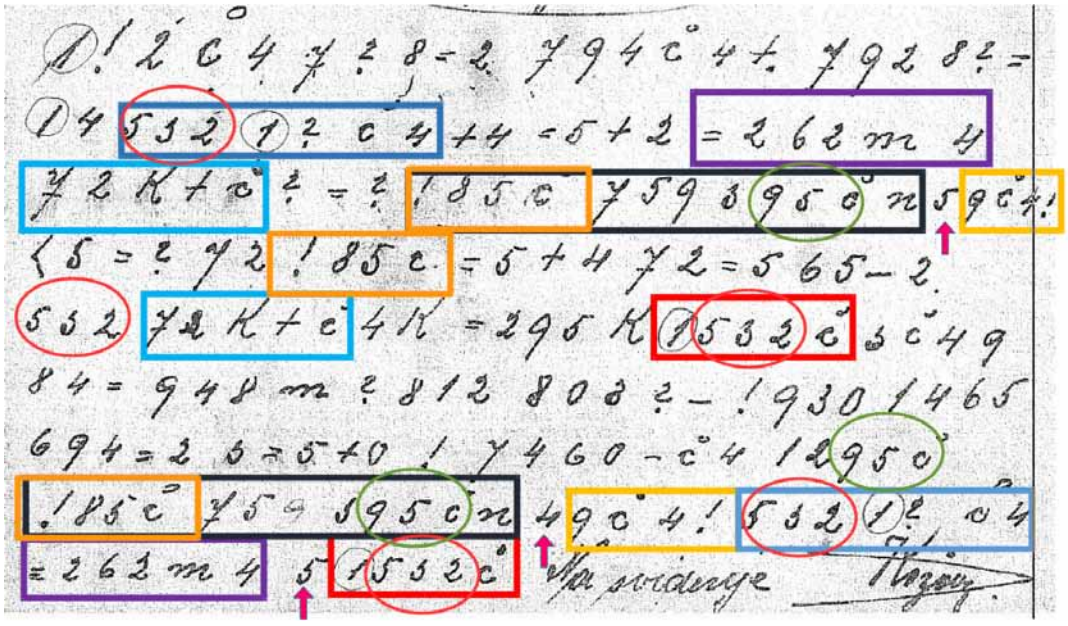
Collaborating Laboratory:
Laboratory for Cryptography and Computer Security

"The hill-climbing algorithm tests a 100-year-old cipher against modern-day computing power."

Sometimes even simple solutions lead to interesting results. Our faculty was presented with a cipher postcard from the early 20th century. For some time no one was able to find a solution by hand, so we decided to build a simple hill-climbing algorithm to test the 100-year-old cipher against modern-day computing power. To guide the search we exploited the characteristics of a structured language. More precisely, we observed the frequencies of letter pairs and triplets to determine the correctness of the decoding. We analysed a Slovenian corpus (Gigafida) and the works of Ivan Cankar to get a good estimate of letter pairs and triplets. The algorithm starts with a completely random decoding map, and then carries out many iterations of switching the letter that contributes the most to producing unlikely letter triplets and pairs with a letter that produces the most likely pairs and triplets. There is much room to improve the algorithm, but in its current state it worked well enough to give us interesting results.



The WWI cipher called Elizika turned out to be a substitution cipher.

Geographical Mapping of Visitor Flows in Tourism

Assoc. Prof. dr. Damjan Vavpotič damjan.vavpotic@fri.uni-lj.si
Nejc Ribič
Karmen Knavs

Collaborating Laboratory:
Information Systems Laboratory

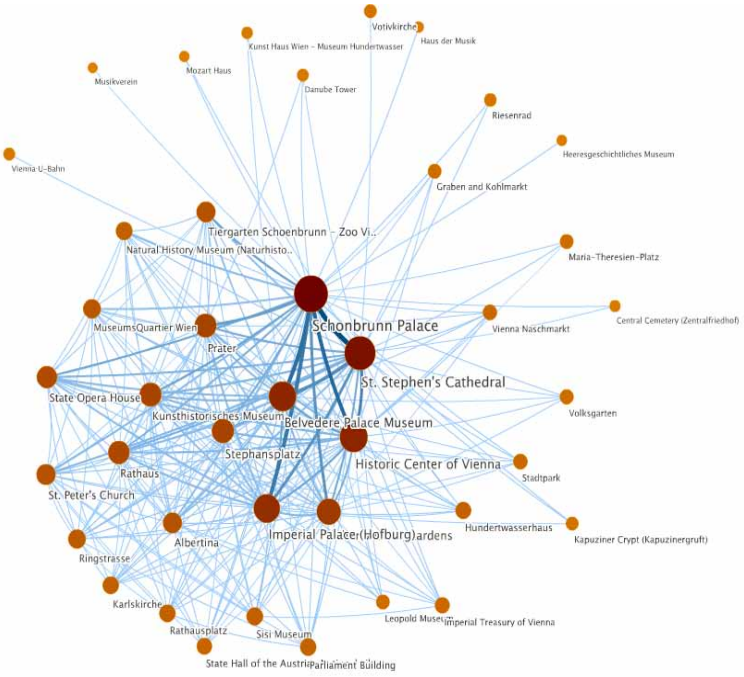
TripAdvisor, Airbnb, Uber, Google, and other IT giants offer tourism web platforms where users can view, change and co-create content without the interference of institutions. These activities are driving tourism demand and significantly changing the industry. The large amounts of data collected by the platforms can be used to analyse tourist behaviour. Our approach is based on the analysis of posts on tourism web platforms, and allows us to identify the most visited geographical locations, to identify visitor flows (repetitive movements within geographical locations), and to reconstruct and visualise tourism attraction networks. These new insights enable destination managers and marketers to create demand-driven tourism experiences. The research is performed in cooperation with the Faculty of Economics, University of Ljubljana.

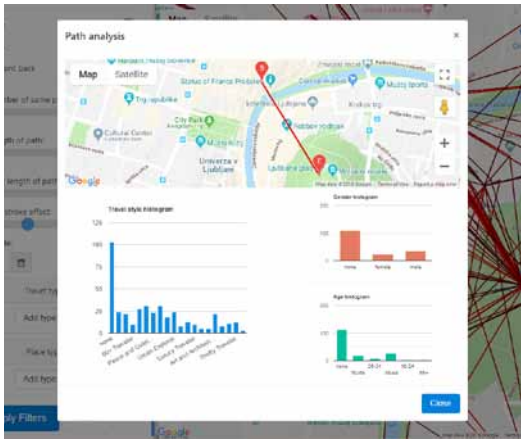
"Reconstructing tourism flows and tourism attraction networks from posts on tourism web platforms."

Ljubica Knežević Cvelbar, Mojca Mayr, Damjan Vavpotič (2018) Geographical Mapping of Visitor Flow in Tourism : a User-Generated Content Approach, Tourism Economics, 24(6): 701-719.

Best paper presentation award at TTRA Europe Chapter Conference 2018 for the paper identifying visitor migration patterns with user generated content: new insights on visitor flows, travel and tourism research association.

Reconstruction of the Vienna tourism attractions network.





Application for analysis of micro tourism flows in Ljubljana.

Research Laboratories

Research at the Faculty of Computer and Information Science at the University of Ljubljana (FRI) is conducted in 19 research laboratories. These provide a communal creative space for knowledge transfer and the flow of ideas between established researchers and students, who are still trying to find what they want to research.

Laboratory for Biomedical Computer Systems and Imaging

The laboratory conducts research in the field of biomedical signal and imaging data. Our research includes describing physiological phenomena, modelling physiologic relationships, graphically displaying anatomic details and physiologic functions, visualising biomedical signals, developing standardised databases, developing detection and recognition techniques, evaluating the performance of recognition techniques, analysing bioelectric patterns, and developing performance measures and protocols, biomedical information technologies and software, dynamic web-interface creation, responsive web design, responsive information visualization.

Prof. dr. Franc Jager
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Laboratory for Cryptography and Computer Security

We focus on cryptography and computer security, discrete mathematics, coding theory and statistical design. We have extensive experience in applied cryptography, especially public key cryptosystems (elliptic curve cryptosystems), cryptographic protocols (AKC) and their implementations in restricted environments, such as smart cards (including HSM and FPGA). We also study algebraic combinatorics (distance-regular graphs, association schemes, finite geometries, codes, finite fields and the like), probability and statistics.

Prof. dr. Aleksandar Jurišić
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Laboratory for Computer Graphics and Multimedia

The laboratory performs R&D in the fields of multimedia technologies, human-computer interaction and computer graphics. Our main research areas are: audio processing and music information retrieval (audio understanding, organisation of music archives), interactive 3D visualisation and 3D graphics (medical imaging, volumetric rendering, games), and e-Learning (learning for people with disabilities, gamification). We have extensive experiences in developing software solutions for various platforms and are active in the development of visualizations and didactic simulations. We collaborate with partners in national, EU and industrial projects.

Assoc. Prof. dr. Matija Marolt
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Laboratory for Ubiquitous Systems

The prime area of research interest is efficient data handling in distributed pervasive environments, which store terabytes of data that present a challenge in at least two areas: the efficient storage and handling of the data. The distributed environment is inherently capable of parallel processing and requires a proper data and work distribution. Currently our research is concentrated on three areas: unstructured text handling, data deduplication and online streaming data processing. The work performed also overlaps with the area of Computer Science Education.

dr. Andrej Brodnik
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Laboratory of e-media

The laboratory focuses on advanced (lightweight) communications (e.g. the Internet of Things), security, privacy, e-business, and human factor modelling. Our research devotes particular attention to the analysis and design of advanced systems (from PKI to critical infrastructures), cryptographic protocols, advanced security and privacy analytics (e.g., big data methods for searching for precursory signals), and the quantitative treatment of the human factor. We have patented lightweight cryptographic protocols and developed practical (industry relevant) food supply chain management solutions based on RFIDs.

Prof. dr. Denis Trček
denis.trcek@fri.uni-lj.si

Laboratory for Cognitive Modelling

The laboratory pursues research in machine learning, neural networks, statistics, image, text and data mining. Recent research has been related to the generation of semi-artificial data, the analysis of big data with the MapReduce approach, , text summarisation using archetypal analysis, web-user profiling, applying evolutionary computation to data mining, spatial data mining with multi-level directed graphs, bottom-up inductive logic programming, heuristic search methods in clickstream mining, multi-view learning.

Prof. dr. Igor Kononenko
igor.kononenko@fri.uni-lj.si

Laboratory for Data Technologies

Areas of interest include data acquisition, management, integration, analysis and visualisation, all within the framework of information system development, management and governance. Special interest is devoted to internet of things, big data, real-time data management, the analysis of large networks, data streams, information extraction, etc. We work closely with industry partners in developing and testing new technologies and approaches.

Prof. dr. Marko Bajec
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Laboratory for Adaptive Systems and Parallel Processing

Our research topics include development of adaptive algorithms in areas of artificial neural networks, data clustering, data mining, information-theoretic modelling and reinforcement learning, and design of computer systems, ranging from high performance computing to on-chip designs. We are mainly focused on problems where the lack of theoretical knowledge prevents exact solutions and where special software and hardware are demanded for efficient processing. One of our main current areas encompasses efficient hardware implementations of deep neural networks. We are also involved in digital logic design of arithmetic circuits, processing on GPUs, smart wireless sensor networks, experimental research in the field of wireless networks, radio-based localization and software-defined radio.

Prof. dr. Branko Šter
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Laboratory for Algorithmics

We conduct research in the areas of approximation and randomised algorithms, linear algebra (matrix multiplication), combinatorial optimisation (routing, problems on graphs, issues regarding the robustness of a facility location), parallel computation (algorithm mapping and scheduling, algorithms in parallel systems, hardware supported multithreading, dataflow computing), algorithm engineering and experimental algorithmics (boosting algorithm efficiency in practice), compiler design (parsing methods, attribute grammars), operating system design, grid computing (data replication on data grids), as well as computability and complexity theory.

Prof. dr. Borut Robič
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Bioinformatics Laboratory

Bioinformatics lab does research in machine learning and data visualization. Our inspiration stems from solving problems from systems biology, biomedicine, and natural sciences. The laboratory is developing Orange (*https://orange.biolab.si*), a popular data mining suite that combines machine learning and interactive data visualizations. Orange is a powerful tool yet simple to use, and we believe data science should be accessible to everyone.

Prof. dr. Blaž Zupan
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Information Systems Laboratory

The laboratory is involved in research in the field of software development processes, IT project management and business analytics. We have extensive experience in improving traditional and agile software development processes in enterprises as well as improving the usefulness of large information systems. We apply advanced analytical approaches to solve business and societal problems in cooperation with our academic, industry and institutional partners.

Assoc. Prof. dr. Damjan Vavpotič
damjan.vavpotic@fri.uni-lj.si

Computer Structures and Systems Laboratory

The laboratory is focused on the computational methods for modelling, simulation and analysis of complex systems, and on mobile sensing, anticipatory mobile computing, and the analysis of mobile data traces. Modelling and simulation approaches are applied in the fields of systems biology, systems medicine and synthetic biology, in the analysis of coordinated behaviour in biological systems, and in the design of Quantum-dot Cellular Automata processing structures. Laboratory thus consists of four groups, i.e. the Computational Biology Group, the Collective Behaviour Group, the Quantum-dot Cellular Automata group and the Mobile Computing Group.

Prof. dr. Nikolaj Zimic
nikolaj.zimic@fri.uni-lj.si

Computer Vision Laboratory

We research the capture, processing and interpretation of 2D and 3D visual data, machine learning in computer vision, and the use of images in computer-human interactions. We work in the following specific areas: interactive visual signage systems, 3D documentation in archaeology and cultural heritage, interpretation of images in biometry, medicine, geology and meteorology, the forensic analysis of images and video, virtual and augmented reality, as well as in the production of computer games and in new media art installations (in cooperation with the Academy of Fine Arts).

Prof. dr. Franc Solina
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Artificial Intelligence Laboratory

The laboratory carries out research in machine learning (particularly argument based machine learning, inductive logic programming, robot learning), qualitative reasoning with robotics applications, intelligent robotics (planning, learning for planning), machine learning in medicine, and intelligent tutoring systems (ITS for programming and game playing, automated hint generation and the automatic assessment of the level of difficulty of problems for humans).

Assist. Prof. dr. Aleksander Sadikov
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Laboratory for Integration of Information Systems

The laboratory has established strong foundation in service computing, cloud computing, digital transformation and Blockchain technologies. It conducts research in the field of the integration and interoperability of applications, cloud-native architectures, microservices and APIs, blockchain and smart contracts, devices, information systems, architectures and platforms. We focus on software architectures, platforms, design patterns. We work on technologies for the execution, monitoring and optimization of business processes and on IoT integration and mobility issues, including localization, authentication and gait analysis algorithms.

Prof. dr. Matjaž Branko Jurič
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Computer Communications Laboratory

Our research is focused on communication networks and protocols, cloud-native architectures and services, cloud and network security, virtualization and containerization. We have researched the orchestration of complex virtual environments, examined SDN/NFV, single packet authorization within software defined perimeter architecture as well as their use in IoT and cloud environments, and developed our own virtual cloud laboratory. Our latest projects focus on carrier-grade container solutions and deploying AI/ML projects/pipelines to production at scale.

Assoc. Prof. dr. Mojca Ciglarič
mojca.ciglaric@fri.uni-lj.si

Software Engineering Laboratory

The laboratory is involved in teaching and research in the areas of software engineering and information systems, with an emphasis on agile software development methods (i.e. factors affecting successful adoption, agile project management, performance evaluation, the introduction of lean concepts, and similar), graph grammars and graph algorithms (parsing graph grammars, etc.), model driven development (reverse engineering, domain specific languages), and web data mining (stochastic models for user behaviour analysis, separating interleaved web sessions, etc.).

Prof. dr. Viljan Mahnič
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Laboratory for Mathematical Methods in Computer and Information Science

We are involved in research in various spheres of continuous and discrete mathematics. On the one hand our research topics include commutative algebra, linear algebra, nonlinear dynamical systems, Brownian motion, martingales, algebraic topology, computational topology, topological data analysis and scientific computing. On the discrete side of the mathematical spectrum, however, we deal with problems in graph theory, particular the structural and colouring problems of graphs, which are also connected to problems in computational geometry.

Assist. Prof. dr. Žiga Virk
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Visual Cognitive Systems Laboratory

The laboratory is involved in basic and applied research of visually enabled intelligent systems. Our research interests include computer vision, machine (deep) learning, and cognitive robotics. We have extensive experience with visual object tracking, object detection and categorization, image segmentation, incremental visual learning, as well as with systems for human-robot interactive learning and development of computer vision solutions for smart mobile devices and industrial applications. Our experience has been accumulated in collaboration with a variety of research partners in a number of EU, national and industry funded projects addressing these research topics.

Assoc. Prof. dr. Danijel Skočaj
danijel.skocaj@fri.uni-lj.si

Research Projects

Research work at the Faculty is carried out in 19 different laboratories. It is made through various projects funded by the European Commission, the Slovenian Research Agency, industrial partners and other funding agencies.

Moreover, some important bottom-up initiatives, in which the Faculty actively participates, are the Strategic Research and Innovation Partnerships (SRIP). The latter were initiated in order to enhance cooperation between different stakeholders (universities, research centres, SMEs, etc.) by mutual coordination of R&D activities, sharing of capacities, developing of human resources, exchanging of knowledge and experience, as well as networking and collective representation of interest abroad. The Faculty is active in 5 different SRIPs: Smart cities and communities, Smart buildings and homes, including wood chain, Sustainable food production, Sustainable tourism, Factories of the Future. Currently, the SRIPs are in the realisation phase of their roadmaps, i. e. action plans (≈ business-development strategies).

Industrial projects

The Faculty is participating on 30 projects funded by different institutions and industry partners, including: NIL Data Communications Ltd. • U-blox AG • Ministry of Public Administration • AŽD PRAHA s.r.o. • Kolektor Group d.d. • Genialis d.o.o. • Mladinska Knjiga Založba d.d. • Ema d.o.o. • Sidera d.o.o. • Nela razvojni center d.o.o. • Agency for communication networks and services of the Republic of Slovenia • Slovenian Environment Agency • Euro plus d.o.o. • ITS4P d.o.o. • Slovenia control, Slovenian Air Navigation Services, Ltd • Smart Blood Analytics Swiss SA • UCS d.o.o. • DFG Consulting d.o.o. • Menina d.d. • NERVteh Ltd • Garex Adria d.o.o. • IPMIT d.o.o. • University College London • Marand d.o.o. • BSP Regionalna Energetska Borza d.o.o. • ISKRATEL Ltd.

its4p
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euro plus
ublox
AZD PRAHA
Mladinska knjiga
Smart Blood Analytics
NIL
UCS universal customization system
NELA
MARAND
sidera
UCL
garex
KOLEKTOR
KOLEKTOR GROUP
OFG CONSULTING D.O.O.
NERVTEH
SOUTH POOL
MeninA
REPUBLIC OF SLOVENIA
MINISTRY OF PUBLIC ADMINISTRATION
AKOS
ISKRATEL
ARCTUR
SLOVENIA CONTROL

Projects funded by the European Commission

CROSSBOW – CROSS BOrder management of variable renewable energies and storage units enabling a transnational Wholesale market • FLEXICIENCY – Energy Services Demonstrations of Demand Response, Flexibility and Energy Efficiency Based on Metering Data • DIGITRANS - Digital Transformation in the Danube Region • GETM3 – Global Entrepreneurial Talent Management • HUBLINKED -Strengthening Europe's Software Innovation Capacity • MiCREATE – Migrant Children and Communities in a Transforming Europe • SWITCH – Software Workbench for Interactive, Time-Critical and Highly Self-Adaptive Cloud Applications • MONROE RICERCANDO – Rapid Interpretation and Cross-Experiment RootCause Analysis in Network Data with Orange: Ricercando • SILICOFCM – In Silico trials for drug tracing the effects of sarcomeric protein mutations leading to familial cardiomyopathy

Other international projects

Digital forensics: evidence analysis via intelligent systems and practices • COSTNET – European Cooperation for Statistics of Network Data Science • GAMENET – European Network for Game Theory • Citizen science to promote creativity, scientific literacy and innovation throughout Europe • CRYPTACUS – Cryptanalysis of ubiquitous computing systems • CRYPTOACTION - Cryptography for Secure Digital Interaction • RECODIS – Resilient communication services protecting end-user applications from disaster-based failures • JRC CDP – Joint Research Centre – Collaborative Doctoral Partnership • cHiPSet – High-Performance Modelling and Simulation for Big Data Applications

Current Structural funds and other national projects

BioPharm.SI: Next Generation of Biologics • EkoSMART – a Smartcity Ecosystem • GOSTOP – Building Blocks, Tools and Systems for the Factories of the Future • Tourism 4.0 • SocioPower • Towards quality of Slovene textbooks • Reading Literacy and Development of Slovenian Language • Natural Science and Mathematical Literacy: Promoting Critical Thinking and Problem Solving • Digital UL • Direct communication between the participants in a construction project • The development of microservices with support for the blockchain technology and its application on the domain of CRM systems • eQuiz • Computational support for identification of genetic predispositions and diagnosis of complex diseases • TraPri: Tradition meets the future – computer vision and augmented reality for the preservation and promotion of natural and cultural heritage • Cultural heritage: documenting contemporary art with new technologies • SloRaDe: Slovenian Computer Heritage • InfoZdrav: Information system for management of samples, material and chemicals in health care • Micro:bits in school • Portal for Cryptography and Computer Security • An introduction of video distance measuring of ski jumps in Ski jumping club Mengeš • SLEDIMedO: Tracker of media announcements • Upgrade of Corpuses Gigafida, Kres, ccGigafida and ccKress • Thesaurus of Modern Slovene: By the Community for the Community • Planning of Algorithms and Programming Teaching, and organizing of Community of Practice

Current programmes, basic research and applied projects, bilateral and other projects funded by the Slovenian Research Agency

Pervasive Computing • Centre for Language Resources and Technologies of University of Ljubljana • DNA sampling II: A method for identification of directly bound proteins at specific loci on bacterial chromosomes • ClolesteROR in metabilic liver disease • Detection of inconsistencies in complex visual data using deep learning • Metabolic and inborn factors of reproductive health, birth • Computational and data visualisation approaches to mining of large-scale data in single-cell genomics • Thinking folklore: dialect and supra-dialect of folclore as folkloristic, ethnological, semantic and computational problem • Molecular and other prognosticators of lung cancer and mesothelioma Advancement of computationally Intensive methods for efficient modern general-purpose statistical analysis and inference • Advanced sensing technologies and modelling for sulfur compounds in food cold chain traceability • New grammar of modern standard Slovene: resources and methods • Augmented Reality and Drones in Archaeology: Smart Fruition and Geo-localized Multimedia Contents • Graph Optimisation and Big Data • Computer Vision • Decomposing cognition: Working memory mechanism and representations • Development of an open-source platform for multivariate analysis of FTIR data • Robust computer vision methods for autonomous boats • Segmentation and recovery of superquadrics • Synergy of the technological systems and processes • Guidelines for destination management based on carryng capacity and tourism flows models • Web-based eBooks with activities: internationalization of Natural Language Processing • Effectiveness of different types of scaffolds in self-regulated e-learning • Artificial intelligence and inteligent systems • Deep Models for Image Embedding in Systems Biology of a Social Amoeba Dictyostelium • Multiobjective discovery of driving strategies for autonomous vehicles • Pathogenic role of paraspeckle-like nuclear bodies in neurodegenerative diseases ALS and FTD • Parallel and distributed systems • Design of information-technology solutions in support of data-based implementation of Common agricultural policy of the EU

Horizon 2020

Interreg
Danube Transnational Programme

Erasmus+

Marie Curie Actions

arrs
SLOVENIAN RESEARCH AGENCY

REPUBLIC OF SLOVENIA
MINISTRY OF EDUCATION, SCIENCE AND SPORT

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

The project is cofinanced by the Republic of Slovenia and by the European Union through the European Regional Development Fund.

REPUBLIC OF SLOVENIA
MINISTRY OF EDUCATION, SCIENCE AND SPORT

EUROPEAN UNION
EUROPEAN SOCIAL FUND

Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia

The project is cofinanced by the Republic of Slovenia and by the European Union through the European Social Fund.

EkoSMART, A Smartcity Ecosystem

Project Type:
Structural Funds Project

Project Coordinator:
Marand Ltd, Slovenia

Principal Investigator at FRI:
Prof. dr. Marko Bajec
marko.bajec@fri.uni-lj.si

Project duration:
2016–2019

Collaborating Laboratories:
Laboratory for Data Technologies
Laboratory for Ubiquitous Systems
Artificial Intelligence Laboratory
Computer Communications Laboratory
Visual Cognitive Systems Laboratory
Laboratory for Integration of Information Systems

The purpose of the EkoSMART programme is to develop a smart city ecosystem with all the support mechanisms required for the efficient, optimised and gradual integration of various smart city areas into a unified and well-connected system of value chains. The programme focuses on three key pillars for smart cities (health, active life and mobility) and is strategically linked with municipalities and other important smart city domains, such as energy, smart buildings, citizen involvement and engagement, and smart communities. EkoSMART introduces a universal architecture for a smart city that is based on self-learning and self-optimising agents which can find a common Nash equilibrium between heterogenous sources. This architecture allows for the realisation of smart city concepts such as interoperability, adaptability, self-configurability, open data, semantic interoperability and the integration of social capital. In economic terms, the vision of the EkoSMART programme is to enable Slovenian smart city innovations and products to enter the global market. This vision will be achieved through the following key approaches: the concentration of a critical mass of knowledge and experience; a focus on the user; evolutionary development; and flexible architecture.

The EkoSMART programme differs from other initiatives in the following ways: there is an emphasis on electronic and mobile health and mobility as the pillars of smart cities; it introduces modular, self-configurable, self-optimising, flexible, adaptable and intelligent universal architecture; there is an intensive focus on the development and implementation of new ICT methods and concepts such as the Internet of things and artificial intelligence for the continued development of technology and human society; it is based on a high-quality consortium of advanced partners, and is therefore also strategically linked to smart home and health programmes; it puts strong emphasis on smart specialisation, i.e. the introduction of interconnected citizen, technology and market value chains.

BioPharm.SI, Next Generation of Biologics

Project Type:
Structural Funds Project

Project Coordinator:
Centre of Excellence for Biosensors, Instrumentation and Process Control, Slovenia

Principal Investigator at FRI:
Prof. dr. Blaž Zupan
blaz.zupan@fri.uni-lj.si

Project duration:
2016–2020

Collaborating Laboratory:
Bioinformatics Laboratory

Biologics are one the latest and perhaps the most complex achievements of medicine. Biologics are drugs that are more specific, with fewer side effects, enabling treatment of previously incurable diseases. Slovenia has achieved great successes in this field: the first biosimilar approved in the US was developed by the Slovenian company Lek and by the National Institute of Chemistry. The manufacturing of biologics is mainly challenged by the complexity of the molecules (proteins) produced by genetically modified cells in precisely controlled environments-bioreactors, while small modifications of the producing cell line, production environment or conditions might impact product quality and efficacy. In the Bioinformatics Laboratory we are collaborating with Lek and other partners of BioPharm.SI to develop the data science infrastructure needed to monitor, store, organise and mine the data from the production. Our aim is to relate production parameters with quality estimates and to optimise the production process. To achieve this, the Bioinformatics Laboratory is adapting its data mining suite Orange, developing data access components, and designing new data visualisation and mining tools to address specific data types and observations and to model the related processes.

GOSTOP, Building Blocks, Tools and Systems for the Factories of the Future

Project Type:
Structural Funds Project

Project Coordinator:
The Jožef Stefan Institute

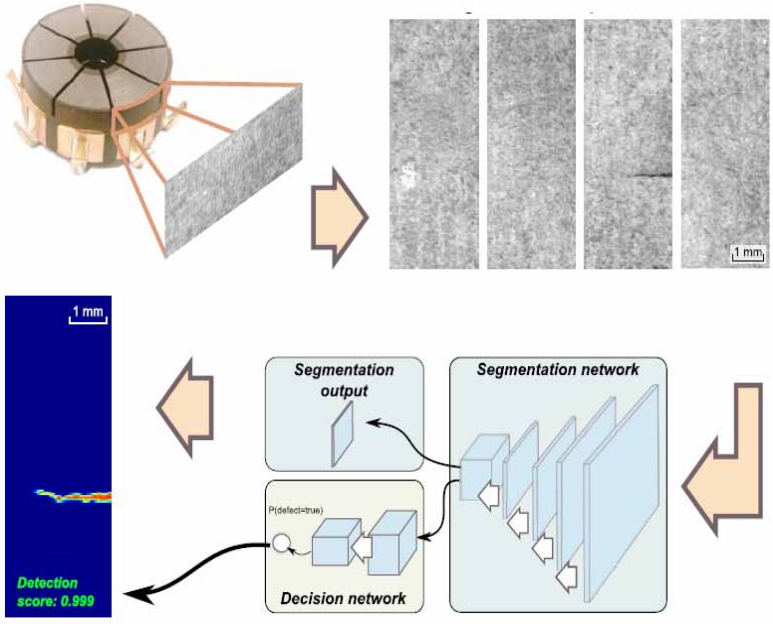
Principal Investigator at FRI:
Assoc. Prof. dr. Danijel Skočaj
danijel.skocaj@fri.uni-lj.si

Project duration: 2016–2020

Collaborating Laboratories:
Visual Cognitive Systems Laboratory

The aim of the proposed GOSTOP programme is to accelerate the development of the Factories of the Future concept in Slovenia and to provide solutions to the current needs of Slovene industry. In GOSTOP, a total of 13 companies and six research organisations which had compatible research and development programmes in the Factories of the Future concept joined forces to push forward its development. Four areas were identified in which decisive breakthroughs could be achieved in Slovenia in the near future: control technologies, tooling, robotics, and photonics.

The Faculty of Computer and Information Science is collaborating with other partners in the area of robotics. The main goal is to develop flexible and adaptable technologies that would allow for fast and simple adaptation to a new product in the production process. One of the major enabling technologies in this respect is machine vision. Our goal is to develop efficient machine vision algorithms, coupled with machine learning approaches, which would allow for fast and flexible adaptation of visual inspection systems to be able to deal with novel quality control problems. We base our research on the latest developments in deep learning and develop novel algorithms that are able to replace the need for handcrafting solutions for individual problem domains with a more general approach based on learning a solution by observing a number of exemplar images.



Tourism 4.0 – Enriched Tourist Experience

Project Type:
Structural Funds Project

Project Coordinator:
Arctur d.o.o., Slovenia

Principal Investigator at FRI:
Assist. Prof. dr. Tomaž Curk
tomaz.curk@fri.uni-lj.si

Project duration:
2018–2021

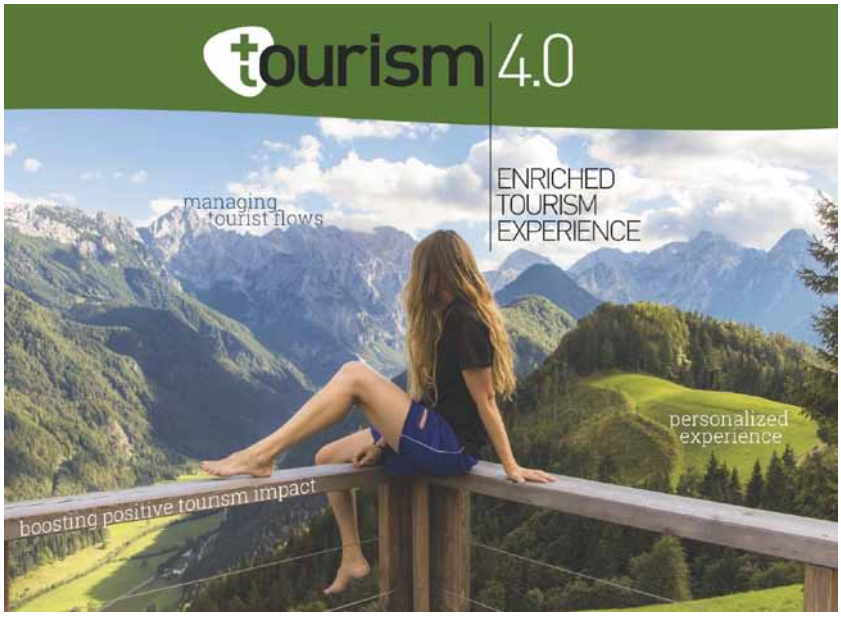
Collaborating Laboratories:
Bioinformatics Laboratory
Laboratory for Data Technologies
Information Systems Laboratory

Project partners:
Arctur d.o.o., Slovenia
Faculty of Tourism Studies – Turistica, University of Primorska
Faculty of Tourism, University of Maribor

The research project is supported by the Association of Municipalities and Towns of Slovenia (SOS).

Tourism industry is growing rapidly. With more than 1.3 billion tourists yearly around the world an implementation of a small change in the sector can have a huge impact on the whole society. Therefore, a paradigm shift is called for and new technologies are at the centre of it. The biggest research and development project in Slovene history, called Tourism 4.0, is addressing this challenge. Based on the modern paradigm known as Industry 4.0, the project aims to improve the added value to tourism through innovation and creativity. With the help of key enabling technologies from the Industry 4.0, such as IoT, Big Data, Blockchain, AI, VR and AR, we plan to developed tools to help manage tourist flows while respecting the user's data privacy and easing the negative impact of tourism on local community and environment.

Our goal is to unlock the innovation potential in the tourism sector to affect every field around it by creating an ecosystem in which infrastructure, people and technology behind it merge into one seamless experience of many personalized outputs. The research project is supported by several government institutions that also strive to support and engage all stakeholders in the tourism ecosystem in order to take lead in the development of Tourism 4.0 and make Slovenia its testbed.



Improving the Quality of Slovene Textbooks

Project Type:
Structural Funds Project

Project Coordinator:
University of Ljubljana, Faculty of Education, Slovenia

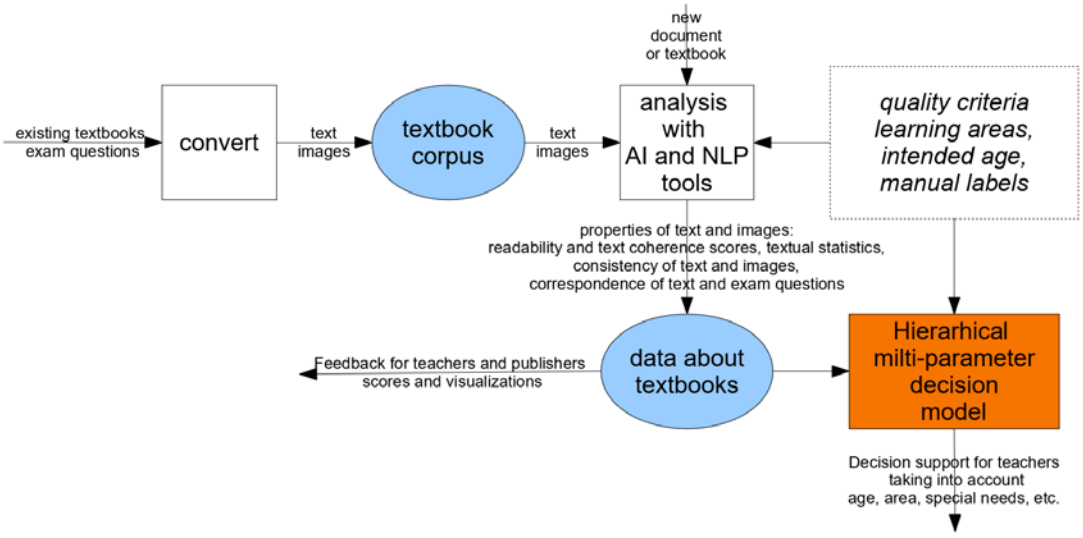
Principal Investigator at FRI:
Prof. dr. Marko Robnik-Šikonja
marko.robnik@fri.uni-lj.si

Project duration:
2017–2022

Collaborating Laboratory:
Laboratory for Cognitive Modeling

The goal of the project is to develop quality metrics for Slovene primary and secondary school textbooks. The UL FRI research group is developing a prototype of an automatic web-based tool, which will allow the evaluation of textbooks based on their textual and pictorial properties. The tool will support the decision-making process for selection of an appropriate textbook.

UL FRI researchers adapted, developed and implemented several readability metrics for the Slovene language. They also used techniques from natural language processing, machine learning, and image recognition to assess readability and text coherence. The decision support will be implemented through a hierarchical multi-parameter decision model, which will be flexible enough to capture the requirements of different areas (social, humanistic and natural sciences), different age groups, education levels, special needs of pupils and so on. The tool will be open-source and publicly available, and will provide a feedback on text readability and coherence.



Thesaurus of Modern Slovene: By the Community for the Community

Project Type:
National Project funded by the Slovenian Ministry of Culture

Principal Investigator at FRI:
dr. Špela Arhar Holdt
spela.arhar@cjvt.si

Project duration:
2018–2019

Collaborating Laboratory and centre:
Laboratory for Cognitive Modeling
Centre for Languages Resources and Technologies

The Thesaurus of Modern Slovene [*http://viri.cjvt.si/sopomenke/eng/*] is the first example of a responsive dictionary, a new type of digital language resource initially compiled using advanced computational methods, then further developed (e.g. through data editing and cleaning) in collaboration with the language community. The purpose of the project is to promote this new type of resource among potential users, with particular emphasis on the user groups that find synonym information invaluable in their work. Within the project, a number of promotional events such as workshops are being organised, resulting in open-access educational materials [*https://www.cjvt.si/promocija-sopomenk/*]. In addition, based on the data collected through advanced monitoring of user feedback and dictionary use, the Thesaurus will be upgraded with elements that will further motivate user participation.

Špela Arhar Holdt, Jaka Čibej, Kaja Dobrovoljc, Apolonija Gantar, Vojko Gorjanc, Bojan Klemenc, Iztok Kosem, Simon Krek, Cyprian Laskowski, Marko Robnik Šikonja (2018) Thesaurus of Modern Slovene: By the Community for the Community, Ljubljana University Press, Faculty of Arts (eds.: Jaka Čibej, Vojko Gorjanc, Iztok Kosem, Simon Krek), 401-410.

Digital UL – with innovative use of ICT towards excellence

Project Type:
Structural Funds Project

Project Coordinator:
University of Ljubljana, Slovenia

Principal Investigator at FRI:
Assoc. Prof. dr. Mojca Ciglarič
mojca.ciglaric@fri.uni-lj.si

Project duration:
2018–2020

Collaborating Laboratories:
Computer Communications Laboratory

The project team includes representatives of 26 UL faculties, 45 study programme coordinators, dydactic experts, experts for innovative technological environments and multimedia, as well as numerous professors who will try innovative ICT-based methods within their courses. The analysis already revealed a wide spectre of ICT use at UL. Several events with foreign guests are planned to reveal also good practices from academy in other countries. In the next phase, the University Centre for innovative didactic approaches based on ICT will be set up. The centre members will present the directions for innovative use of ICT to UL staff, they will also organize pilot courses based on innovative ICT use at every faculty, pilots will be later evaluated and analysed and directions for subsequent work will be promoted. Within the centre, a collaborative environment with technology support services will be set up, where all the services – didactic, multimedia and tech support – will be hosted.

Good experiences from pilot courses will be sustainably built into existing study programmes, while the quality of new methods will be evaluated periodically.

Beside taking part in one pilot course, the main role of UL FRI is in the design and architecture of technology support - collaborative environment and later reliability and high availability of the Centre infrastructure.

FLEXICIENCY, Energy Services Demonstrations of Demand Response, FLEXibility and Energy effICIENCY Based on Metering Data

Project Type:
EU project – H2020

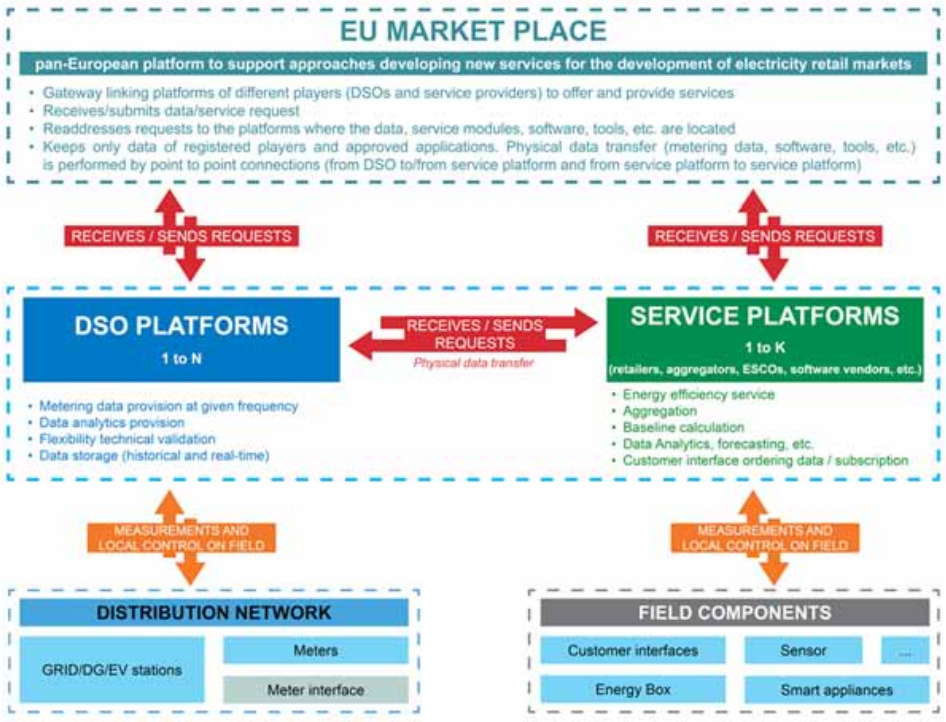
Project Coordinator:
Enel Distribuzione s.p.a., Italy

Principal Investigator at FRI:
Prof. dr. Matjaž Branko Jurič
matjaz.juric@fri.uni-lj.si

Project duration:
2015–2019

Collaborating Laboratories:
Laboratory for Integration of Information Systems

The aim of the FLEXICIENCY project is to address flexibility and efficiency within the European energy market, putting the focus on consumers and making use of data from smart metering. More specifically, the project's mission is to create new opportunities for the energy business and expand the DSO's market facilitator role for new services. As neutral players in the market, they can support the creation of new business opportunities and innovative services for end users, based on consumer data collected by smart meters. The initiative marks an important step towards the achievements of 2020 energy consumption and CO2 emissions targets through the development of advanced energy services and the implementation of new policies and market regulations that promote the creation of smart grids. The activities in 2017 covered research and development activities on the EU Market Place – management of regulated and nonregulated services, integration between the EU Market Place and Market Player platforms for an effective data exchange, as well as management of service activities.



CROSSBOW, CROSS BOrder Management of Variable Renewable Energies and Storage Units Enabling a Transnational Wholesale Market

Project Type:
EU project – H2020

Project coordinator:
ETRA Investigación y Desarrollo S.A., Spain

Principal Investigator at FRI:
Prof. dr. Matjaž Branko Jurič
matjaz.juric@fri.uni-lj.si

Project duration:
2017–2021

Collaborating Laboratory:
Laboratory for Integration of Information Systems

The CROSSBOW project aims at the successful deployment of a set of technological solutions which will make it possible to increase the shared use of resources to enable transmission networks to carry out the cross-border management of variable renewable energies and storage units. This will enable the higher penetration of clean energies whilst reducing network operational costs and improving the economic benefits of RES and storage units.

The project will demonstrate a number of different technologies offering TSOs increased grid flexibility and robustness through the following improvements: better control of cross-border balancing energy at interconnection points; new storage solutions – distributed and centralised-, offering ancillary services to operate Virtual Storage Plants (VSP); better ICT and communications – i.e., better network observability, enabling flexible generation and Demand Response schemas and the definition of a transnational wholesale market, proposing fair and sustainable remuneration for clean energies though the definition of new business models supporting the participation of new players and the reduction of costs.

SWITCH, Software Workbench for Interactive, Time Critical and Highly Self-Adaptive Cloud Applications

Project Type:
EU project – H2020

Project coordinator:
Universiteit van Amsterdam, The Netherlands

Principal Investigator at FRI:
Prof. dr. Marko Bajec
marko.bajec@fri.uni-lj.si

Project duration:
2015–2018

Collaborating Laboratory:
Laboratory for Data Technologies

The SWITCH project addresses the urgent industrial need for developing and executing time critical cloud applications. Time critical applications, such as disaster early warning, collaborative communication and live event broadcasting, can only realise their expected business value when they meet critical requirements for performance and user experience. The very high requirements on network and computing services, particularly for well-tuned software architecture with sophisticated data communication optimisation, mean that the development of such time critical applications is often customised to dedicated infrastructure, and system performance is difficult to maintain when this infrastructure changes. This fatal weakness in the existing architecture and software tools yields very high development costs, and makes it difficult fully to utilise the virtualised, programmable services provided by networked clouds to improve system productivity. SWITCH aims at improving the existing development and execution model of time critical applications by introducing a novel conceptual model, the application-infrastructure co-programming and control model, in which application Quality of Service (QoS)/Quality of Experience (QoE), together with the programmability and controllability of the cloud environments, can all be included in the complete lifecycle of applications.

Based on this conceptual model SWITCH provides: a SWITCH Interactive Development Environment (DRIP) - an interactive environment for developing applications and controlling their execution; a Distributed Real-time Infrastructure Planner (DRIP) – a real-time infrastructure planner for deploying applications in clouds; and an Autonomous System Adaptation Platform (ASAP) – for monitoring and adapting system behaviour. The SWITCH consortium has well-balanced partners with complementary expertise from both academic and industrial backgrounds. By demonstrating the software using diverse use cases, the consortium specifically aims at exploitation of the business potential of the SWITCH results.

MONROE RICERCANDO, Rapid Interpretation and Cross-Experiment Root-Cause Analysis in Network Data with Orange: Ricercando

Project Type:
EU project – H2020

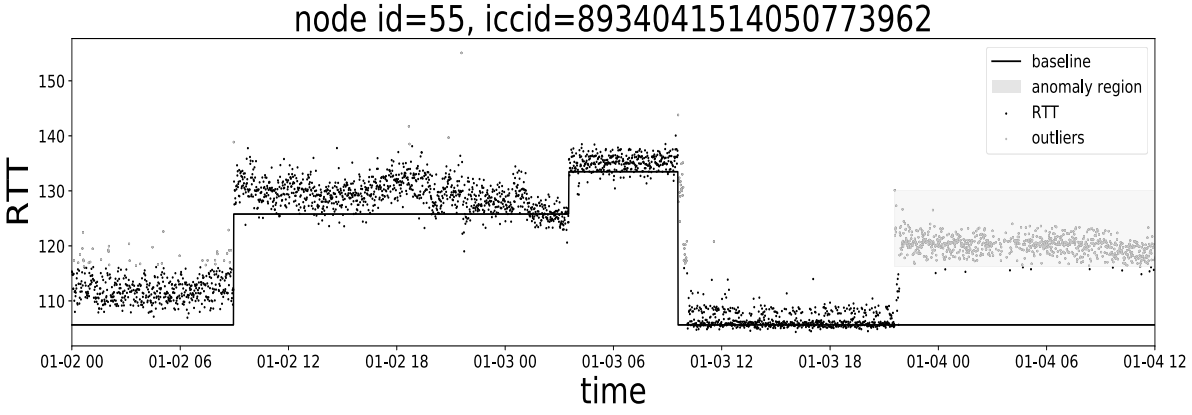
Project Coordinator:
Simula Research Laboratory, Norway

Principal Investigator at FRI:
Assist. Prof. dr. Veljko Pejović
veljko.pejovic@fri.uni-lj.si

Project duration:
2016–2018

Collaborating Laboratory:
Laboratory for Adaptive Systems and Parallel Processing
Bioinformatics Laboratory
Computer Structures and Systems Laboratory

Mobile broadband (MBB) networks have revolutionised the way we communicate, yet our understanding and means of troubleshooting such complex systems remain modest. The EU project MONROE (Measuring Mobile Broadband Networks in Europe) has designed, deployed and is currently operating the first European transnational open platform for independent large-scale monitoring and assessment of the performance of MBB networks (*https://www.monroe-project.eu*). Within the MONROE framework, project RICERCANDO (Rapid Interpretation and Cross-Experiment Root-Cause Analysis in Network Data with Orange), led by an interdisciplinary team of networking and data mining experts from the Faculty of Computer and Information Science of the University of Ljubljana, aims to advance tools for the integrative exploration, visualisation and interpretation of MBB data and meta-data across multiple experiments. The integration of these data with advanced data mining and interactive data exploration features supports human experts in the process of detecting and understanding the root-cause of the network problems and performance degradation. RICERCANDO tools are now available as open-source software at: *https://github.com/ivek1312/ricercando/*



Detecting ping round trip time (RTT) anomalies using RICERCANDO. Our tool compares measured RTT values with the expected behaviour inferred from a pre-built machine learning model (baseline).

DIGITRANS, Digital Transformation

Project Type:
EU project – Interreg Danube Transnational Programme

Project Coordinator:
MFG Innovation Agency Media and Creative Industries Baden-Württemberg, Germany

Principal Investigator at FRI:
Prof. dr. Matjaž Branko Jurič
matjaz.juric@fri.uni-lj.si

Project duration:
2017–2019

Collaborating Laboratory:
Laboratory for Integration of Information Systems

Digital technologies such as IoT, big data and cloud computing are dramatically changing the way business is being done. Transformations based on these technologies enable more comprehensive and systematic business models, while simultaneously lowering the overall costs to companies. One of the biggest challenges SMEs and start-ups face is the effective transition from current business models to new, technologically advanced and user-friendly ones.

The goal of the project is to adapt business models, activities and processes in an efficient way and make use of the opportunities digital technologies provide.

This will be achieved by: developing an appropriate innovation method which will enable SMEs to create competitive digital business models; establishing incubator premises in the partner regions based on the newly developed DIGITRANS method; developing online learning content and a method toolbox integrated into online learning platform; and teaching SMEs the skills needed to handle the transformation process. This will be done by providing appropriate training.

SILICOFCM, In Silico Trials for Drug Tracing the Effects of Sarcomeric Protein Mutations Leading to Familial Cardiomyopathy

Project Type:
EU project – H2020

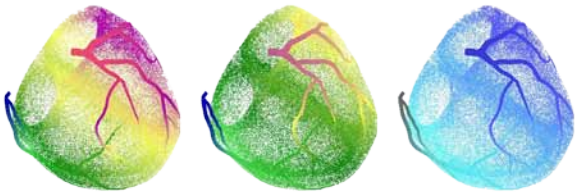
Project coordinator:
BioIRC Ltd, Serbia

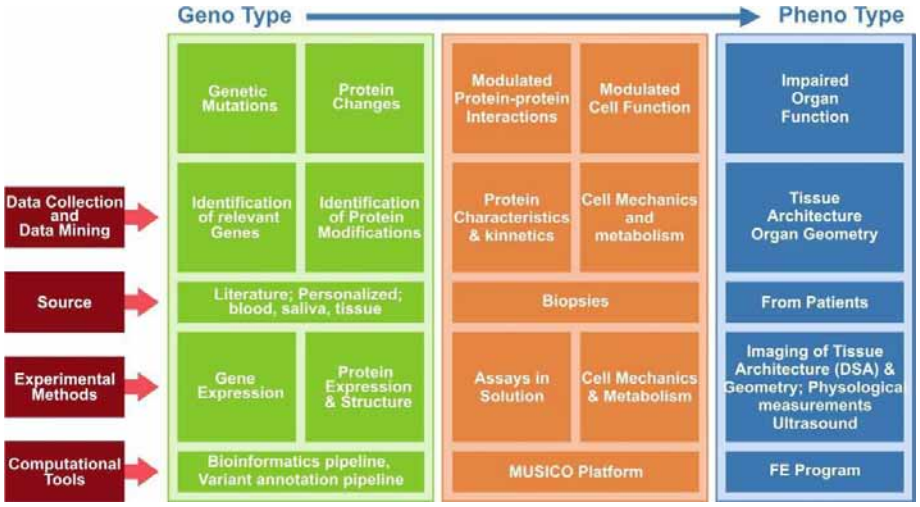
Principal Investigator at FRI:
Prof. dr. Zoran Bosnić
zoran.bosnic@fri.uni-lj.si

Project duration:
2018–2021

Collaborating Laboratory:
Laboratory for Cognitive Modeling

Cardiomyopathies are defined as abnormalities of the heart that are unexplained by the most frequent heart diagnoses. Familial cardiomyopathies (FCM) are most commonly diagnosed. Novel diagnoses and therapies need to be developed to affect the disease process and time course more fundamentally. Within the project, we will develop a cardiomyopathy risk stratification tool to mine heterogeneous patient data and thus provide an identification of high-risk patients (sudden cardiac death or life threating arrhythmias) that will be supplemented by prediction reliability estimates. We plan to adapt and evaluate the recently proposed algorithms for explanation of predictive models and predictions that will provide efficient and reliable identification of disease patterns from large volumes of heterogeneous and noisy data.





The developed tools will enable collection and analysis of patient-specific data. They will also aid the development of patient-specific models for monitoring and assessment through the progression of diseases.

HUBLinked, Strengthening Europe's Software Innovation Capacity

Project Type:
EU project – Erasmus+

Project coordinator:
Dublin Institute of Technology, Ireland

Principal Investigator at FRI:
Assoc. Prof. dr. Mojca Ciglarič
mojca.ciglaric@fri.uni-lj.si

Project duration:
2017–2019

Collaborating Laboratories:
Computer Communications Laboratory

By creating a sustainable strategic network of major European ICT hubs and Universities, the goal of HubLinked is to strengthen Europe's software innovation capacity by learning from regions of proven ICT strength. HubLinked will improve the effectiveness of university-industry linkages, help develop global software innovator graduates, and upskill academic and industry staff.

HubLinked has several deliverables: • effective linkages between faculties and companies; • the curriculum framework for industry-oriented, internationalised, innovation-focused and interdisciplinary computer science degrees; • global Labs – modules for international teams of students working together across time zones; • student exchange and placement opportunities; • online professional development opportunities for staff.

GETM3, Global Entrepreneurial Talent Management 3

Project Type:
EU project – H2020 MSCA RISE

Project coordinator:
University of Northumbria at Newcastle, United Kingdom

Principal Investigator at FRI:
Assoc. Prof. dr. Tomaž Hovelja
tomaz.hovelja@fri.uni-lj.si

Project duration:
2017–2020

Collaborating Laboratory:
Information Systems Laboratory

GETM3 focuses on young talent as a key driver of future development, developed through the co-operation of three stakeholders: employers (including MNC's and SME's), universities and students/graduates. Despite the widely recognised importance of young talent (e.g. Europe 2020), the potential of such individuals remains largely untapped. They are educated and entrepreneurial and yet experience instability in employment. At the same time, employers report skills mismatches and difficulties with attracting, managing and retaining young talent. To tackle this paradoxical situation, an innovative, multi-perspective approach is needed. The main objective of GETM3 is to improve employability and future global talent management to support economic development by capitalising on entrepreneurialism as a key characteristic of the young. To achieve this objective we aim to integrate research outputs and develop GETM3 across the following dimensions: generations, genders, disciplines, countries, sectors and stakeholders.

Higher-education partners on the project GETM3.

Industry partners on the project GETM3.

MiCREATE, Migrant Children and Communities in a Transforming Europe

Project Type:
EU project – H2020

Project coordinator:
Science and Research Centre Koper, Slovenia

Principal Investigator at FRI:
Assoc. Prof. dr. Matija Marolt
matija.marolt@fri.uni-lj.si

Project duration:
2019–2021

Collaborating Laboratory:
Laboratory of Computer Graphics and Multimedia

European countries and their education systems are encountering many challenges due to growing ethnic, cultural and linguistic diversity. The research project aims at a comprehensive examination of the contemporary integration processes of migrant children, analysis of the social impacts of these integration programmes, and development of integration measures and identification of social investments, particularly in educational policies and school systems, that aim to empower migrant children and build their skills.

To bring the fieldwork and desk research findings into practice, novel ways for stimulating the integration of migrants will be developed, including two ICT tools to be used by children: the Tool for Raising Awareness about Ethnic Diversity in Schools (an application which will allow interactive and real-time experience, where the users will be encouraged to take a challenge to spend one week as a migrant in a diverse institutional setting and context), and the Digital Storytelling Tool (an application that will enable the making of visual and written stories by children).

ICT tools stimulate the inclusion of diverse groups of migrant children.

Detection of Inconsistencies in Complex Visual Data Using Deep Learning

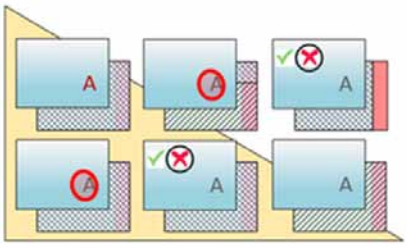
Project Type:
Basic research project funded by the Slovenian research agency

Principal Investigator at FRI:
Assoc. Prof. dr. Danijel Skočaj
danijel.skocaj@fri.uni-lj.si

Project duration:
2018–2021

Collaborating Laboratory:
Visual Cognitive Systems Laboratory

Obtaining a large amount of visual data has become a trivial task in today's technological world. However, making use of this enormous amount of data poses a huge challenge. Computer vision and machine learning, in particular deep learning, offer answers to these issues, although most of the proposed approaches rely on labelled training data. They thus still require a significant human effort for labelling the required amounts of data, which is very costly, tedious and sometimes error-prone, or even impossible. In this project we will address this issue for a particular computer vision task of anomaly detection in images. Our aim is to go beyond traditional supervised learning. The objective of the project is to develop novel deep learning methods for modelling complex consistency and detecting inconsistencies in visual data using training images annotated with different levels of accuracy. We will validate the developed methods in three related but different problem domains; visual inspection, remote sensing, and visual surveillance.



Guidelines for Destination Management Based on Carrying Capacity and Tourism Flows Models

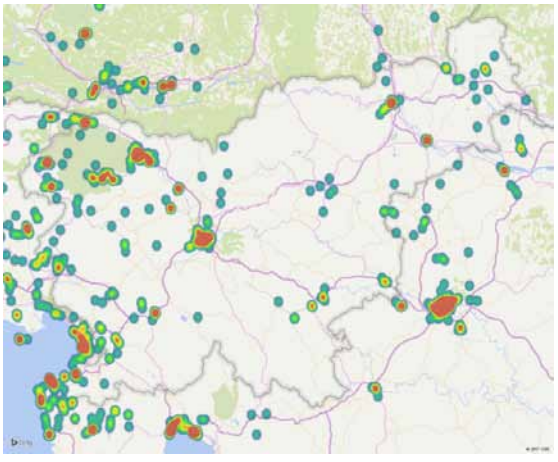
Project Type:
Target research programme funded by the Slovenian research agency and the Slovenian Ministry of Economic Development and Technology

Principal Investigator at FRI:
Assoc. Prof. dr. Damjan Vavpotič
damjan.vavpotic@fri.uni-lj.si

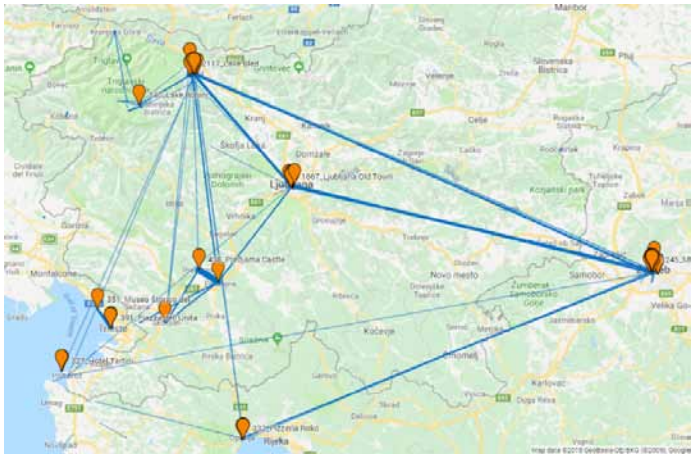
Project duration:
2018–2019

Collaborating Laboratory:
Information Systems Laboratory

The project will provide guidelines for sustainable management and in this way influence the reduction of environmental and social damage to the tourist economy in Slovenia and beyond its borders. The project is also aligned with goals of the Slovenian Tourism Development Strategy 2017-2021. This strategy's vision is to create five-star experiences of green, active and healthy boutique tourism products for all tourists visiting Slovenia. With customised data collection and analysis based on big data, we will be able to understand customers' needs better and to facilitate the process of developing such five-star experiences. The Slovenian tourist economy will thus become more competitive, and the country will consolidate its position as a green destination. The contribution of the project to the development of science is also significant. The project is built on the latest findings in the field of destination management, using advanced methodology and integration of the concept of visitor flows with that of carrying capacity. The project is performed in cooperation among the University of Ljubljana's Faculty of Economics (lead partner) and Faculty of Computer and Information Science, and the Scientific Research Centre of the Slovenian Academy of Sciences and Arts.



Heat map showing number of tourist posts in Slovenia.



Main tourism flows in Slovenia and its surroundings.

Design of information-technology solutions in support of data-based implementation of Common agricultural policy of the EU

Project Types:
Target research programme funded by the Slovenian research agency and the Slovenian Ministry of Economic Development and Technology

Principal Investigator at FRI:
Prof. dr. Blaž Zupan
blaz.zupan@fri.uni-lj.si

Project duration:
2018–2020

Collaborating Laboratory:
Bioinformatics Laboratory

Together with project partners from the Faculty of Social Sciences and the Chamber of Agriculture and Forestry of Slovenia, we are planning information technology solutions to integrate Slovene agricultural databases and provide support to decision makers in the field of agricultural policies. The role of UL FRI is primarily to identify and analyze the possibilities of using approaches from data science. We plan to develop several prototypes that will use the data from various databases and apply machine learning. We will implement the prototypes in our Orange data mining toolbox.

Thinking Folklore: Dialect and Supra-Dialect of Folklore as a Folkloristic, Ethnological, Semantic and Computational Problem

Project Type:
Basic research project funded by the Slovenian research agency

Principal Investigator at FRI:
Assoc. Prof. dr. Matija Marolt
matija.marolt@fri.uni-lj.si

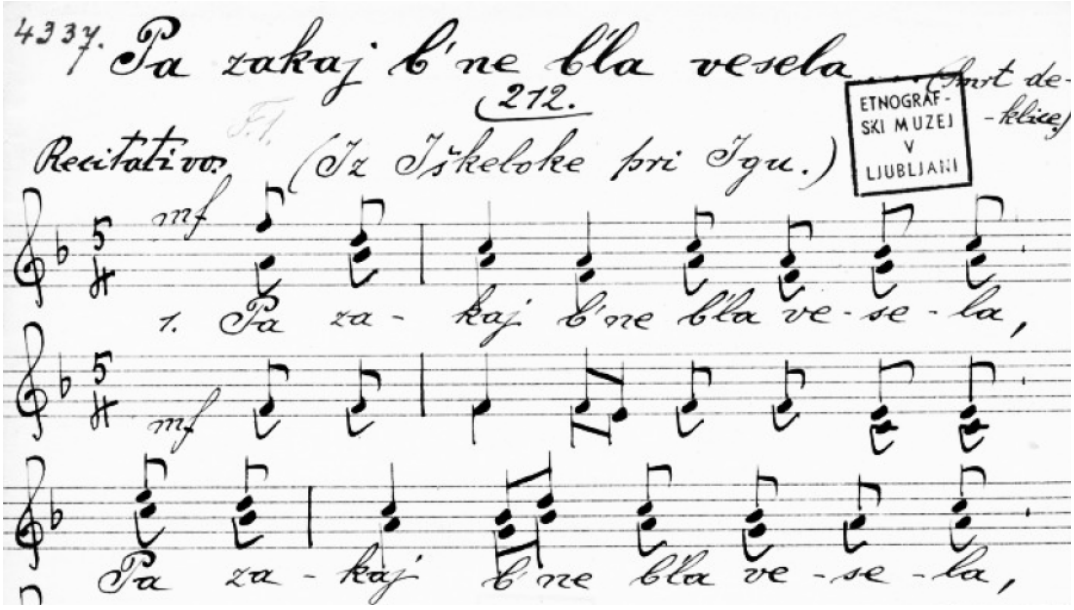
Project duration:
2018–2021

Collaborating Laboratory:
Laboratory for Computer Graphics and Multimedia

In the project Thinking Folkore we cooperate with the Ethnomusicological Institute of SRC SASA to address the question of dialect and supra-dialect of folk song. Specifically, we examine the transitioning between three types of language codes - dialect, literary language, and supra-dialect as an intermediate form of the two.

Our research work focuses on the development of novel audio analysis methods to automate the search for words in their different dialectal forms in folk music field recordings, and simultaneously quantify the phonetic differences between their pronunciations. We are developing new approaches that address the specifics of the materials, in particular the use of dialect, which can significantly deviate from the written transcriptions. On one hand, the developed methods will enable word searching in large collections of sound recordings, which will substantiate the textological analyses, and on the other hand also build the basis for the development of algorithms for the assessment of phonetic parameters of pronunciation in order to quantify the differences between dialect and supra-dialect in speech and singing.

Record of the folk song.



On the Feasibility of Using AKOSTEST.NET Data for Net Neutrality Violation Detection in Slovenia

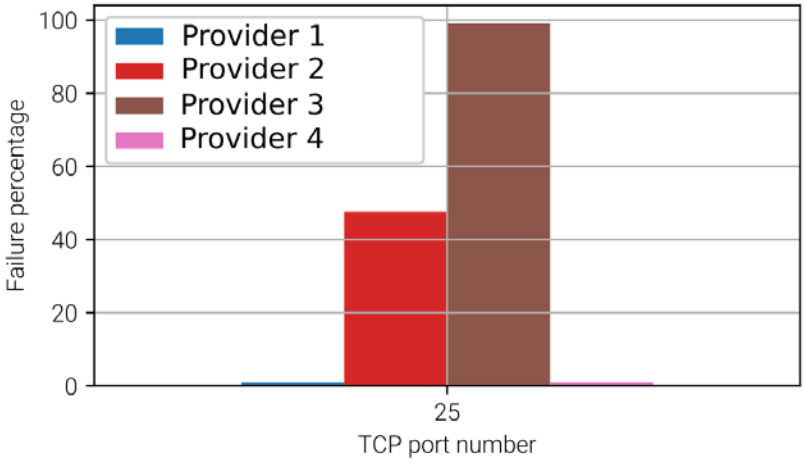
Project Types:
Industrial project

Principal Investigator at FRI:
Assist. Prof. dr. Veljko Pejović
veljko.pejovic@fri.uni-lj.si

Project duration:
2017–2018

Collaborating Laboratory:
Computer Structures and Systems Laboratory

Democratic principles, from freedom of speech to fair business practices, rely on Net neutrality, i.e. equal access to the communication infrastructure and services. While EU regulations stipulate Net neutrality the actual enforcement is challenging, as regulators have to collect and analyse a large amount of network measurements and pinpoint cases of neutrality violations. Through a large-scale distributed measurement campaign (akostest.net), the Agency for Communication Networks and Services of the Republic of Slovenia (AKOS) has acquired a massive dataset of Internet performance measurements in Slovenia. In this project we developed data mining and visualisation tools specifically tailored for the analysis of these data. We then analysed about one million multi-dimensional data records and identified practices, such as port blocking, that might violate the principles of Net neutrality. Finally, we proposed a holistic multi-stakeholder approach ensuring high quality measurement data upon which reliable Net neutrality violation inferences should be based.



TCP port 25 (often used for SMTP email service) blocking practices among four selected Slovenian operators (anonymised).

Development and Implementation of Data Model, Controls, and Software Tools for Air Quality Measurements

Project Type:
Industrial project

Principal Investigator at FRI:
Assoc. Prof. dr. Matjaž Kukar
matjaz.kukar@fri.uni-lj.si

Project duration:
2017–2020

Collaborating Laboratory:
Laboratory for Cognitive Modeling

Air quality measurements are an important part of environmental monitoring. With modernisation of the monitoring network in Slovenia enormous amounts of data are collected and analysed every day. However, the persistence of historical database organisation practices hampers efficient analytical work. Within the project we will collect and analyse existing user requirements and ongoing processes and suggest improvements in data modelling and organisation. Such improvements will serve as the blueprint for modernisation of database organisation aiming both at retaining compatibility with existing applications, whenever possible, and improving query performance. The modernised database will serve as a foundation for implementation of automatic services, based on statistical models and machine learning, for data quality control.

Smart Blood Analytics Swiss SA

Project Types:
Industrial project

Principal Investigator at FRI:
Assoc. Prof. dr. Matjaž Kukar
matjaz.kukar@fri.uni-lj.si

Project duration:
2018–2019

Collaborating Laboratory:
Laboratory for Cognitive Modeling

The main objective of this project is to establish a flexible and scalable approach to utilising machine learning predictors in the cloud, specifically to support medical diagnosis based on blood analysis. The massive commercial application of machine learning predictors can be a challenge, as they must be able to deal with wildly varying numbers of prediction requests. Conservative pre-allocation of estimated maximum required capacities in the cloud has two significant drawbacks: (1) cost: it is very likely that most of the time pre-allocated capacities will be underutilised, and therefore an unnecessary expense; and (2) inflexibility: how can we be sure that pre-allocated capacities are sufficient? If a spike in prediction requests exceeds our estimations, it may lead to unacceptably long response times, or even the system crashing. The UL FRI team will provide the expertise in machine learning and cloud computing, while Smart Blood Analytics Swiss SA's team will provide data and expertise for objective evaluation of results. This opens up opportunities for innovation in effective cloud-based deployment of predictive services. The main focus of collaboration is therefore building successful machine learning predictors utilising various medical blood tests and deploying them in a flexible and scalable cloud-based framework, based upon requirements and inputs provided by Smart Blood Analytics Swiss SA's research team and advisors.

Integrative Analysis of RNA-Protein Binding

Project Type:
Industrial project

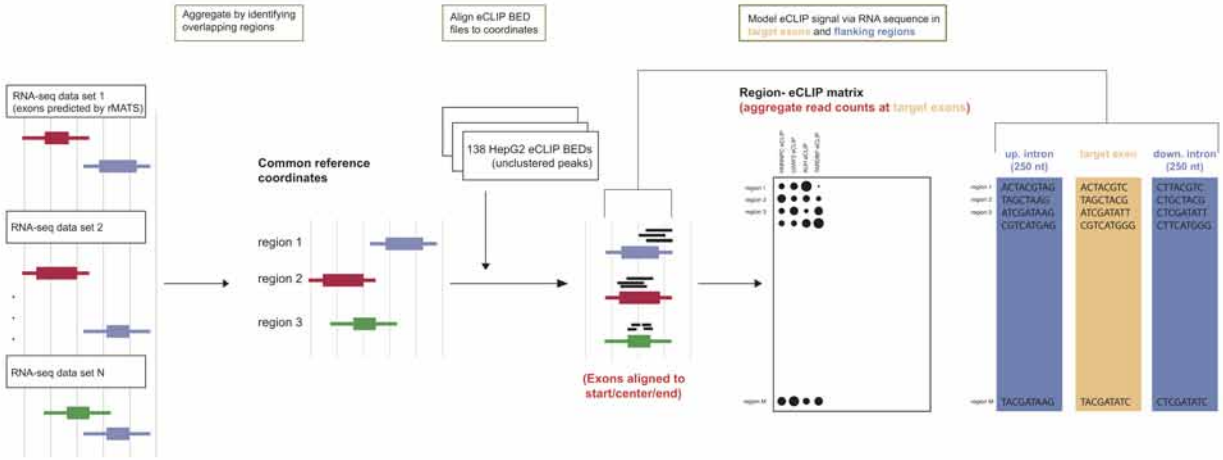
Principal Investigator at FRI:
Assist. Prof. dr. Tomaž Curk
tomaz.curk@fri.uni-lj.si

Project duration:
2016–2018

Collaborating Laboratory:
Bioinformatics Laboratory

One of the major challenges facing biologists is how to integrate experimental data with publicly available data. Recently, the American ENCODE project has produced vast amounts of data that can be of great use, but require new computational approaches and dedicated researchers. The data produced as a part of the ENCODE project (RNAseq, eCLIP, RNA bind'n'Seq) need to be integrated with other genomic data sources (Sequence information, RNA Structure, phylogenetic conservation, etc) in order to answer the main biological questions: What are the sequence and secondary structural elements in 3' UTRs that control their interactions with RNA-binding proteins?

To help answer this question, in collaboration with University College London (UCL), we have develop and implemented software tools, including a pipeline for the new-generation sequencing (NGS) read mapping and annotation, which addresses these challenges: efficient processing of large quantities of ENCODE data, discovery of new splice junctions with RNAseq, predictive statistical modeling of differential exon usage based on contextual information.



Creative Path to Practical Knowledge

A successful measure, which connects knowledge and experience for a successful transition from the educational system into the work environment, is carried out by support of the Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia and financed by the European Social Fund and the Slovenian Ministry of Education, Science and Sport.

This program is aimed to increase employability of youth and to support the cooperation between universities and private companies. Students take different central roles as experts in this small scale projects, from all academic fields, and use their theoretical knowledge by applying it towards research and practical solutions. With the help of academic and practical mentors, students are solving individual business's and society's challenges, which are momentarily most actual, using specific theoretical knowledge from the educational process, as well as the partner's work approach with the support of their infrastructure.

In 2018, our researchers were involved in several projects, out of which, in 5 they were also principal investigators. In the rest of these projects, they collaborated as academic mentors.

GradKom: Direct Communication Between the Participants in a Construction Project

Principal Investigator:
Assist. Prof. dr. Tomaž Dobravec
tomaz.dobravec@fri.uni-lj.si

The aim of the GradKom project was to develop an application for simplified graphic communication between the participants in a construction project (e.g., the builders, supervisors, contractors, and so on). A mobile application allows the user to record a memo (a captured photo with additional textual and/or graphical information) when a critical event occurs during the project implementation. A recorded memo is added to the project's file as an input to the other participants for further processing. In this way all the crucial information about the project is always available on the spot, which enables the continuation of work without delays.

The Development of Microservices with Support for Blockchain Technology and Its Application to the Domain of CRM Systems

Principal Investigator:
Prof. dr. Matjaž B. Jurič
matjaz.juric@fri.uni-lj.si

The project addressed the challenges faced by companies when utilising the benefits of modern digital technologies. We studied the microservice technology as a mechanism for developing cloud-native applications, and blockchain technology as a foundation for the internet of value. We developed mechanisms for integrating blockchain technology and microservices, thus reducing the complexity of the software and speeding up its development. We designed generic APIs for accessing different blockchain platforms. The developed mechanisms addressed the problems identified by the partner company, which is developing decentralised solutions for CRM systems.

IdentGen: Computational Support for Identification of Genetic Predispositions and Diagnosis of Complex Diseases

Principal Investigator:
Assist. Prof. dr. Miha Moškon
miha.moskon@fri.uni-lj.si

The project was conducted in a collaboration with the Faculty of Medicine (University of Ljubljana) and was focused on the development of an information system that aids the diagnosis and treatment of three complex genetic diseases, i.e. hepatocellular carcinoma, familial erythrocytosis and major depressive disorder leading to suicide. The system eases the management of the obtained clinical and experimental samples, as well as their analyses. Significant emphasis was also placed on the compliance of the system with recent data protection regulation laws, such as GDPR.

eQuiz

Principal Investigator:
Prof. dr. Aleksandar Jurišić
aleksandar.jurisic@fri.uni-lj.si

For certain people mathematics is not the most exciting subject, and even very smart individuals may run away from the basics. It is not that they cannot study math, but instead another issue. After some examination, we found that the greatest problem is how to stay motivated while learning, and thus that people need platforms to keep them motivated in this context. This is where eQuiz sees its purpose. It is based on well-defined and entertaining problems to keep learners motivated, and thus enable them to learn the focal content through play.

The current version of eQuiz has been developed at the Laboratory for Cryptography and Computer Security. In addition to the laboratory personnel, several students were also included in the developing process (attending various subject). The last version is available at *https://equiz.fri.uni-lj.si*

TraPri – Tradition Meets the Future – Computer Vision and Augmented Reality for the Preservation and Promotion of Natural and Cultural Heritage

Principal Investigator:
Assoc. Prof. dr. Danijel Skočaj
danijel.skocaj@fri.uni-lj.si

The main objective of the project was to increase interest in the preservation of natural and cultural heritage using modern technology. As a target domain we selected enoteca with a large number of wine bottles, where we wanted to promote the traditional indigenous grapes from Vipava Valley. We developed a prototype of a mobile application for the Android operating system as well as a web-based content management system that enables efficient and attractive communication and interaction with visitors using computer vision (automatic recognition of bottle labels) and augmented reality (promoting indigenous grapes).

The project was implemented in collaboration with University of Ljubljana, Faculty of Sports, the Ski Association of Slovenia and AZ Net Ltd.

Innovative Student Projects for Public Benefit

Another successful mechanism supported by the Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia and financed by the European Social Fund and the Slovenian Ministry of Education, Science and Sport, is carried out by public tenders called Project work with the public and non-profit sectors in the local and regional environment – Innovative student projects for public benefit.

The purpose of this mechanism is reinforcement of cooperation and connectivity between higher education system and other environments (the public and non-profit sectors in the local/regional sphere), as well as conducting of liberal models in connection to crossing between education and the labour market. This ensures the participants' obtainment of concrete, practical experiences during their years of education, thus increasing the ease of crossing over from education to work.

In 2018 our researchers were involved in several projects, out of which, in 7 they were also principal investigators. In the rest of these projects, they collaborated as academic mentors.

InfoZdrav: Information System for the Management of Samples, Material and Chemicals in Health Care

Principal Investigator:
Assist. Prof. dr. Miha Moškon
miha.moskon@fri.uni-lj.si

The project was conducted in a collaboration with the community health care centre Trbovlje, Labena and the Faculty of Medicine (University of Ljubljana). We have developed Labek, a system that aids the work process performed within the diagnostic laboratories of community health care centres. Labek complements the laboratory information systems which are currently used in these laboratories to perform routine laboratory work. The proposed system allows the laboratory personnel to manage the supply of materials and chemicals, perform new orders and manage samples not directly related with the routine laboratory work.

SloRaDe: Slovenian Computer Heritage

Principal Investigator:
Assist. Prof. dr. Jurij Mihelič
jurij.mihelic@fri.uni-lj.si

In the project we focused on the heritage of the Slovenian computer industry, which was at its prime in the last few decades of the 20th century. We investigated the computers that were developed and produced in that period, including examining the related production companies and institutions as well as talking with several important actors who contributed to their development. We also developed an emulator for the Gorenje Dialog computer. The results of the project are collected on the webpage *https://jurem.github.io/SloRaDe*. The project was conducted in collaboration with The Museum and Galleries of Ljubljana.

Micro:bits in School

Principal Investigator:
Assoc. Prof. dr. Patricio Bulić
patricio.bulic@fri.uni-lj.si

In this project, students from three departments (the Faculty of Computer Science, Faculty of Electrical Engineering and Faculty of education) developed a set of easy to follow lesson plans and presentations for teaching programming with micro:bit computers in primary school classrooms. The students also organised a one-week workshop for pupils at the local primary school.

An Introduction to the Video Distance Measuring of Ski Jumps in Mengeš Ski Jumping Club

Principal Investigator:
Assoc. Prof. dr. Matjaž Kukar
matjaz.kukar@fri.uni-lj.si

The great competitive results of Slovenian ski jumpers in world cup and continental competitions have sparked much interest with regard to more active participation in this attractive sport. At junior levels it is now normal for national competitions to have more than 100 jumpers. However, expensive and logistically demanding commercial video distance measuring tools are only used at the top-level competitions (world cup, continental cup). We are experimenting with two affordable approaches to automate and speed up video distance measuring. The first approach uses a deep convolutional neural network with 10 hidden layers in order to automatically detect the correct landing frame. Each frame is classified either as "in the air"' or "`on the ground'". This approach achieves very high classification accuracy for determining the type of frame. However, as errors always occur near the correct landing frame, human intervention is still necessary. The second approach utilises classic computer vision image segmentation techniques to acquire the positions of a ski jumper's skis and legs in order to determine the correct landing point within the frame, and therefore the distance based on the measuring grid (currently with an accuracy of 0.5-1 m).

We are optimistic that the system will be effective for practical use on small hills in the near future. However, moving to larger hills will require additional research in order to allow for two, three or four network cameras. The system still needs further testing (especially the automated components) under artificial lighting conditions (for night competitions).

SLEDIMedO: Tracker of Media Announcements

Principal Investigator:
Assist. Prof. dr. Jurij Mihelič
jurij.mihelic@fri.uni-lj.si

In this short project we developed an application for tracking media announcements. Our primary focus was announcements related to projects funded or co-funded by the European Union and published on various news and project-related websites. The first part of the project dealt with the development of web scrapers for about one hundred news sites, while the second consisted of the development of the search application. The end result of the project is available at *http://lalg.fri.uni-lj.si/~sledimedo*. The project was conducted in collaboration with the Centre for European Perspective.

Cultural Heritage: Documenting Contemporary Art with New Technologies

Principal Investigator:
Assoc. Prof. dr. Narvika Bovcon
narvika.bovcon@fri.uni-lj.si

New media art is especially prone to disappear because its software and hardware components are subject to technological development. Therefore, translations into other artistic and discursive media have to be made in order to archive and document contemporary and new media art. The recreation of an exhibition set-up (with new technologies) is one way of building a bridge in time that can extend the information and experience of the exhibition until the next rearticulation. Our project consisted of video and photographic capture of the Salon ZDSLU 2017 exhibition (by the Association of the Slovenian Fine Artists Societies), which was composed of 3D interactive panoramas and layered with textual information about the 37 installations on show.

Portal for Cryptography and Computer Security

Principal Investigator:
Assist. Prof. dr. Aljaž Zalar
aljaz.zalar@fri.uni-lj.si

The main goal of this project was to share knowledge of cryptography and computer security through entertaining riddles, which are aimed at maintaining a high level of motivation among users. Ten students of computer science, multimedia and graphic design collaborated with the Cryptographic Society of Slovenia to further develop the portal for cryptography, called "Kriptogram" (available at *http://lkrv.fri.uni-lj.si/crypto-portal*). Users of the portal can now gain knowledge about classical ciphers, learn new alphabets, read about time stamping, secure passwords and other secret sharing channels. The portal is translated into English and thus is also accessible to international visitors.

“The curiosity, the enthusiasm, the desire for knowledge, that is what it takes to turn a good engineer into a brilliant researcher.”

Ratko Pilipović,
doctoral student

Doctoral Study Programmes

Computer and information science is one of the leading breakthrough areas with regard to shaping the economy, education, culture, administration and other disciplines. The marked rise of computer technology in developed countries dictates the need for highly qualified human resources which are capable of developing new computer and information technologies and implementing them in innovative environments. This study programme is designed to appeal to young people, especially those who plan on pursuing research and scientific work in computer science and informatics. The main focus of the doctoral study is on research, enabling students to receive training in both independent and team work, which encourages interdisciplinarity and also offers students the opportunity to cooperate with internationally recognised domestic and foreign experts. Special emphasis is devoted to combining scientific and professional areas, elective courses and an academic mentor programme so as to encourage students throughout the course of their studies.

At the Faculty of Computer and Information Science we offer the Doctoral study Programme in Computer and Information Science. There is a wide range of courses available which offer students the opportunity to further their research work in a specific field. The aim of the programme is to provide computer science education to independent researchers, teachers and future leaders. We also run an Interdisciplinary Study Programme Biosciences in cooperation with several faculties (the Biotechnical Faculty, the Faculty of Electrical Engineering, the Faculty of Mechanical Engineering and the Faculty of Health Sciences).

Highlights of the Doctoral Students' Research

"A very large part of space-time must be investigated,
if reliable results are to be obtained."

Alan Turing

Alan Lukežič
alan.lukezic@fri.uni-lj.si

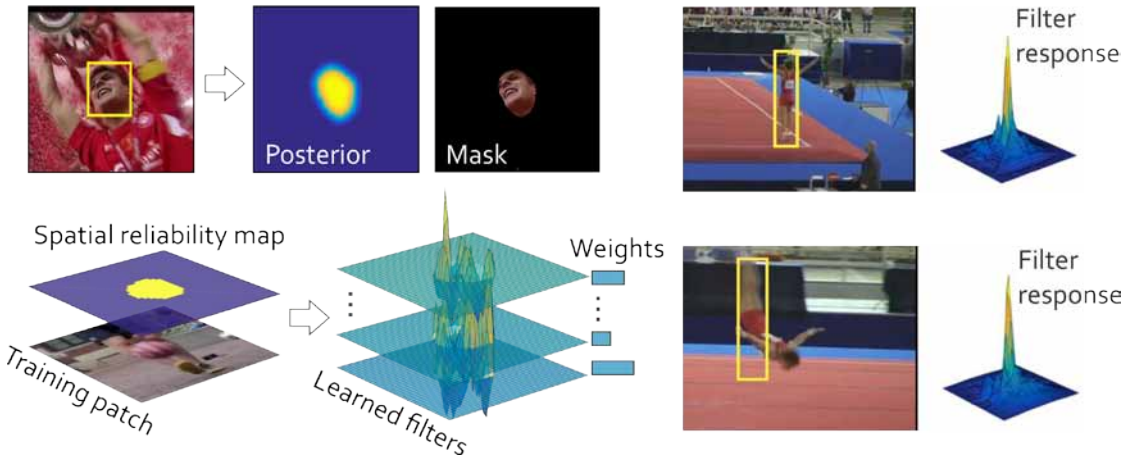
Supervisor:
Assoc. Prof. dr. Matej Kristan
Visual Cognitive Systems Laboratory

"We proposed a new constrained learning of visual models using segmentation for object tracking."

Real-Time Visual Object Tracking with Constrained Discriminative Correlation Filters

In visual object tracking, a target is continuously localized in a video-sequence given a single example of its appearance provided in the first frame. In this work we introduced a new formulation of the target visual model by a discriminative correlation filter with channel and spatial reliability. The spatial reliability map adapts the filter support to the part of the object suitable for tracking, which enables an arbitrary search (and training) region size and overcomes the limitations related to the rectangular target shape assumption which is often made in practice. An important benefit of a large training region is that background samples from a wider area around the target are obtained to improve the filter discriminative power. The spatial reliability map is estimated using the output of a graph labeling problem solved efficiently in each frame. An efficient optimization procedure is applied for learning a correlation filter with the support constrained by the spatial reliability map since the standard closed-form solution cannot be generalized to this case. Most of the existing methods for visual object tracking are based on the deep neural networks which require specialized hardware (GPU). Our method requires CPU only and it was a top-performing tracker on the VOT17 real-time challenge.

Alan Lukežič, Tomáš Vojíř, Luka Čehovin Zajc, Jiří Matas, Matej Kristan (2018) Discriminative correlation filter tracker with channel and spatial reliability, International journal of computer vision, 126(7): 671-688.



The filter, which is learned using a spatial reliability map as a constraint, is used to localize the target.

AI-driven Fog and Cloud Computing

dr. Salman Taherizadeh
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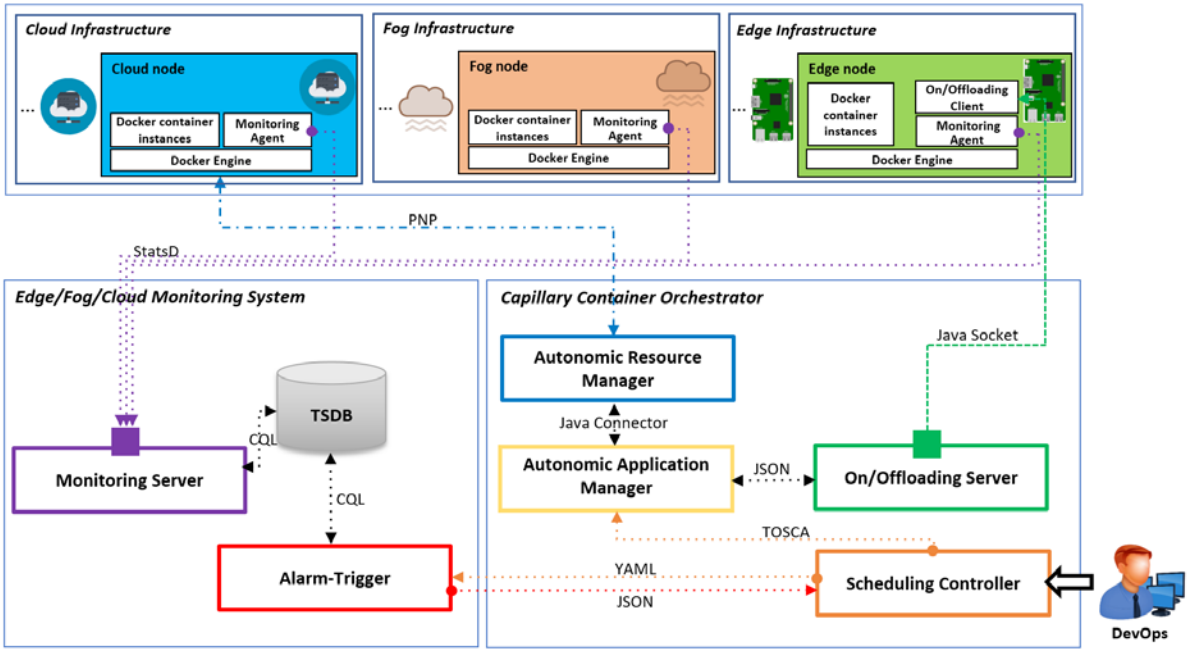
Supervisor:
Assoc. Prof. dr. Vlado Stankovski,
University of Ljubljana, Faculty of Civil and Geodetic Engineering

Project Administrator:
prof. Marko Grobelnik
Artificial Intelligence Laboratory,
Jozef Stefan Institute

The adoption of advanced Internet of Things (IoT) technologies has impressively improved in recent years by placing such services at the extreme Edge of the network. There are, however, specific Quality of Service (QoS) trade-offs that must be considered, particularly in situations when workloads vary over time or when IoT devices are dynamically changing their geographic position. We propose a capillary computing architecture, which benefits from mainstream Fog and Cloud computing approaches and relies on a set of new services, including an Edge/Fog/Cloud Monitoring System and a Capillary Container Orchestrator. All necessary Microservices are implemented as Docker containers, and their orchestration is performed from the Edge computing nodes up to Fog and Cloud servers in the geographic vicinity of moving IoT devices. A car equipped with a Motorhome Artificial Intelligence Communication Hardware (MACH) system as an Edge node connected to several Fog and Cloud computing servers was used for testing.

Salman Taherizadeh, Vlado Stankovski, Marko Grobelnik (2018) A capillary computing architecture for dynamic Internet of Things: Orchestration of microservices from Edge devices to Fog and Cloud providers, Journal Sensors, 18(9).

"A paradigm shift is emerging from centralised Cloud to AI-driven distributed Edge and Fog computing."



Melanija Vezočnik
melanija.vezocnik@gmail.com

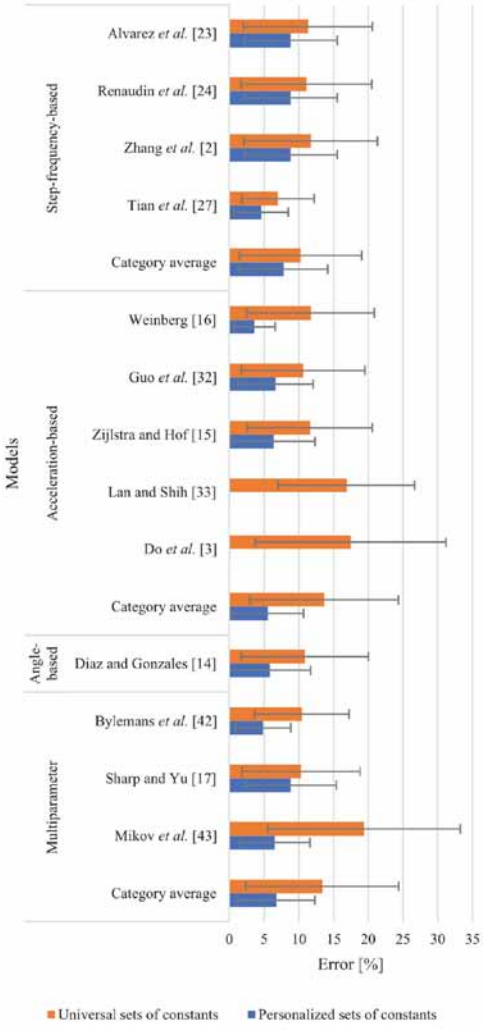
Supervisor:
Prof. dr. Matjaž Branko Jurič
Laboratory for Integration of Information Systems

Inertial Sensor-Based Step Length Estimation

Inertial sensors of smartphones and other Internet-of-Things devices present a very promising tool to monitor users' activity including their step length. We have conducted an in-depth analysis and comparison of representative step length estimation models using smartphone inertial sensors: step-frequency-based, acceleration-based, angle-based, and multiparameter. Hereby, we have studied the influence of different walking speeds and four typical sensor positions on the models' performance. To the best of our knowledge, this is the first performance evaluation for so many models that has ever been conducted in the same testing environment with the same persons. Consequently, we have prepared an open-source dataset that contains over 22 km of gait measurements obtained from a group of 15 healthy adults.

Melanija Vezočnik, Matjaž B. Jurič (2019) Average step length estimation models' evaluation using inertial sensors: a review. IEEE Sensors Journal, 19(2): 396-403.

"Evaluation of representative step length estimation models using over 22 km of acquired gait measurements."



Overall performance of the models for personalized and universal sets of constants. Average errors and standard deviations are showed.

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Supervisor:
Prof. dr. Ivan Bratko,
Artificial Intelligence Laboratory

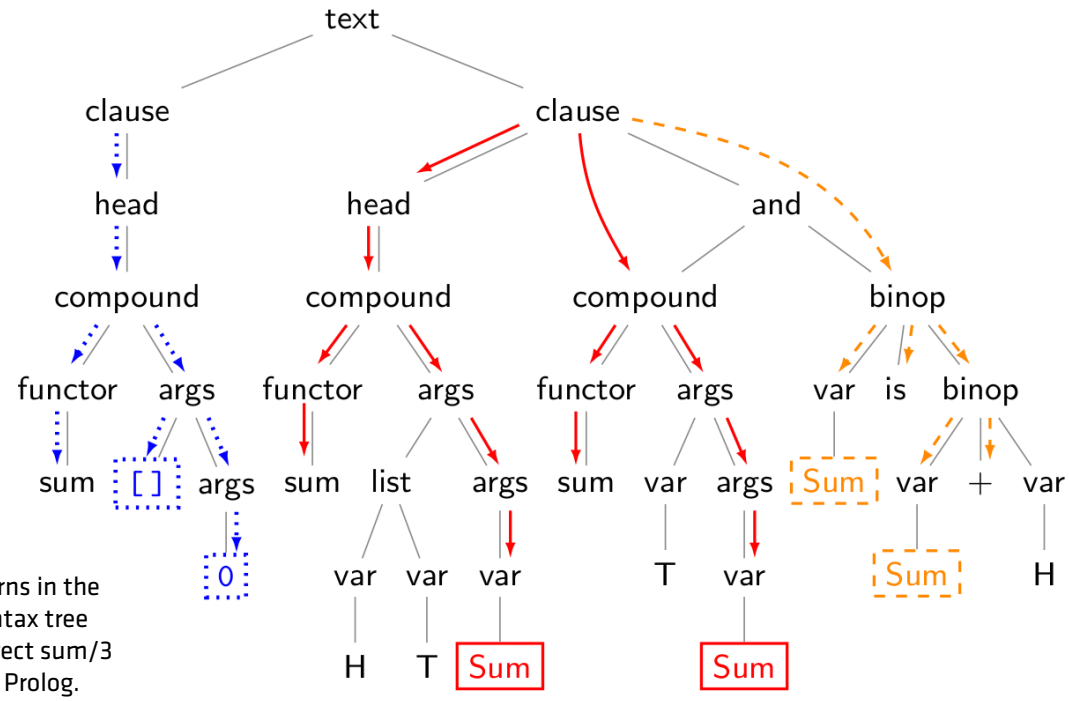
Discovering Syntactic Features in Student Programs

A major problem in automated student program analysis is the large number of possible variations in solutions to a specific exercise. We propose a novel way to encode program features in terms of abstract-syntax-tree patterns. These syntactic patterns are discovered automatically from a set of submissions and are invariant with respect to many common program transformations. They can thus be used as stable features for distinguishing between correct and incorrect programs. We show the viability of these features by learning rules that predict program correctness from syntactic patterns. Discovered rules correctly classify over 90% of beginner Prolog programs. Furthermore they are easy to interpret, supporting the teacher's analysis of common approaches and misconceptions for different programming tasks. Finally, we show that the approach is highly language-independent by evaluating it on a set of Python programs.

Timotej Lazar, Martin Možina, Ivan Bratko (2017) Automatic Extraction of AST Patterns for Debugging Student Programs, Artificial Intelligence in Education. AIED 2017, Lecture Notes in Computer Science, vol. 10331, Springer (eds.: In: André E., Baker R., Hu X., Rodrigo M., du Boulay B.).

Martin Možina, Timotej Lazar (2018) Syntax-Based Analysis of Programming Concepts in Python, Artificial Intelligence in Education, AIED 2018, Lecture Notes in Computer Science, vol. 10948, Springer (eds.: Penstein Rosé C. et al.).

"Syntactic patterns can be used to predict correctness of student programs in a vast solution space."



Three patterns in the abstract syntax tree for an incorrect sum/3 predicate in Prolog.

Borja Bovcon
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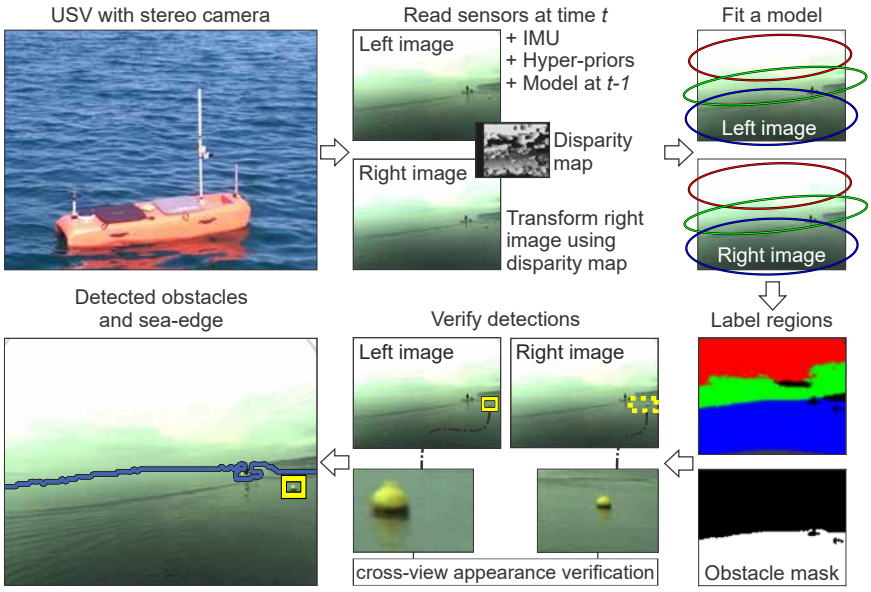
Supervisor:
Assoc. Prof. dr. Matej Kristan
Visual Cognitive Systems Laboratory

"We propose a new graphical model for obstacle detection by semantic segmentation of stereo images recorded by a robotic boat."

Segmentation-Based Obstacle Detection for Unmanned Surface Vehicles

Recent development in field robotics has led to establishment of small-sized robotic boats -- unmanned surface vehicles (USVs). These vessels are portable and particularly practical for remote inspection of difficult-to-reach areas, which may pose a harmful threat to humans. One of the main challenges in autonomous navigation is precise and timely obstacle detection. Cameras show a great promise for this task due to their light weight, low power consumption and information richness. Nevertheless, aquatic environments pose significant challenges for computer-vision-based obstacle detection. We have proposed a new segmentation-based obstacle detector, which generates a water segmentation mask and treats all objects in the water as obstacles. In addition to visual information it also incorporates the roll and pitch measurements from the on-board inertial measurement unit (IMU). This enables projecting the horizon onto the input image and dynamically adjust hyper-priors of the segmentation model, providing a reliable segmentation even in unfavourable weather conditions. The approach jointly fits the semantic model to a stereo pair of images for improved robustness. To evaluate the proposed method under realistic challenging conditions, we have proposed a new dataset for marine obstacle detection. It consists of multiple stereo sequences, time-synchronized with on-board sensors (compass, IMU and GPS) and is currently the largest of its kind. Extensive experimental analysis showed that our proposed approach significantly outperforms all current state-of-the-art methods.



Borja Bovcon, Rok, Mandeljc, Janez Perš, Matej Kristanj (2018) Stereo obstacle detection for unmanned surface vehicles by IMU-assisted semantic segmentation, Robotics and autonomous systems, 104.

Borja Bovcon, Matej Kristan (2018) Obstacle detection for USVs by joint stereo-view semantic segmentation, IROS 2018, International Conference on Intelligent Robots and Systems, Madrid, Spain, 5807-5812.

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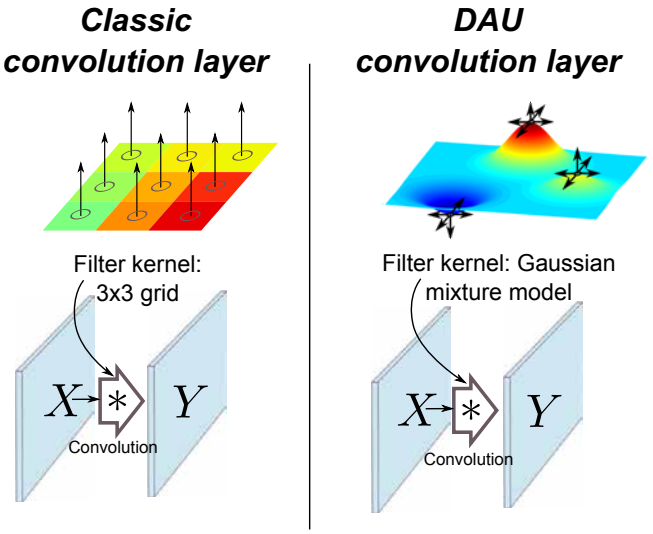
Spatially-Adaptive Filter Units for Deep Neural Networks

Current convolutional networks rely on convolutions with a fixed-grid filter kernel. This poses a problem for semantic segmentation tasks where wide context information is required. Classical deep convolutional networks access context information through large receptive field size by either gradual resolution reduction or by application of hand-crafted dilated convolutions to prevent increase in the number of parameters. We proposed a novel displaced aggregation unit (DAU) based on deep compositional network that provides a new way to attain large receptive field sizes in deep networks. In contrast to classical filters with units (pixels) placed on a fixed regular grid, the displacement of the proposed DAUs are dynamic and learned from data. This enables filters to spatially-adapt their receptive field to a given problem. The DAUs have proven useful on the classification and semantic segmentation tasks, and by observing spatial distributions of DAU filters they have enabled analysis of deep networks from a novel perspective.

Domen Tabernik, Matej Kristan, Aleš Leonardis (2018) Spatially-Adaptive Filter Units for Deep Neural Networks, The IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2018, 9388-9396.

"The displaced aggregation unit (DAU) provides a novel approach for deep learning models to attain large receptive field sizes with efficient allocation of parameters."



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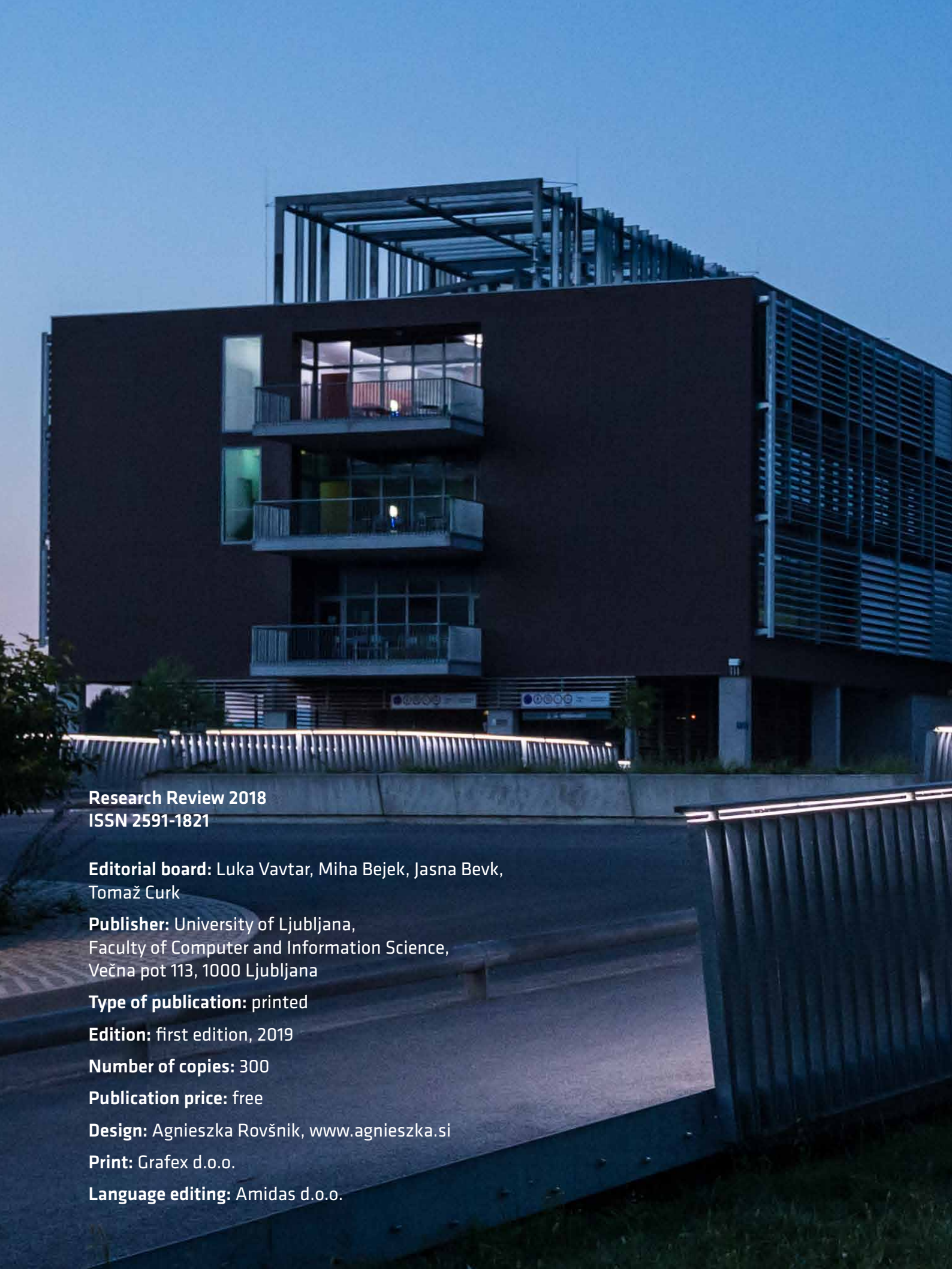

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