2019

Research Review

University of Ljubljana
Faculty of Computer and Information Science

2019
Research Review

Remarks by the Dean

Dear reader,

In the past year there was a lot of top research performed at the Faculty of Computer and Information Science at the University of Ljubljana, and our network with international and local partners from academia, industry and society has grown stronger.

Computer and information science is constantly moving the boundaries of what is possible, and we are proud that our researchers have made important contributions in several areas. The data-mining environment Orange, which we have been developing for the last 20 years, is constantly evolving with add-ons for different domains such as text and image mining, analysis of data in molecular and single-cell biology, geodata mining and so on. In the last year promising results were gathered in reconstructing tourism flows from posts on tourism web platforms, new tools were developed for linguistic analysis, and a novel technique was developed that uses graph symmetries for algorithmic speedups.

In the field of artificial intelligence and machine learning there were many breakthroughs due to progress in deep learning with neural networks, such as building a large dataset with 200 categories of traffic signs, designing effective object tracking algorithms, enhancing personal identification methods focusing on ear recognition and the periocular region, and also developing new methods for biometric data protection using face deidentification. As one of the pioneers of artificial intelligence worldwide, we acknowledge the importance of dealing with both the benefits and dangers arising from its wider use. We are looking forward to contributing our expertise at the International Research Centre on Artificial Intelligence that was established in Slovenia in 2019 under auspices of UNESCO.

In the wake of new and unusual circumstances that emerged around the world in 2020, caused by the coronavirus pandemic, it is clear that information technologies and computer resources were essential tools in dealing with this crisis and its consequences. Although there is still a lot of work to be done and we will all have to re-evaluate our future research plans as well as past achievements in the light of COVID crisis, in 2019 we had already carried out several projects that resonate with the new reality: a platform for remote patient monitoring, research in enhancing student motivation in e-learning, the use of data mining in predicting diseases, and a platform for monitoring society's state of mind.

Aside from our research work, we are the largest Slovenian faculty offering study programmes in computer science, with 1,450 active students at the bachelor's, master's and doctoral levels. Our research-oriented doctoral study programme is taught in English and open to international students.

We invite you to explore the contents of this booklet, find out more about our highlights from the past year and our ongoing research projects, get acquainted with our research laboratories and meet our 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.

In 2019, the University of Ljubljana celebrated its hundredth anniversary.

1923

Doctoral Students

6093

Employees

4252

Researchers

479 948

Citations Scopus (2014–2019)

458

EU projects

428 805

Citations WoS (2014–2019)

3728

Publications

65.677.013,00 €

Revenue for research and development *

* data for 2018

126

Ongoing Projects

EU: **10**
International: **8**
Industry: **33**
Slovenian Research Agency: **48**
Structural funds: **23**
Other national projects: **4**

163

Publications

SCI journals: **102**
1st quartile: **44**
Exceptional (top 5%): **15**
Conference: **63**

Faculty of Computer and Information Science

30

Doctoral Students

146

Researchers

174

Employees

21 607

Citations Scopus (2014–2019)

15 553

Citations WoS (2014–2019)

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.
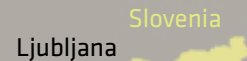
Slovenia:
A Green Country

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.
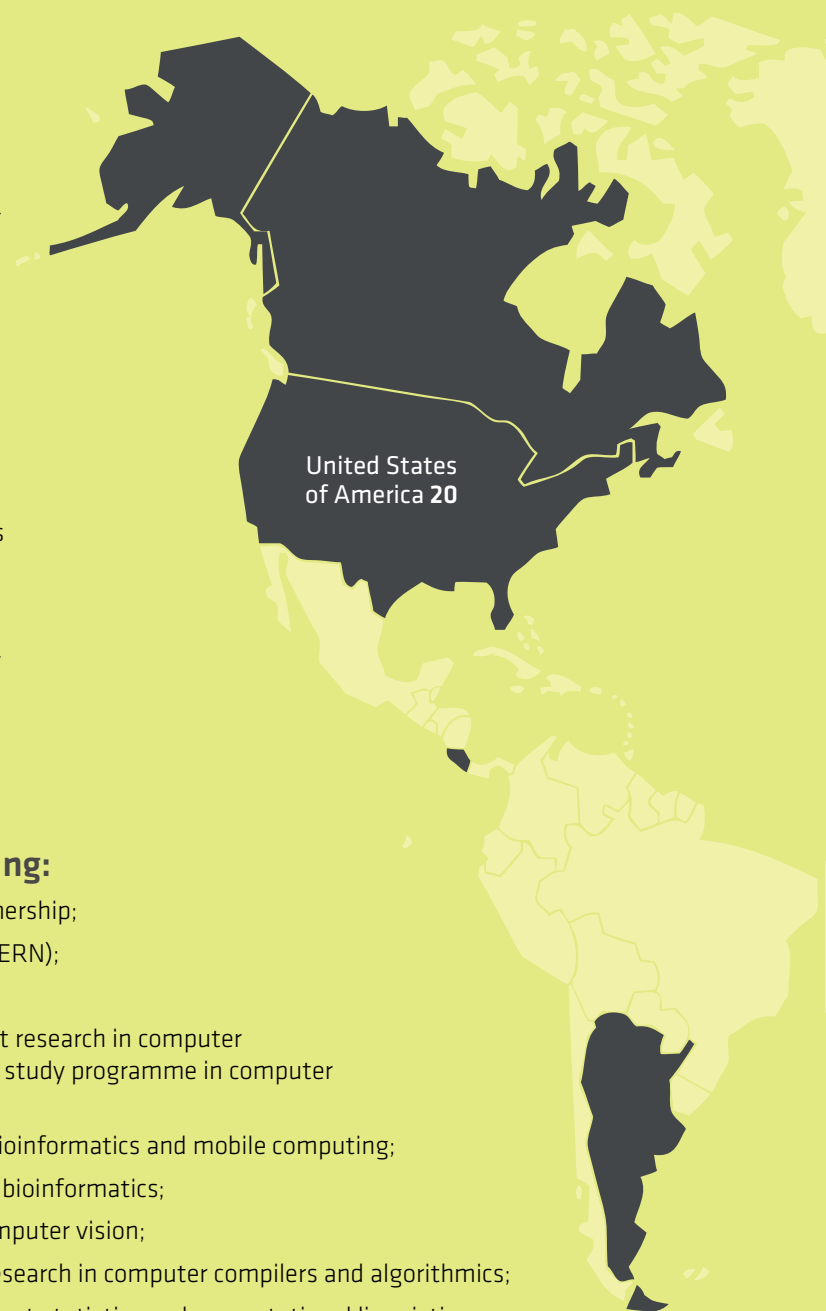
Slovenia

Ljubljana

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.

United States of America **20**

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;
- KAUST – King Abdulah University of Science and Technology.

204
collaborations

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

The Netherlands **8**
Sweden **7**
United Kingdom **19**
Germany **17**
Austria **13**
Belgium **6**
Slovenia **16**
France **8**
Spain **8**
Serbia **9**
Portugal **5**
Switzerland **7**
Italy **10**

Australia **5**

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.

King Abdullah University of Science and Technology (KAUST)

Since 2019, laboratories from UL FRI and KAUST have been engaged in common research topics related to computer graphics, visualization, and network computing. The joint research concentrated on volume rendering and visualization of microscopy data. In 2022, they solidified their partnership by establishing an agreement for master student exchanges through research internships. This alliance was further strengthened in 2023 with the initiation of a dual Ph.D. program, empowering candidates from both institutions to collaboratively contribute to cutting-edge research.

Highlights

"I've always been more interested
in the future than in the past."

———

Grace Hopper

Ear Biometrics

Assist. Žiga Emeršič ziga.emersic@fri.uni-lj.si
Dejan Štepec dejan.stepec@xlab.si
Assoc. Prof. Dr. Vitomir Štruc vitomir.struc@fe.uni-lj.si
Assoc. Prof. Dr. Peter Peer peter.peer@fri.uni-lj.si

Collaborating Laboratories:
Computer Vision Laboratory
Laboratory for Machine Intelligence (UL FE)

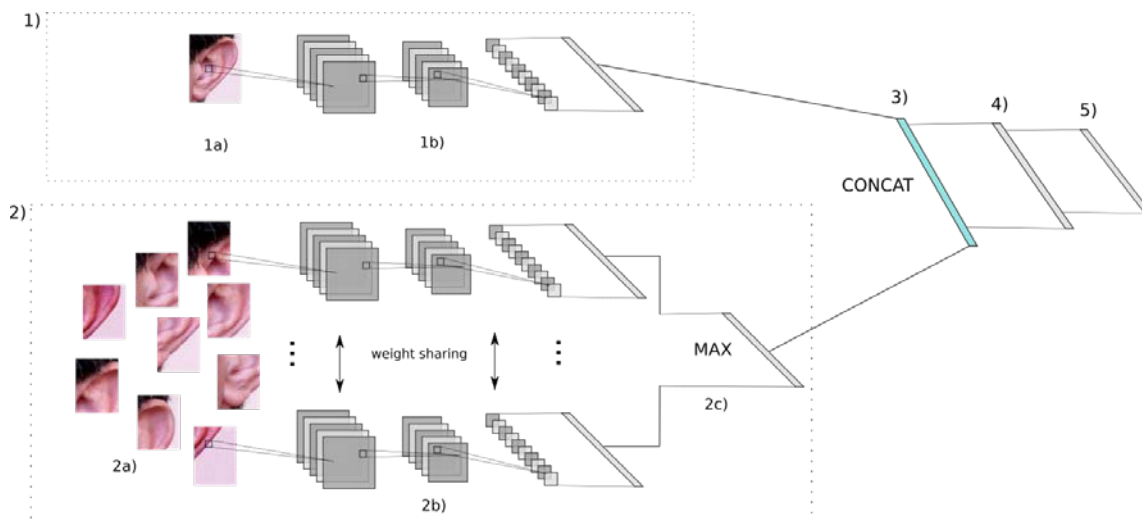"Ear recognition competition and new state-of-the-art in ear recognition."

We organized The Unconstrained Ear Recognition Challenge (UERC) 2019 at IAPR International Conference on Biometrics [1], which was the second ear recognition challenge. Twelve institutions entered the competition and submitted a total of thirteen recognition approaches, ranging from descriptor-based methods to deep-learning models. The majority of successful submissions were based on ensemble methods combining either representations from multiple deep models or handcrafted with learned image descriptors.

Using the UERC's dataset, we proposed and evaluated a new model designed as a dual-path convolutional neural network (CNN) [2], achieving new state-of-the-art. One path processes the input in a holistic manner and the second path captures local image characteristics from image patches sampled from the input image. A novel pooling operation, called patch-relevant-information pooling, was also proposed and used. We proposed the first ever unified deep ear detection and recognition pipeline, providing a foundation for future research [3].

[1] Žiga Emeršič, Aruna Kumar S. V., B. S. Harish, et al., Peter Peer, Vitomir Štruc (2019) The unconstrained ear recognition challenge 2019. International Conference On Biometrics, IAPR, [pdf].

[2] Dejan Štepec, Žiga Emeršič, Peter Peer, Vitomir Štruc (2019) Constellation-based deep ear recognition. Deep Biometrics, Springer, [pdf].

[3] Žiga Emeršič, Janez Križaj, Vitomir Štruc, Peter Peer (2019) Deep ear recognition pipeline. Recent Advances in Computer Vision: Theories and Applications, Springer, [pdf].

Overview of the proposed, two-path architecture Deep Constellation Model for Ear Recognition.

Biometric identity recognition based on sclera blood vessels and the periocular region

Matej Vitek matej.vitek@fri.uni-lj.si
Peter Rot peter.rot@fri.uni-lj.si
Assoc. Prof. Dr. Vitomir Štruc vitomir.struc@fe.uni-lj.si
Assoc. Prof. Dr. Peter Peer peter.peer@fri.uni-lj.si

Collaborating Laboratories:
Computer Vision Laboratory
Laboratory for Machine Intelligence (UL FE)

State-of-the-art periocular recognition pipelines require an explicit segmentation step. We showed that roughly equivalent results can be achieved with a deep network that does not use explicit segmentation [1].

In sclera blood vessel recognition, we expanded the research of our (successful) deep architectures from 2018 SSBC [2]. We studied the suitability of different segmentation methods for sclera and blood vessels for subsequent identity recognition [3]. We evaluated different recognition methods and studied the effect of different subject and image characteristics (age, gender, image resolution, eye gaze direction) on sclera-based recognition accuracy [4].
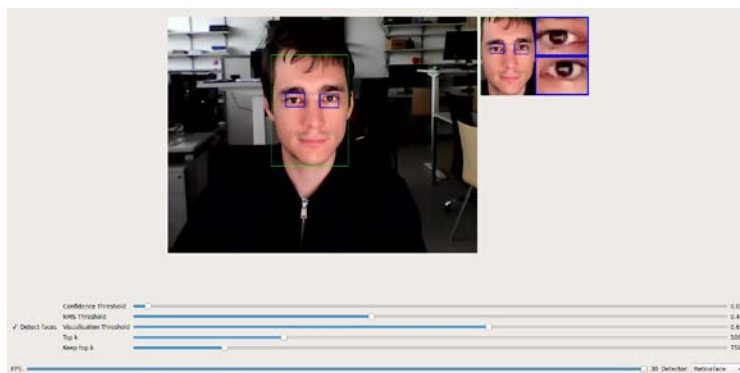
Lastly, we collected a novel dataset for ocular biometrics. The MOBIUS dataset contains 17,000 eye images of varying quality captured with commercial off-the-shelf mobile cameras, more accurately representing a real world scenario. We are currently annotating the various eye regions and focusing our research toward more light-weight mobile solutions for sclera-based identity recognition.

> "Alternative eye modalities for personal identification and authentication."

[1] Peter Rot, Matej Vitek, Blaž Meden, Žiga Emeršič and Peter Peer (2019) Deep periocular recognition: a case study. IEEE International Work Conference on Bioinspired Intelligence, [pdf].
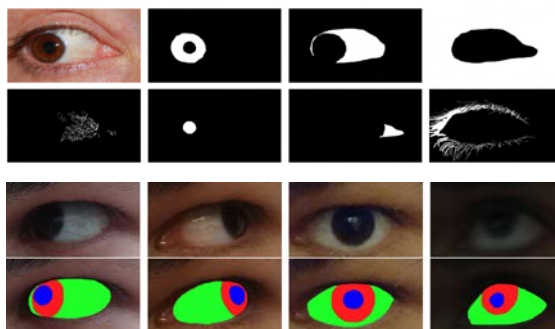
[2] Abhijit Das, Umapada Pal, Miguel A. Ferrer, Michael Blumenstein, Dejan Štepec, Peter Rot, Žiga Emeršič, Peter Peer, Vitomir Štruc (2018) Sclera segmentation benchmarking competition. IAPR International Conference on Biometrics, https://ieeexplore.ieee.org/document/8411237.

[3] Peter Rot, Matej Vitek, Klemen Grm, Žiga Emeršič, Peter Peer, Vitomir Štruc (2020) Deep sclera segmentation and recognition. Handbook of Vascular Biometrics, Springer (eds.: Andreas Uhl, Christoph Busch, Sébastien Marcel, Raymond Veldhuis), https://www.springer.com/gp/book/9783030277307.

[4] Matej Vitek, Peter Rot, Vitomir Štruc and Peter Peer (2020) A comprehensive investigation into sclera biometrics: a novel dataset and performance study. Neural Computing and Applications, https://rdcu.be/b1Wov.

A demo application for the detection and localisation of ocular information is available in the Computer Vision Laboratory.

Our dataset contains rich sets of annotations, which are crucial for deep learning research.

Varying image qualities present in the MOBIUS dataset.

Image and Video Authentication and Person Identification in Surveillance Video

Sen. Lect. Dr. Borut Batagelj borut.batagelj@fri.uni-lj.si

Collaborating Laboratory: Computer Vision Laboratory

"Computer forensics for image and video material are in high demand."

We are surrounded by an increasing amount of visual information. A news story used to be trusted more if it was accompanied by images or video. Not anymore! Fake news is everywhere, from social networks, tabloids, even scientific publications, political propaganda, to the forgery of evidence in law courts. With the prevalence of digital cameras and the rise and availability of software for image manipulation, forgery is easy today. Computer forensic experts for image and video materials are therefore in high demand, in particular by law courts.

At our faculty, Dr. Borut Batagelj is a specialist in computer forensics and a court expert. He often examines seized digital image material to check whether an image has been altered. He examines surveillance shots, where he tries to improve the image using image processing techniques to show the evidence sought or to more easily identify persons in images. He uses computer recognition methods for comparing facial features, physical characteristics and personal behaviour to determine if an accused person is captured in images.

Human height estimation from video.

Development of new face deidentification and attribute protection approaches

Blaž Meden blaz.meden@fri.uni-lj.si
Peter Rot peter.rot@fri.uni-lj.si
Assoc. Prof. Dr. Vitomir Štruc vitomir.struc@fe.uni-lj.si
Assoc. Prof. Dr. Peter Peer peter.peer@fri.uni-lj.si

Collaborating Laboratories:
Computer Vision Laboratory
Laboratory for Machine Intelligence (UL FE)

Face recognition is evolving rapidly as a consequence of recent advances in deep learning. The technology now enables high recognition accuracy of individuals also in settings where subjects are not aware of being monitored. Such systems significantly improve the performance of security and forensic applications, but can also violate privacy rights, if misused.
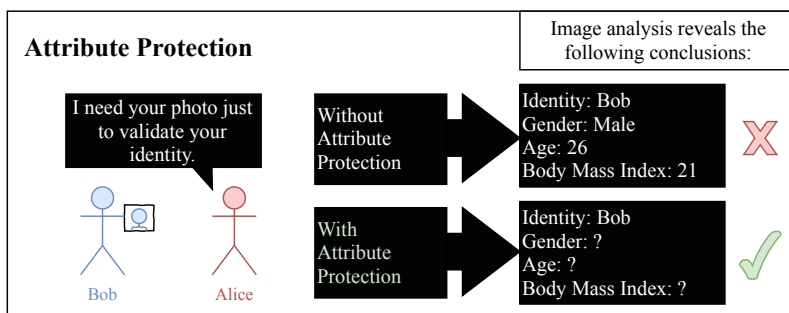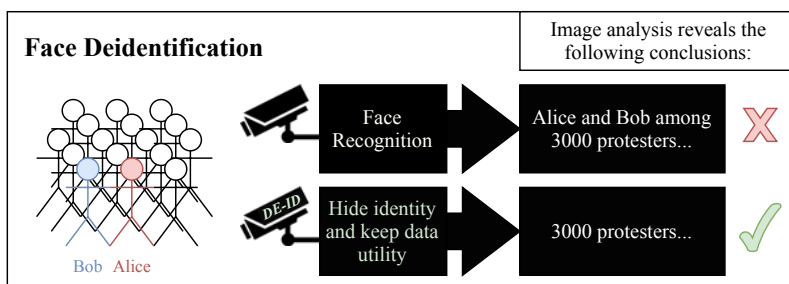
People are naturally able to characterize a photographed person with many different attributes and properties. If we can recognize a person in a photo, his biometric identity is revealed. The process of removing a person's identity from a photo is called deidentification [1, 2]. Other attributes about a person in an image can be soft biometrics (age, ethnicity, gender), behavioural biometric (movement of facial muscles in an identifiable manner) or other non-biometric attributes (attractiveness, etc.) [3]. Attributes other than identity, e.g., body mass index and sexual orientation, can be predicted from facial images only. Attempts to protect such attributes are called attribute protection.

We are developing new ideas on how to preserve and protect human privacy.

"New methods for protection of the most sensitive types of facial biometric data available today."

[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, [pdf].

[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, [pdf].

[3] Marija Ivanovska, Blaž Bortolato, Peter Rot, Janez Križaj, Peter Peer, Damer Naser, Philipp Terhoerst, Vitomir Štruc (2020) Learning privacy-enhancing face representations through feature disentanglement. IEEE FG 2020, accepted.

Face deidentification hides the identity of individuals from imagery, while attribute protection manipulates images to protect facial attributes. Both approaches can be used to protect privacy in specific applications.

Segmentation and recovery of superquadric models using convolutional neural networks

Prof. Dr. Franc Solina franc.solina@fri.uni-lj.si
Assist. Tim Oblak tim.oblak@fri.uni-lj.si
Jaka Šircelj jaka.sircelj@fe.uni-lj.si
Assist. Dr. Klemen Grm klemen.grm@fe.uni-lj.si
Assist. Dr. Aleš Jaklič ales.jaklic@fri.uni-lj.si
Assoc. Prof. Dr. Peter Peer peter.peer@fri.uni-lj.si
Assoc. Prof. Dr. Vitomir Štruc vitomir.struc@fe.uni-lj.si
Uroš Petkovič
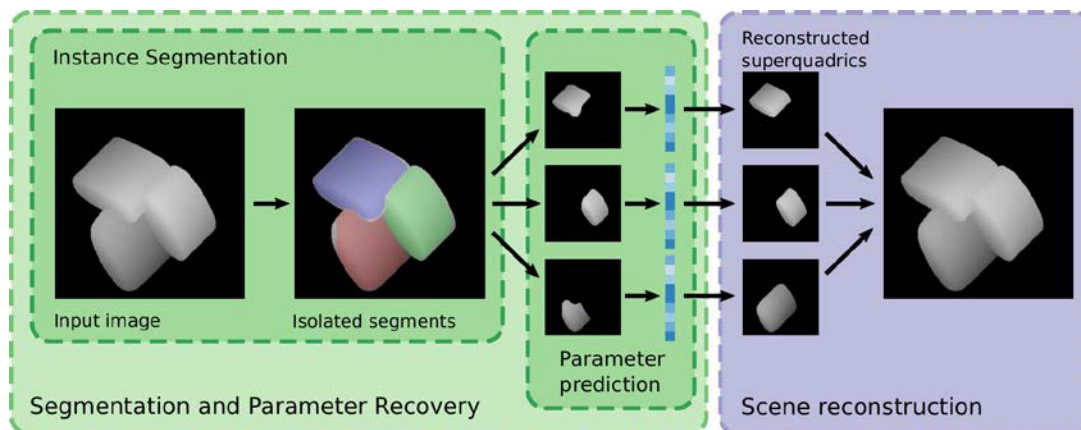
Collaborating Laboratory:
Computer Vision Laboratory

Project: Segmentation and recovery of superquadrics

In this project we study the problem of representing 3D images with part-level parameterized volumetric shape primitives, in this case superquadrics. The state-of-the-art method requires an iterative solution which is too slow for real-time applications. Therefore, we are developing a convolutional neural network (CNN) to describe complex structures with a small number of superquadrics in a fraction of the time required by competing approaches. We are evaluating the proposed approach on synthetic as well as real-world depth data. In addition to using range images as input (3D depth images seen from a particular view point), we are also studying the use of more general 3D point clouds.

Specifically, we have developed a two-stage approach built around convolutional neural networks (CNNs). In the first stage, our approach uses a Mask-RCNN model to identify superquadric-like structures in depth scenes, and then fits superquadric models to the segmented structures using a specially designed CNN regressor.

> "Fast description of visual scenes with 3D part-level models using a CNN-based approach."

Šircelj, Jaka, Oblak, Tim, Grm, Klemen, Petković, Uroš, Jaklič, Aleš, Peer, Peter, Štruc, Vitomir, Solina, Franc. Segmentation and recovery of superquadric models using convolutional neural networks. V: Lukežič, Alan (ed.), Tabernik, Domen (ed.), Grm, Klemen (ed.). Proceedings of the 25th Computer Vision Winter Workshop Conference, Rogaška Slatina, February 3-5, 2020. Electronic ed. Ljubljana: Slovensko društvo za razpoznavanje vzorcev (Slovenian Pattern Recognition Society). 2020, str. 74-81, illustr. http://data.vicos.si/cvww20/CVWW20-proceedings.pdf. [COBISS.SI-ID 1538520259]

Convolutional neural network (CNN) for description of complex structures with a small number of superquadrics.

Digital Transformation and Digital Business Models

Prof. Dr. Matjaž Branko Jurič matjaz.juric@fri.uni-lj.si

Collaborating Laboratory:
Laboratory for Integration of Information Systems

Project: Digital Transformation in the Danube Region

The increasing digitization of business processes by e.g. the Internet of Things or Industry 4.0 requires developing new business models for companies to remain competitive on global markets. There is no digital transformation without appropriate business transformation. SMEs from less developed Danube regions, but also from strong regions such as Baden-Württemberg (DE), are suffering from the digital revolution as they still do not have enough competencies to cope with the challenges of digital transformation. Therefore DIGITRANS aims at developing an appropriate innovation method that will enable SMEs to create competitive digital business models within an incubator space established especially for this purpose.

DIGITRANS focuses on the Creative Industries, Health and Advanced manufacturing – three sectors relevant to all Smart Specialization Strategies from the partner regions with regard to piloting the innovation method and tools to be developed transnationally by the consortium. By developing a transnationally validated blended learning training programme in connection with a specific online learning environment, SMEs will be empowered and equipped with the relevant skills to handle their digital transformation process successfully and create competitive business models. To achieve this, the following outputs will be generated: new digital business method, validated innovation space with appropriate tools, targeted e-learning environment allowing SMEs and business support organizations to learn independently, documented business model cases demonstrating the DIGITRANS method's effectiveness, blended learning training concept to deliver the DIGITRANS method in partner regions and beyond, regional policy workshops and recommendations to support regional policy stakeholders to integrate the DIGITRANS method into their digital strategy.

https://digitrans.me

"DIGITRANS focuses on the Creative Industries, Health and Advanced Manufacturing – three sectors relevant to all Smart Specialization Strategies from the partner regions with regard to piloting the innovation method and tools to be developed transnationally by the consortium."

Vitabits – an end-to-end system for remote monitoring of patients with chronic diseases

Prof. Dr. Marko Bajec marko.bajec@fri.uni-lj.si
Assist. Prof. Dr. Slavko Žitnik slavko.zitnik@fri.uni-lj.si
Dr. Marko Janković marko.jankovic@fri.uni-lj.si

Collaborating Laboratory: Laboratory for Data Technologies

Project: SOSTOP/Vitabits

> "Vitabits helps you control your lifestyle and monitor your health."

Vitabits is a platform for remote patient monitoring. It enables medical specialists to be in

contact with their patients and continuously observe their vital signs measured in the patients'

home environment. The platform is specialized for remote monitoring of patients with chronic diseases such as congestive heart failure, diabetes, asthma, arterial hypertension, COPD and so forth.

Using the platform, patients can easily measure their vital signs at home. In addition, Vitabits

can be used for identifying eating habits, tracking daily activity by counting steps and measuring sedentary, recreation and sleeping time, and for providing patients with personalized educational material that promotes a healthy and active lifestyle. Based on regular observation of patients' health conditions, medical specialists can provide more accurate diagnosis and adjust treatments as needed. This contributes to the higher efficiency of health care and consequently lowers the associated costs.

Computational models of the CholesteROR pathway role in the development of NAFLD

Prof. Dr. Miha Mraz miha.mraz@fri.uni-lj.si
Assist. Prof. Dr. Miha Moškon miha.moskon@fri.uni-lj.si
Prof. Dr. Nikolaj Zimic nikolaj.zimic@fri.uni-lj.si
Lidija Magdevska lidija.magdevska@fri.uni-lj.si

Collaborating Laboratory: Computer Structures and Systems Laboratory

Project: CholesteROR in metabolic liver disease, ARRS (J1-9176)

Non-Alcoholic Fatty Liver Disease (NAFLD) is the most prevalent form of chronic liver disease in the world. It affects 25% of the global adult population and as many as 1/3 of people in the developed world. The disease is manifested by a spectrum of liver pathologies ranging from simple steatosis to liver cell injury with fibrosis and can end in cirrhosis or liver cancer.

We focus on the CholesteROR pathway that links Retinoic Acid Orphan Receptor Gamma (RORC) signalling to cholesterol. The hepatic RORC signalling is in its early phase of understanding, thus innovative systems solutions that in addition to experimentation include modelling and validation in clinical samples must be used to propose new NAFLD modulators.

We have been developing dynamical models that provide novel insights into the role of the CholesteROR pathway in the development of NAFLD. These models will not only help in proposing molecular players of NAFLD, but also allow us to personalise the diagnostic and therapeutic interventions for each individual patient.

"Integrative models to enhance and personalize the diagnostics and therapeutics of NAFLD."

Lidija Magdevska, Miha Mraz, Nikolaj Zimic, Miha Moškon (2018) Initial state perturbations as a validation method for data-driven fuzzy models of cellular networks. BMC bioinformatics, 19.1: 333, [pdf].

Žiga Pušnik, Miha Mraz, Nikolaj Zimic, Miha Moškon (2019) Computational analysis of viable parameter regions in models of synthetic biological systems. Journal of Biological Engineering, 13: 75, [pdf].

Integrative data-driven modelling approaches enhance the diagnostics and therapeutics of complex-systems disorders.

SocioPower

Dr. Neli Blagus   neli.blagus@fri.uni-lj.si

Collaborating Laboratory: Laboratory for Data Technologies

Project: SocioPower

The rapid expansion of different social media, blogs and forums in recent years has enabled impressive insights into society and its behaviour. The SocioPower project addresses the challenge of collecting, storing and analyzing such large amounts of data from various online media. With special emphasis on texts in Slovenian, we develop tools for text preprocessing, keyword extraction, topic identification, text summarization and sentiment identification. This last aspect includes not only common sentiment classification, but also target sentiment analysis, where the key idea is to find the sentiment of specific entities mentioned in documents. Furthermore, the testing and evaluation of the SocioPower platform will be performed on Slovenian news articles, providing an analysis of topics that emerge in society and their intensity, as well as an insight into the thinking of different society groups and identification of their problems.

> "The SocioPower project addresses the challenge of collecting, storing and analyzing large amounts of data from different online media."

Example of the use of the Sociopower platform in a smart city.

Thinking Folklore

Assoc. Prof. Dr. Matija Marolt matija.marolt@fri.uni-lj.si
Sr. Instr. Dr. Alenka Kavčič alenka.kavcic@fri.uni-lj.si
Assist. Dr. Ciril Bohak ciril.bohak@fri.uni-lj.si
Assist. Dr. Matevž Pesek matevz.pesek@fri.uni-lj.si

Collaborating Laboratory: Laboratory of Computer Graphics and Multimedia

Project: Thinking Folklore: dialect and supra-dialect of folklore as a folkloristic, ethnological, semantic and computational problem, ARRS (J7-9426)

"Automatic analysis of dialectal speech and singing in ethnomusicological field recordings."

In Thinking Folkore, we are collaborating 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 pronunciation. We are developing new approaches to address the specifics of materials, in particular the use of dialect, which can significantly deviate from transcriptions. On one hand, the developed methods will enable word searching in large collections of sound recordings, which will substantiate textual analysis, and on the other hand it will also build the basis for development of algorithms for assessment of phonetic parameters of pronunciation in order to quantify the differences between dialect and supra-dialect in speech and singing.

Matila Marolt, Ciril Bohak, Alenka Kavčič and Matevž Pesek (2019) Automatic segmentation of ethnomusicological field recordings. Applied Sciences, 9(3): 1-12, [pdf].

Effectiveness of Scaffolds in the e-Learning Environment

Assoc. Prof. Dr. Matija Marolt matija.marolt@fri.uni-lj.si
Sr. Instr. Dr. Alenka Kavčič alenka.kavcic@fri.uni-lj.si
Assist. Dr. Ciril Bohak ciril.bohak@fri.uni-lj.si
Assist. Dr. Matevž Pesek matevz.pesek@fri.uni-lj.si
Assist. Žiga Lesar ziga.lesar@fri.uni-lj.si

Collaborating Laboratory: Laboratory of Computer Graphics and Multimedia

Project: Effectiveness of different types of scaffolds in self-regulated e-learning, ARRS (J5-9437)

"Appropriate e-learning scaffolds can enhance students' learning motivation."

E-learning has many advantages over traditional learning from printed materials, as it enables interactivity, visualization of concepts through videos and animations, and adaptive presentation of content. However, the success of learning depends on students' individual characteristics. By embedding various scaffolds into the e-learning unit, we can promote the use of cognitive and metacognitive processes and enhance students' learning motivation.

In this project, we are investigating how different types of scaffolds (cognitive, metacognitive, motivational and a combination of all three types) influence the results of learning and if the effectiveness of different types of scaffolds is related to students' individual characteristics (abilities, prior knowledge, learning motivation and self-regulatory competences). For the main study, we prepared the instruments for assessing students' individual characteristics, developed two e-learning units from the field of natural sciences and a web application for navigating through the unit, managing scaffolds and monitoring the student's learning activities.

Cognitive, metacognitive and motivational scaffolds in the e-learning unit.

Insight into Motivation for Student Mobility

Assoc. Prof. Dr. Mojca Ciglarič mojca.ciglaric@fri.uni-lj.si
Assist. Dr. Matjaž Pančur matjaz.pancur@fri.uni-lj.si
Assist. Miha Grohar miha.grohar@fri.uni-lj.si
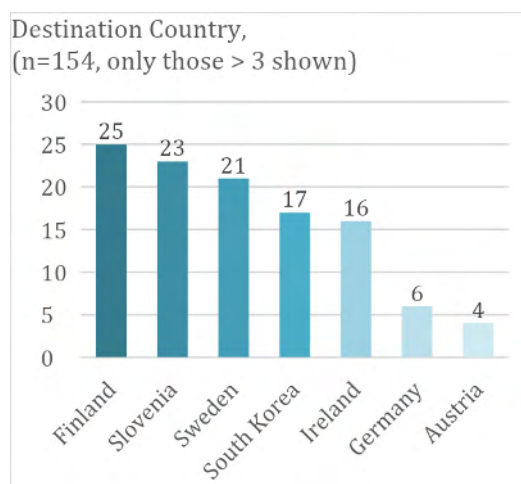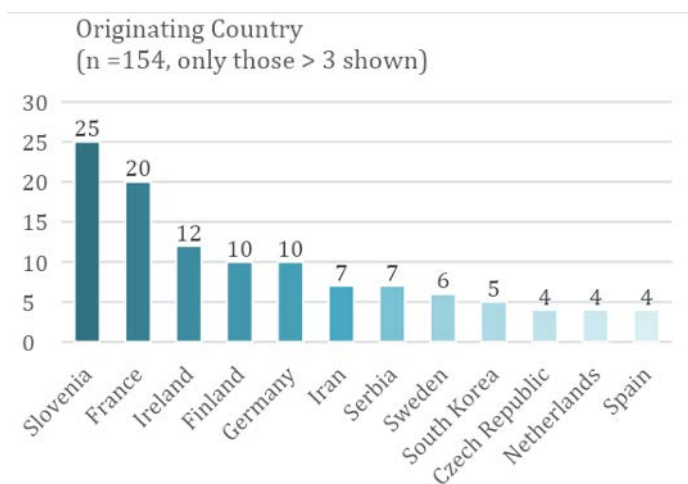Dr. David Modic david.modic@fri.uni-lj.si

Collaborating Laboratory:
Computer Communications Laboratory

Project: Hublinked – Strengthening Europe's Software Innovation Capacity

Today's software development is driven by creativity and innovation. Software development teams are working across continents and time zones. Computer Science students are often not prepared for these types of collaboration.

Our ambition was to create a resource nexus for European exchange students and through it to help them prepare for international collaboration, initially as students, and later as high-value workers and team leaders. In order to make this nexus relevant, we need to understand the needs of our students, specifically their motivations. We were looking to scrutinise common beliefs about student exchanges (e.g., the academic excellence of the host institution is a strong predictor of choice). The analysis showed the language of the courses to be the strongest predictor of choice. A well-structured plan of exchange, a programme matching personal preferences, the cost of living in the host country and several other elements all rank higher than the research impact factor of the department and its academic excellence.

> "We dispel some common misconceptions about the needs of exchange students and establish a sound foundation for further efforts."

A summary of answers from 154 incoming or outgoing mobility students at 6 EU universities. The survey will be administered to students on mobility yearly at all six universities and the results will be used as feedback for quality assurance.

GETM3 – Global Entrepreneurial Talent Management 3

Assoc. Prof. Dr. Tomaž Hovelja Tomaz.Hovelja@fri.uni-lj.si
Assoc. Prof. Dr. Damjan Vavpoti Damjan.Vavpotic@fri.uni-lj.si
Doc. Dr. Dejan Lavbič Dejan.Lavbic@fri.uni-lj.si
Assist. Prof. Dr. Ciril Bohak Ciril.Bohak@fri.uni-lj.si
Assist. Dr. Matjaž Pančur Matjaz.Pancur@fri.uni-lj.si

Northumbria University, Dublin Institute of Technology, Dublin City University, Ekonomska fakulteta Univerze v Ljubljani, Univerza v Varšavi, Tehnološka univerza v Varšavi, Kyungpook National University

Collaborating Laboratory: Information Systems Laboratory

Project: Global Entrepreneurial Talent Management 3, H2020 MSCA-RISE 2016 – Grant Agreement number: 734824

"The FRI team helped develop recommendations for the European Commission on curriculum innovations for EU universities that would increase the entrepreneurship of the young professionals/ students of STEM programmes."

Despite the widely recognized importance of young talent (e.g. Europe 2020), this potential remains largely untapped. Such young people are educated and entrepreneurial, and yet experience instability in employment. At the same time, employers report a skills mismatch and difficulties in attracting, managing and retaining young talent. GETM3 tackles this paradoxical situation by proposing an innovative, multi-perspective approach that improves the employability of the young. The approach is being developed through co-operation among three stakeholders: employers (including MNC & SMEs), universities and students/graduates in our 15-partner consortium; comprising of a transnational, inter-disciplinary, inter-generational, gender balanced and inter-sectorial research team.

The team from the Faculty of Computer and Information Science has focused on deliverables related to employer toolkits for young talent evaluation, curriculum innovations in universities that would increase the entrepreneurialism of young professionals, case studies of young entrepreneurs' success stories in STEM, and the preparation of a researcher handbook that covers the key dimensions on how policy makers can improve the employability of the young professionals by capitalizing on entrepreneurialism as their key characteristic. We are especially proud of the recommendations that we developed for the European Commission in the researcher handbook that cover curriculum innovations for EU universities that would increase the entrepreneurship of the young professionals/students in STEM programmes.

GPU backend for Stan

Assoc. Prof. Dr. Erik Štrumbelj erik.strumbelj@fri.uni-lj.si

Collaborating Laboratory:
Laboratory for Cognitive Modelling
Laboratory for Adaptive Systems and Parallel Processing

Project: Advancement of computationally intensive methods for efficient modern general-purpose statistical analysis and inference
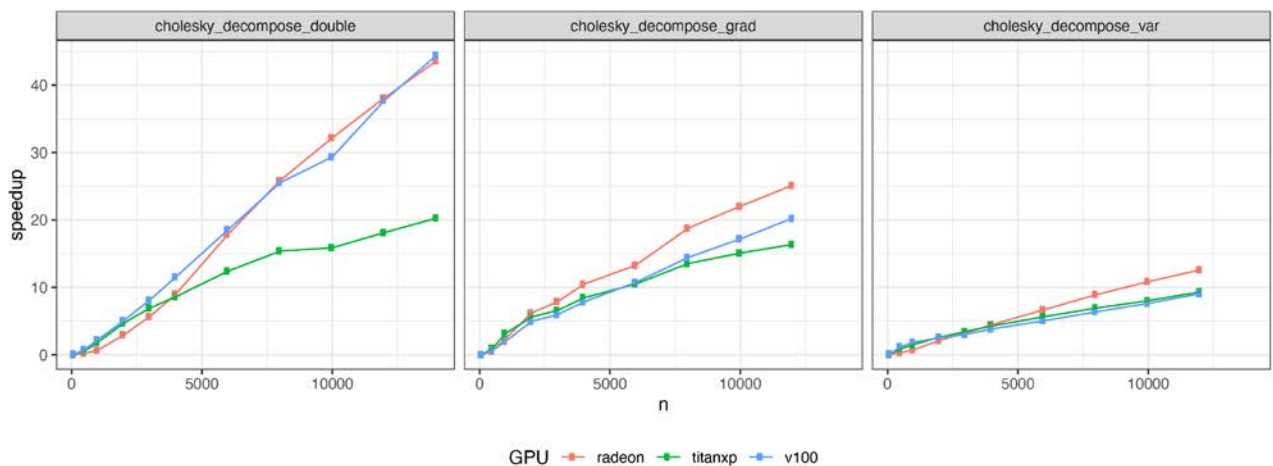
The main objective of the initial research project was to speed up computation for modern statistical inference, which is typically based on Markov Chain Monte Carlo. The work evolved into an extensible framework that enables users to utilize heterogeneous compute devices and a growing library of efficient implementations of matrix algebra primitives, model likelihoods and other common computational bottle-necks in statistical computation. One of the main advantages of the framework is that it is based on OpenCL. This allows users to utilize hardware from different vendors, unlike similar libraries based on NVIDIA CUDA, which are limited to a single vendor.

Our work has been integrated into Stan, the state-of-the-art tool for Bayesian modelling, and in 2019 the principal investigator received the Amazon Research Award for the continuation of this research. Our research was also partially supported by the Slovenian Research Agency (ARRS, project grant L1-7542 and research core funding P5-0410).

Link to the Article: https://arxiv.org/abs/1907.01063

> "Contributing to the development of state-of-the-art Bayesian modelling software."

Češnovar, R., Bronder, S., Sluga, D., Demšar, J., Ciglarič, T., Talts, S., & Štrumbelj, E. (2019). GPU-based Parallel Computation Support for Stan. arXiv preprint arXiv:1907.01063.

Cholesky decomposition speedups for different GPUs and varying input matrix size n × n. We measured the performance of the Cholesky decomposition on matrices of doubles, matrices of VAR, and the gradient of the Cholesky decomposition.

Intermediacy of publications

Assist. Prof. Dr. Lovro Šubelj lovro.subelj@fri.uni-lj.si

Collaborating Laboratory:
Laboratory for Data Technologies

"Intermediacy offers a principled approach for tracing scientific knowledge."

Researchers spend a lot of time keeping track of the literature in their field. Computational methods can be used to increase the efficiency with which researchers study the literature. We propose a method called intermediacy that enables tracing the historical development of scientific knowledge. Based on citation relations, intermediacy aims to identify publications that play a major role in the historical development from an older publication to a more recent one. Main path analysis currently is the most commonly used approach for addressing this problem. We show the advantages of intermediacy over main path analysis. When implemented in interactive search interfaces, intermediacy may help to significantly increase the efficiency with which researchers study the literature in their field.
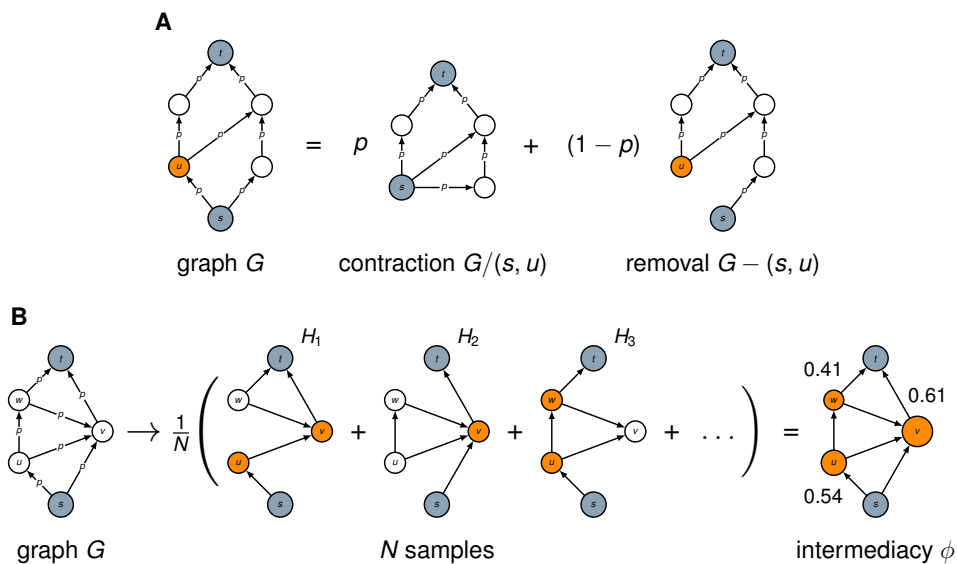
Illustration of the calculation of intermediacy using the exact algorithm (A) and using the Monte Carlo approximation (B).

Geographical mapping of visitor flows in tourism

Assoc. Prof. Dr. Damjan Vavpotič damjan.vavpotic@fri.uni-lj.si
FRI students: Nejc Ribič, Karmen Knavs, Gal Oblak
Prof. Dr. Ljubica Knežević Cvelbar ljubica.knezevic@ef.uni-lj.si
Dr. Mojca Mayr

Collaborating Laboratory:
Information systems laboratory

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

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, and such 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 visualize 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.
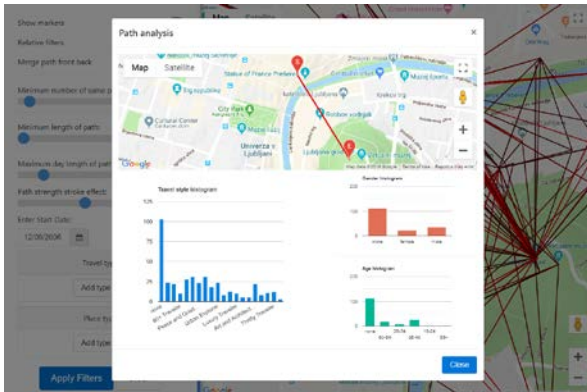
Ljubica Knežević Cvelbar, Damjan Vavpotič. Use of consumer basket to understand the tourists' behaviour: presented at the 7th International Association for Tourism Economics (IATE) conference, La Plata, Argentina, 4th September 2019.

Ljubica Knežević Cvelbar, Mojca Mayr, Damjan Vavpotič. Identifying visitor migration patterns with user generated content: new insights on visitor flows: presented within Doctoral Day at the Travel and Tourism Research Association's (TTRA 2018) European Chapter Conference, Ljubljana, 26th April 2018.

Year 2019: Thea Sinclair Award for Journal Article Excellence – the outstanding paper in Tourism Economics for the year 2019

Year 2018: 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

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.

Application for analysis of micro tourism flows in Ljubljana.

Reconstruction of Vienna tourism attractions network.

Guidelines for destination management based on carrying capacity and tourism flows models
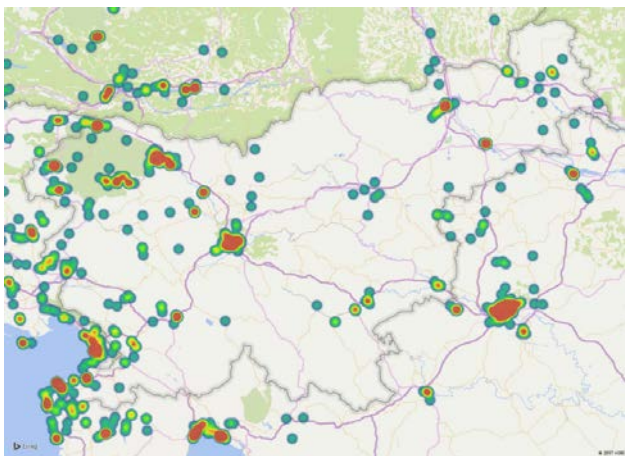
Assoc. Prof. Dr. Damjan Vavpotič   damjan.vavpotic@fri.uni-lj.si
Prof. Dr. Ljubica Knežević Cvelbar   ljubica.knezevic@ef.uni-lj.si

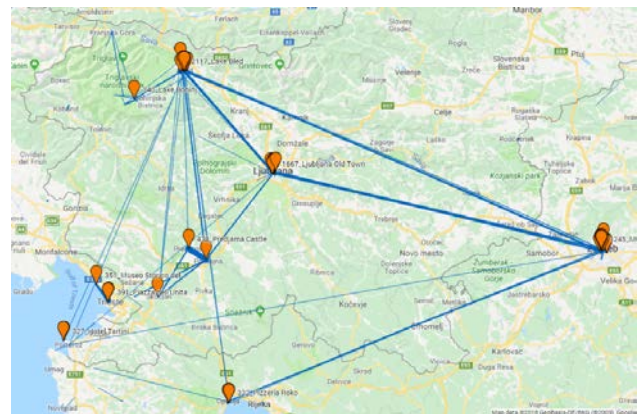**Collaborating Laboratory:**
Information systems laboratory

Project: Guidelines for destination management based on carrying capacity and tourism flows models, ARRS - Target research programme (V5-1724)

The project was completed in 2019 and resulted in important practical and scientific contributions. Practical contributions include guidelines for sustainable tourism management to reduce the environmental and social damage of tourism in line with the Slovenian Tourism Development Strategy 2017-2021. With innovative data collection and analysis based on big data approaches, we enabled better understanding of tourists' needs, thus enhancing the competitiveness of Slovenia's tourism industry. The project's scientific contributions built on the latest findings in the field of destination management, using advanced methodology and integration of the concept of visitor flows with carrying capacity. The research was published in journals and at conferences, and received journal article excellence and best paper presentation awards. The project was performed in cooperation among the Faculty of Economics and Faculty of Computer and Information Science, both at the University of Ljubljana, and the Scientific Research Centre of Slovenian Academy of Sciences and Arts.

"Using innovative data collection and analysis approaches to better understand tourists' needs and to develop guidelines for sustainable tourism management."

Heat map showing number of tourist posts in Slovenia.

Main tourism flows in Slovenia and its surroundings.

Algorithmic Techniques in Graph Optimization

Dr. Andrej Brodnik andrej.brodnik@fri.uni-lj.si
Prof. Dr. Borut Robič borut.robic@fri.uni-lj.si
Assist. Prof. Dr. Boštjan Slivnik bostjan.slivnik@fri.uni-lj.si
Assist. Prof. Dr. Tomaž Dobravec tomaz.dobravec@fri.uni-lj.si
Assist. Prof. Dr. Jurij Mihelič jurij.mihelic@fri.uni-lj.si
Assist. Prof. Dr. Uroš Čibej uros.cibej@fri.uni-lj.si

Collaborating Laboratories:
Laboratory for Ubiquitous Systems
Laboratory of Algorithmics

Project: Graph Optimisation and Big Data, ARRS (N2-0053)

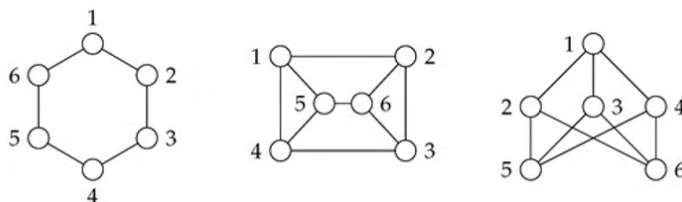> "Using graph symmetries for algorithmic speedups and succinct data representation."

Uroš Čibej, Luka Fürst, Jurij Mihelič (2019) A symmetry-breaking node equivalence for pruning the search space in backtracking algorithms. Symmetry, 11(10), [HYPERLINK "https://www.mdpi.com/2073-8994/11/10/1300"pdf].

Uroš Čibej, Jurij Mihelič (2019) A polynomial-time algorithm for recognizing subgraph-symmetry-compressible graphs. Middle-European Conference on Applied Theoretical Computer Science, [HYPERLINK "http://library.ijs.si/Stacks/Proceedings/Information-Society/2019/IS2019_Volume_I%20-%20MATCOS.pdf"pdf].

Andrej Brodnik, Sandi Režonja (2019) Construction of stable mesh using self-assembly chains. The IPSI BgD Transactions on Internet Research, 15(2), [HYPERLINK "http://ipsitransactions.org/journals/papers/tir/2019jul/p11.pdf"pdf].
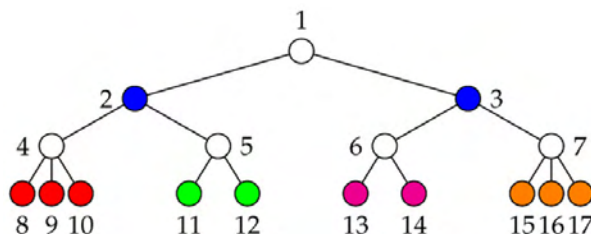
Tomaž Dobravec (2020) ALGator - an automatic algorithm evaluation system. Advances in Computers, 116(1), [HYPERLINK "https://doi.org/10.1016/bs.adcom.2019.07.002"pdf].

Graphs and networks are ubiquitous structures for representing data in many applications. Finding optimal patterns in graphs is part of graph optimization. Since many such problems are computationally hard to solve, efficient algorithms are becoming crucial in the era of Big Data. We developed a novel technique for pruning the search space of backtracking algorithms, an algorithm for embedding of chains in a mesh, and a tool for empirical evaluation of algorithms. The pruning technique applies to various problems where the goal is to find a pattern that can be represented with a monomorphism relation, and it is based on the exploitation of graph symmetries. If graphs exhibit many symmetries, often a significant speedup is possible. The technique also shows the potential for efficient storage of graphs. The second result is important for the creation of nanostructures in system biology. The algorithm employs an exhaustive search in a smaller domain with generalization to a bigger space. Finally, the third result gives an evaluation tool applicable in the distributed/parallel environment and Big Data.

greedy: {1,4 | 2,6 | 3 | 5} greedy: {1,4 | 5,6 | 2 | 3} greedy: {1,2 | 3,4 | 5,6}
opt: {1,3,5 | 2 | 4 | 6}   opt: {1,4,5 | 2 | 3 | 6}   opt: {1,5,6 | 2,3,4}

Greedy and optimal algorithmic symmetries in example graphs.

Symmetry-breaking node equivalence in a tree.

Tools and resources for linguistic analysis

Prof. Dr. Marko Robnik Šikonja marko.robnik@fri.uni-lj.si
Dr. Simon Krek simon.krek@guest.arnes.si
Dr. Špela Arhar Holdt arhar.spela@gmail.com
Dr. Kaja Dobrovoljc kaja.dobrovoljc@gmail.com
Bojan Klemenc bojan.klemenc@fri.uni-lj.si
Jaka Čibej jaka.cibej@gmail.com
Luka Krsnik krsnik.luka92@gmail.com

Collaborating Laboratory: Laboratory for Cognitive Modelling

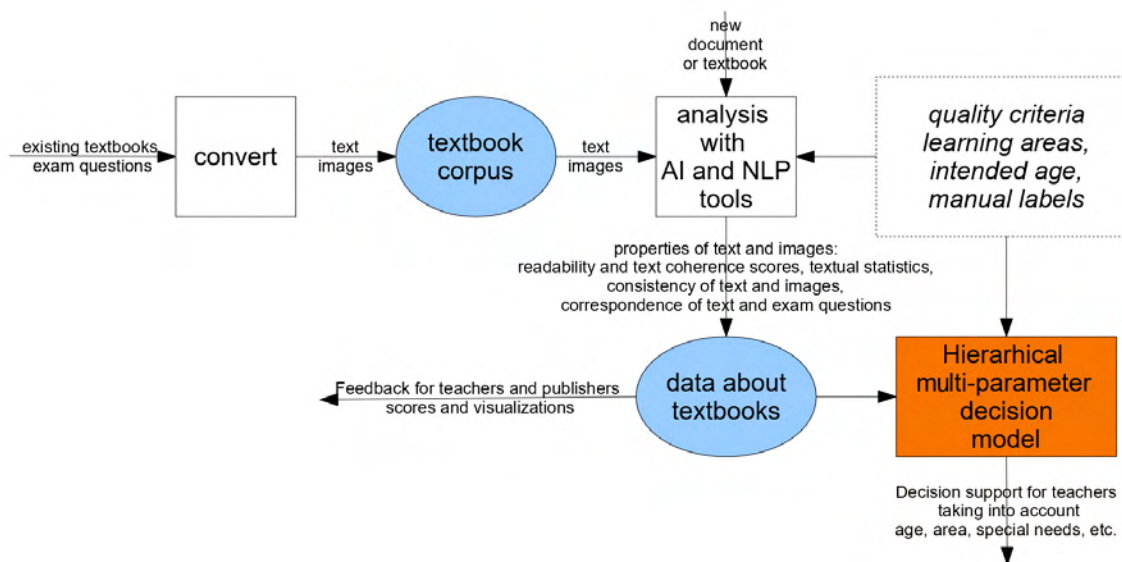**Project:** New grammar of modern standard Slovene: resources and methods

Researchers from the UL FRI collaborate in the Centre for Language Resources and Technologies of the University of Ljubljana (CJVT UL). This interdisciplinary research unit is aimed at the scientific research, development, and maintenance of crucial digital language resources and language technologies for contemporary Slovene.

The project "New grammar of contemporary standard Slovene: sources and methods" explores the linguistic and methodological foundations of a complex analysis of written and spoken Slovene. The resulting methodology and data provide a foundation for the empirical description of Slovene and will enable several language technology applications. This analysis represents the first step towards a new descriptive, corpus-based grammar of Slovene. Among other outcomes, the UL FRI researchers have created tools for the extraction of n-grams and skip-grams from huge corpora, tools for the extraction of patterns from dependency parse trees, and improved Sloleks, the Slovene morphological lexicon. The language technologies and resources created as part of this project are publicly available.

"Novel tools and resources for effective analysis of lexical phenomena in large corpora."

Krsnik, Luka; Arhar Holdt, Špela; Čibej, Jaka; Dobrovoljc, Kaja; Ključevšek, Aleksander; Krek, Simon; Robnik-Šikonja, Marko, 2019, Corpus extraction tool LIST 1.0, Slovenian language resource repository CLARIN.SI, http://hdl.handle.net/11356/1227.

Krsnik, Luka; Dobrovoljc, Kaja and Robnik-Šikonja, Marko, 2019, Dependency tree extraction tool STARK 1.0, Slovenian language resource repository CLARIN.SI, http://hdl.handle.net/11356/1284.

Dobrovoljc, Kaja; Krek, Simon; Holozan, Peter; Erjavec, Tomaž; Romih, Miro; Arhar Holdt, Špela; Čibej, Jaka; Krsnik, Luka; Robnik-Šikonja, Marko, 2019, Morphological lexicon Sloleks 2.0, Slovenian language resource repository CLARIN.SI, http://hdl.handle.net/11356/1230.

The interface of corpus extraction tool LIST is multilingual.

Readability of Slovene texts

Prof. Dr. Marko Robnik-Šikonja marko.robnik@fri.uni-lj.si
Tadej Škvorc tadej.skvorc@fri.uni-lj.si
Dr. Simon Krek simon.krek@guest.arnes.si
Dr. Špela Arhar Holdt arhar.spela@gmail.com
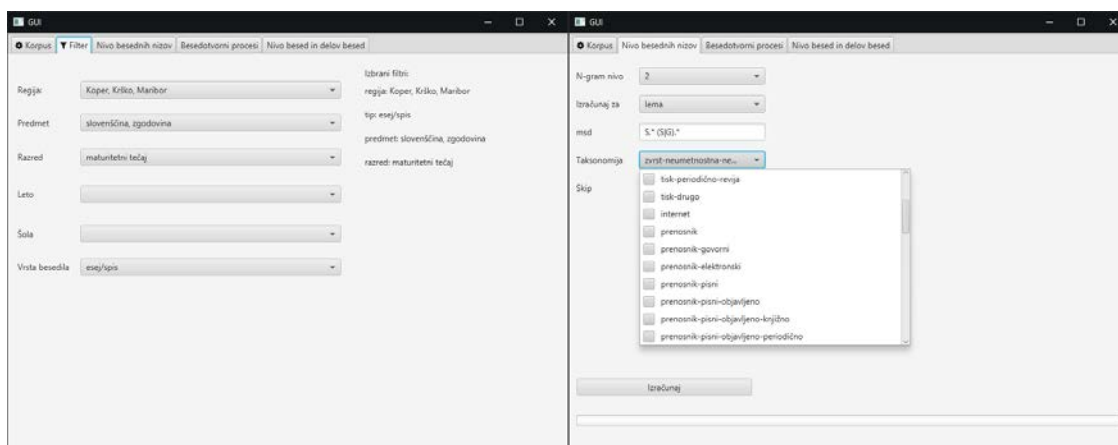Dr. Senja Pollak senja.pollak@ijs.si

Collaborating Laboratory: Laboratory for Cognitive Modelling

Project: Improving the Quality of Slovene Textbooks

We developed quality metrics for Slovene primary and secondary school textbooks and a prototype of an automatic web tool for assessment of the readability of Slovene texts. The tool will allow users to evaluate a text's readability based on its syntactic, lexical, and morphological properties. It will support teachers' decision-making with regard to the selection of an appropriate textbook.

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

Škvorc, Tadej, Simon Krek, Senja Pollak, Špela Arhar Holdt, and Marko Robnik-Šikonja. "Predicting Slovene Text Complexity Using Readability Measures". Contributions to Contemporary History, 59, no. 1 (2019).

"Several readability metrics were tested and adapted for Slovene."

Schematic of a software solution for assessment of readability and textbooks.

NetSDM: Semantic data mining with network analysis

Prof. Dr. Marko Robnik Šikonja marko.robnik@fri.uni-lj.si
Dr. Jan Kralj jan.kralj@ijs.si
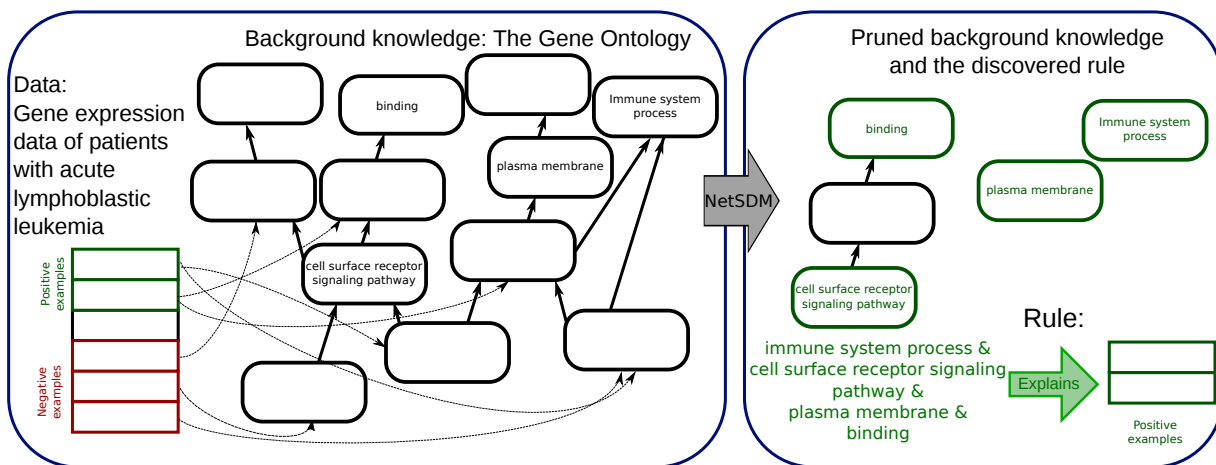Prof. Dr. Nada Lavrač nada.lavrac@ijs.si

Collaborating Laboratory: Laboratory for Cognitive Modelling

Project: Language resources and technologies for Slovene; ARRS research programme (P6-0411)

Semantic data mining (SDM) is a form of relational data mining that uses annotated data together with complex semantic background knowledge to learn rules that can be easily interpreted. The drawback of SDM is the high computational complexity of existing SDM algorithms, resulting in long run times even when applied to relatively small data sets. We developed an effective SDM approach, named NetSDM, which first transforms the available semantic background knowledge into a network format, followed by node ranking based on network analysis and then pruning to significantly reduce the size of the original background knowledge. Our evaluation of the NetSDM methodology using acute lymphoblastic leukaemia and breast cancer data demonstrates that NetSDM achieves dramatic reductions in the time needed, and that the learned rules are comparable or better than those obtained by the original SDM algorithms.

"A novel, effective approach to semantic data mining based on network analysis of background knowledge."

Kralj, Jan, Robnik Šikonja, Marko, Lavrač, Nada. NetSDM: semantic data mining with network analysis. Journal of Machine Learning Research. 2019, vol. 20, pp. 1-50. [pdf]

Overview of the NetSDM methodology.

Improving Parkinson's disease patients' quality of life

Prof. Dr. Marko Robnik Šikonja marko.robnik@fri.uni-lj.si
Dr. Anita Valmarska anita.valmarska@fri.uni-lj.si
Prof. Dr. Nada Lavrač nada.lavrac@ijs.si
Dr. Dragana Miljković dragana.miljkovic@ijs.si

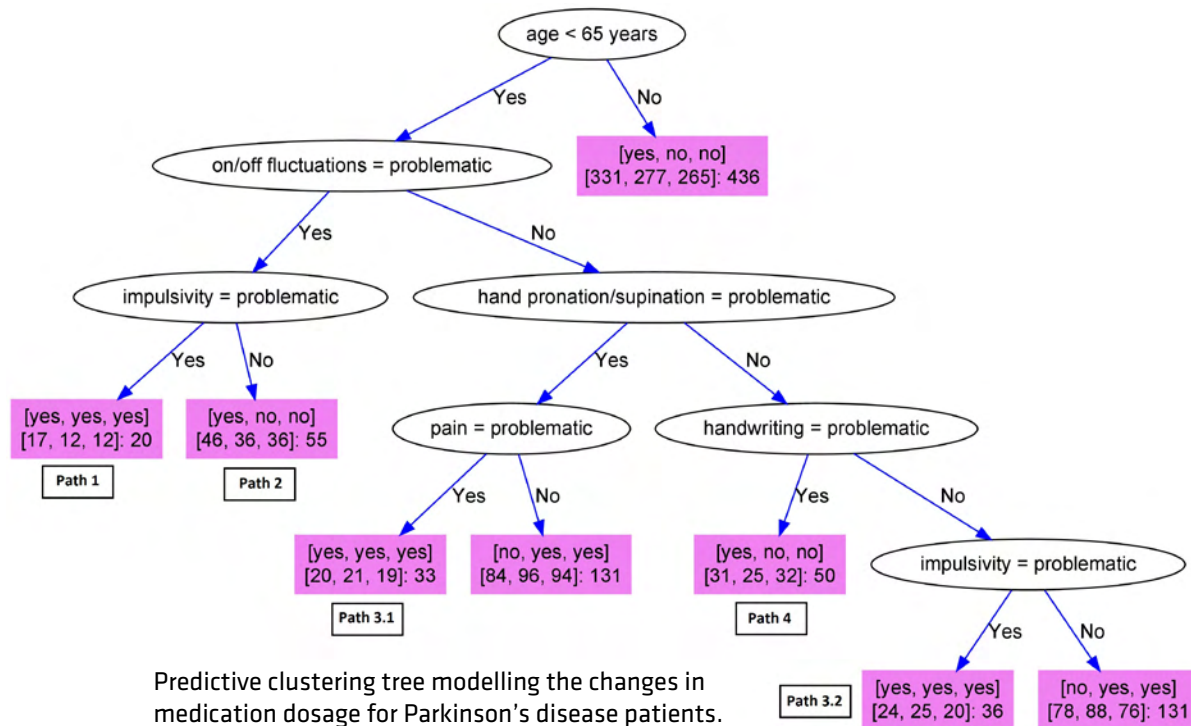**Collaborating Laboratory:** Laboratory for Cognitive Modelling

Project: Parkinson's disease data mining

The quality of life of patients with Parkinson's disease degrades significantly with disease progression. We developed three approaches towards personalized management of Parkinson's disease patients, based on discovering groups of similar patients. The first algorithm detects the impacts of various symptoms on disease progression. Experiments on the Parkinson's Progression Markers Initiative data reveal a subset of symptoms influencing disease progression which are already established in the literature, as well as symptoms that have only recently been considered as possible indicators of disease progression by clinicians. The second novelty of this work is a methodology for detecting patterns of changes in medication dosage based on patient status. The methodology combines multitask learning using predictive clustering trees and short time series analysis to better understand when a change in medication is required. The third novelty is a method for visualization of the patient's overall status and their anti-Parkinson's medication therapy. The resulting patterns of disease progression show that there are differences between male and female patients.

> "Novel analytic methods for improving the quality of life for Parkinson's disease patients."

Valmarska, Anita, Miljković, Dragana, Konitsiotis, Spyros, Gatsios, Dimitros, Lavrač, Nada, Robnik Šikonja, Marko. Symptoms and medications change patterns for Parkinson's disease patients stratification. Artificial Intelligence in Medicine. 2018, vol. 91, pp. 82-95

Valmarska, Anita, Miljković, Dragana, Robnik Šikonja, Marko, Lavrač, Nada. Connection between the Parkinson's disease subtypes and patients' symptoms progression. In Artificial Intelligence in Medicine: proceedings. Cham: Springer, 2019. pp. 263-268

Predictive clustering tree modelling the changes in medication dosage for Parkinson's disease patients.

Visual object tracking VOT challenges

Assoc. Prof. Dr. Matej Kristan matej.kristan@fri.uni-lj.si
Assist. Prof. Dr. Luka Čehovin luka.cehovin@fri.suni-lj.si
Mag. Alan Lukežič alan.lukezic@fri.uni-lj.si
Prof. Dr. Aleš Leonardis ales.leonardis@fri.uni-lj.si
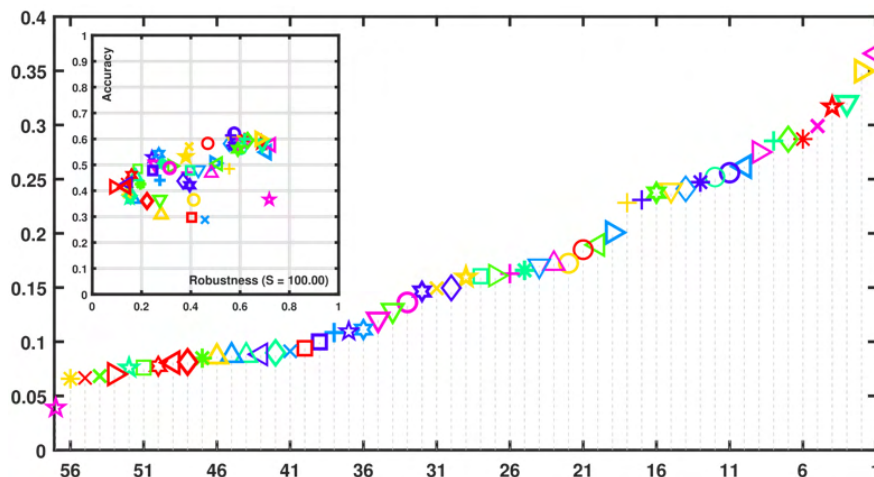
Collaborating Laboratory:
Visual Cognitive Systems Laboratory

Visual object tracking is one of the core problems in computer vision. In its most general formulation, the task is to localize the target in each frame given the target annotated in the first frame. Due to the high application potential, numerous trackers are proposed each year. To maintain a concise overview and comparison of different approaches, the visual object tracking (VOT) initiative was established in 2013. Since then, seven VOT challenges have been organized annually and the results presented at the VOT workshops organized in conjunction with major computer vision conferences. The most recent such event, VOT2019, was held in conjunction with the ICCV2019. The challenge involved the main short-term tracking sub-challenge, short-term real-time tracking sub-challenge, long-term tracking sub-challenge, the RGB+Thermal sub-challenge, and the long-term RGB+depth sub-challenge. The VOT2019 main challenge alone evaluated 78 trackers and the results were published in a joint paper co-authored by 183 researchers from 59 different institutions from around the world. Over the last seven years, the VOT has produced ten papers, and seven of these are VOT results papers published at the annual workshops. These papers are highly cited in the tracking community (ResearchGate shows over 1,100 citations).

Link to the Article: http://prints.vicos.si/publications/375

> "The VOT is the largest visual object tracking challenge in computer vision and has built a strong community of computer vision specialists working in the field of visual object tracking."

Matej Kristan, Jiri Matas, Ales Leonardis, Michael Felsberg, Roman Pflugfelder, Joni-Kristian Kamarainen, Luka Čehovin Zajc, Ondrej Drbohlav, Alan Lukezic et al. The Seventh Visual Object Tracking VOT2019 Challenge Results, ICCV 2019 workshops, 2019

The VOT maintains challenging datasets and evaluation toolkits, and defines a rigorous performance evaluation methodology.

Detection of inconsistencies in complex visual data using deep learning

Assoc. Prof. Dr. Danijel Skočaj danijel.skocaj@fri.uni-lj.si
Domen Tabernik domen.tabernik@fri.uni-lj.si
Vitjan Zavrtanik vitjan.zavrtanik@fri.uni-lj.si
Jon Natanael Muhovič jon.muhovic@fri.uni-lj.si
Jakob Božič jb3065@student.uni-lj.si
Assoc. Prof. Dr. Matej Kristan matej.kristan@fri.uni-lj.si
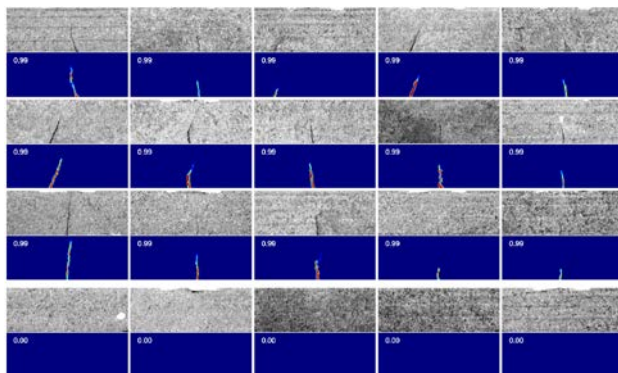
Collaborating Laboratory:
Visual Cognitive Systems Laboratory

Project: DIVID – Detection of Inconsistencies in Complex Visual Data Using Deep Learning, basic research project funded by the Slovenian research agency

> "Our goal is to develop novel deep learning methods for modelling complex consistency and detecting inconsistencies in visual data."
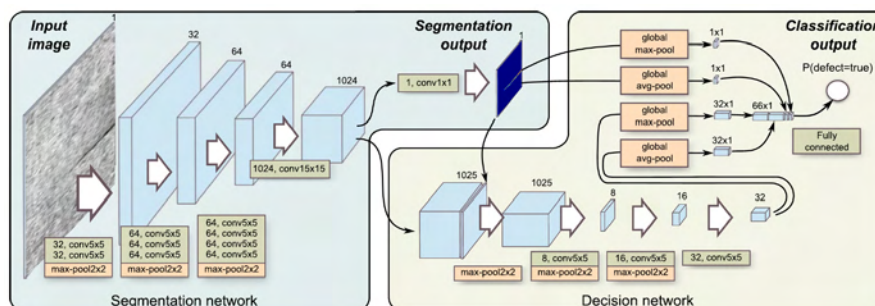
Obtaining a large amount of visual data has become a trivial task in today's technological world. However, making use of this enormous amount of data poses a huge challenge. Computer vision and machine learning, in particular deep learning, offer answers to these issues, although most of the proposed 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 address this issue of a particular computer vision task of anomaly detection in images. Our aim is to go beyond traditional supervised learning. We are therefore developing weakly supervised, semi-supervised, and unsupervised deep learning methods for modelling complex consistency and detecting inconsistencies in visual data using training images annotated with different levels of accuracy. We validate the developed methods in three related but different problem domains: visual inspection, remote sensing, and visual surveillance.

Domen Tabernik, Samo Šela, Jure Skvarč, Danijel Skočaj. Segmentation-based deep-learning approach for surface-defect detection. Journal of Intelligent Manufacturing, ISSN 0956-5515, 2019

Surface with (or without) defects and automatically segmented defects.

Two-stage end-to-end deep learning architecture for weakly supervised surface-defect detection.

Computer vision for robotic boats

Assoc. Prof. Dr. Matej Kristan matej.kristan@fri.uni-lj.si
Assist. Prof. Dr. Janez Perš janez.pers@fe.uni-lj.si
Mag. Borja Bovcon borja.bovcon@fri.uni-lj.si
Mag. Jon Natanael Muhović jon.muhovic@fri.uni-lj.si
Mag. Alan Lukežič alan.lukezic@fri.uni-lj.si
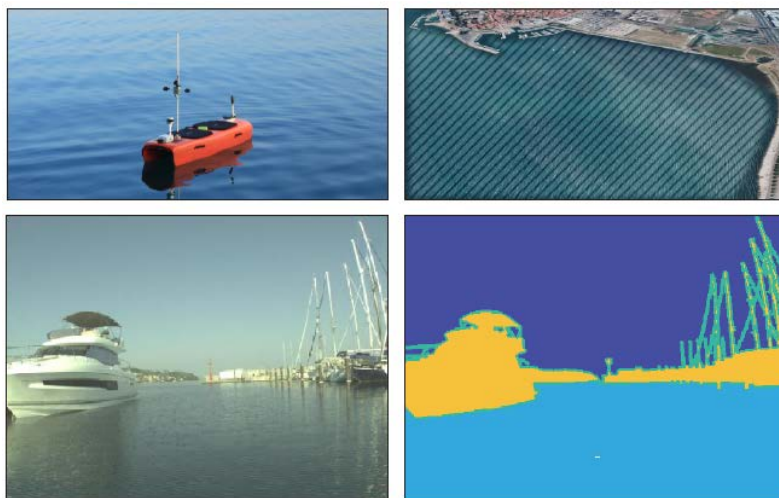
Collaborating Laboratories:
Visual Cognitive Systems Laboratory (ViCoS, FRI)
Laboratory for Machine Intelligence (LMI, FE)

Project: Robust computer vision methods for autonomous boats

Recent developments in field robotics have led to the 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 be dangerous for humans. One of the main challenges in autonomous navigation is precise and timely obstacle detection. Cameras show 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. The goals of the project are to develop robust computer vision methods for the core tasks required for safe navigation: obstacle detection, tracking and holistic environment perception. We have proposed several methods for obstacle detection by semantic segmentation, sensor fusion and 3D reconstruction, and designed algorithms for real-time short-term and long-term tracking. The methods have been evaluated on sensory data captured on a real USV.

Link to the Article: https://www.vicos.si/Projects/Viamaro

> "Our goal is to develop novel environment perception methods for autonomous navigation on unmanned surface vehicles, i.e., robotic boats."

Muhovič, Jon Natanael, Mandeljc, Rok, Bovcon, Borja, Kristan, Matej, Perš, Janez. Obstacle tracking for unmanned surface vessels using 3-D point cloud. IEEE Journal Of Oceanic Engineering, ISSN 0364-9059, 2019

Bovcon, Borja, Muhovič, Jon Natanael, Perš, Janez, Kristan, Matej. The MaSTr1325 dataset for training deep USV obstacle detection models. In: Maciejewski, Tony (ed.). IROS Macau 2019. Danvers (MA): IEEE. cop. 2019, p. 3431-3438

Alan Lukežič, Ugur Kart, Jani Käpylä, Ahmed Durmush, Joni-Kristian Kämäräinen, Jiří Matas, and Matej Kristan. CDTB: A Color and Depth Visual Object Tracking Dataset and Benchmark, IEEE International Conference on Computer Vision (ICCV), 2019

A USV and example of semantic segmentation for obstacle detection.

Democratized image analytics by visual programming through integration of deep models and small-scale machine learning

Prof. Dr. Blaž Zupan blaz.zupan@fri.uni-lj.si
Assist. Prof. Dr. Tomaž Curk tomaz.curk@fri.uni-lj.si
Assist. Primož Godec primoz.godec@fri.uni-lj.si
Assist. Dr. Lan Žagar lan.zagar@fri.uni-lj.si
Assist. Vesna Tanko vesna.tanko@fri.uni-lj.si
Prof. Dr. Janez Demšar janez.demsar@fri.uni-lj.si
Assist. Dr. Marko Toplak marko.toplak@fri.uni-lj.si
Assist. Res. Dr. Ajda Pretnar ajda.pretnar@fri.uni-lj.si
Assist. Dr. Tomaž Hočevar tomaz.hocevar @fri.uni-lj.si
Assist. Rok Gomišček rok.gomiscek@fri.uni-lj.si
Aleš Erjavec ales.erjavec@fri.uni-lj.si
Assist. Dr. Andrej Čopar andrej.copar@fri.uni-lj.si
Aleš Erjavec ales.erjavec@fri.uni-lj.si
Amra Omanović amra.omanovic@fri.uni-lj.si
Assist. Dr. Martin Stražar martin.strazar@fri.uni-lj.si
Assist. Prof. Dr. Marinka Žitnik marinka.zitnik@fri.uni-lj.si

Collaborating Laboratory:
Bioinformatics Laboratory

"Orange Data Mining software democratizes image analytics by visual programming through integration of deep models and small-scale machine learning."

Deep learning's application for biological data analysis presents significant challenges, including the need for large annotated data sets and complex programming. To address these issues, we developed an approach utilizing smaller image sets and an accessible data science suite, which integrates deep learning, data visualization, and modeling. This suite, featured in a Nature Communications article, is embodied in a general-purpose data mining tool called Orange.

Orange facilitates the creation of data analysis workflows through visual programming, allowing users to assemble components akin to Lego bricks. Applied to diverse image sets, we successfully inferred phenotype prediction models, often exceeding the accuracy of trained molecular biologists. Our methods require no programming or extensive knowledge about deep learning and are freely available. While, in the paper, we focused on image analytics, the concepts introduced have broad applicability in data science.

Godec P., Pančur M., Ilenič N., Čopar A., Stražar M., Erjavec A., Pretnar A., Demšar J., Starič A., Toplak M., Žagar L., Hartman J., Wang H., Bellazzi R., Petrovič U., Garagna S., Zuccotti M., Park D., Shaulsky G., Zupan B.

Orange data mining platform, with an example of image analytics workflow for analyzing images from biology (from Godec et al. 2019, in Nature Communication).
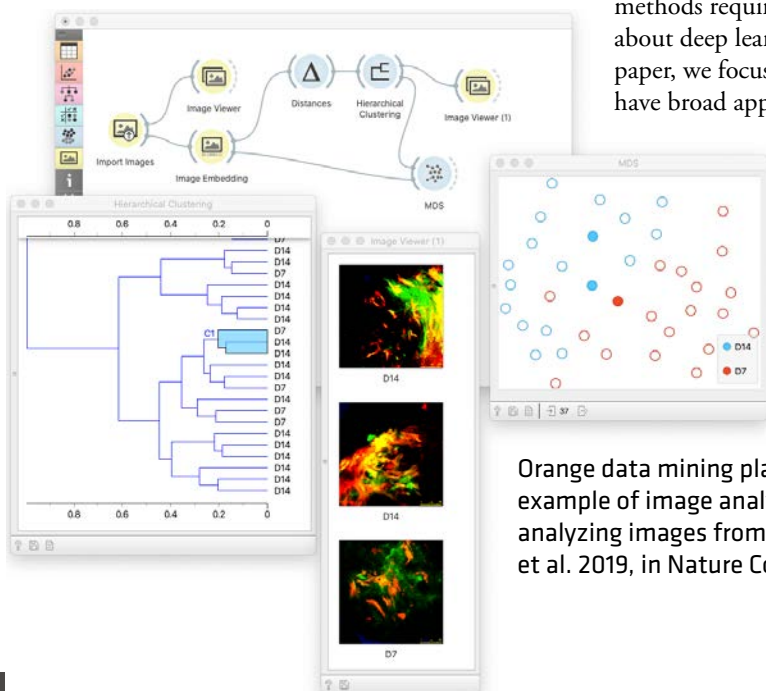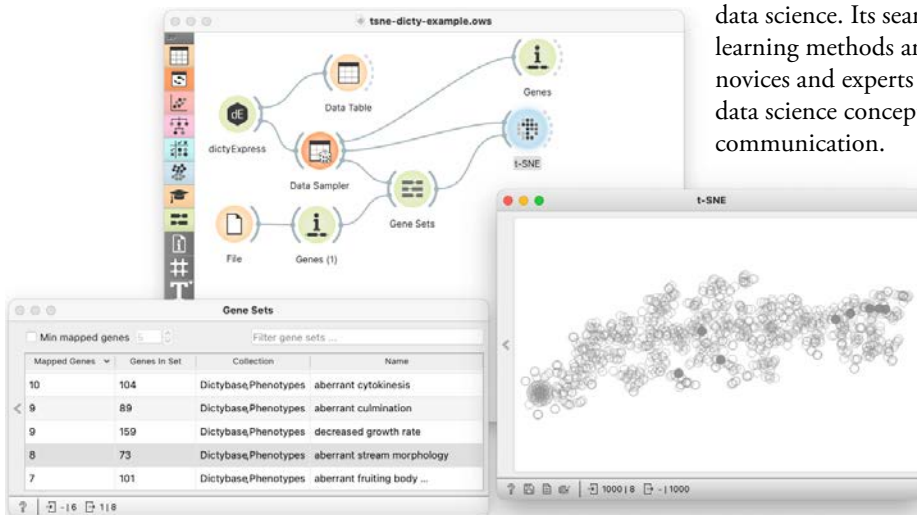
Orange: data mining, fruitful and fun

Prof. Dr. Blaž Zupan blaz.zupan@fri.uni-lj.si
Assist. Prof. Dr. Tomaž Curk tomaz.curk@fri.uni-lj.si
Assist. Primož Godec primoz.godec@fri.uni-lj.si
Assist. Dr. Lan Žagar lan.zagar@fri.uni-lj.si
Assist. Vesna Tanko vesna.tanko@fri.uni-lj.si
Prof. Dr. Janez Demšar janez.demsar@fri.uni-lj.si
Assist. Dr. Marko Toplak marko.toplak@fri.uni-lj.si
Assist. Res. Dr. Ajda Pretnar ajda.pretnar@fri.uni-lj.si
Assist. Dr. Tomaž Hočevar tomaz.hocevar @fri.uni-lj.si
Assist. Rok Gomišček rok.gomiscek@fri.uni-lj.si
Aleš Erjavec ales.erjavec@fri.uni-lj.si
Assist. Dr. Andrej Čopar andrej.copar@fri.uni-lj.si
Aleš Erjavec ales.erjavec@fri.uni-lj.si
Amra Omanović amra.omanovic@fri.uni-lj.si
Assist. Dr. Martin Stražar martin.strazar@fri.uni-lj.si
Assist. Prof. Dr. Marinka Žitnik marinka.zitnik@fri.uni-lj.si

Collaborating Laboratory:
Bioinformatics Laboratory

The Bioinformatics Laboratory of the University of Ljubljana, the recipient of the prestigious Golden Plaque, has developed a unique data mining tool, Orange (https://orange.biolab.si). This state-of-the-art software revolutionizes data science by offering an intuitive, visual programming interface for designing data analysis workflows, thereby democratizing data science. Its seamless integration of cutting-edge machine learning methods and interactive data visualizations enables novices and experts to easily create and understand complex data science concepts, making it ideal for prototyping and communication.

> "Orange is a user-friendly data mining tool blending visual programming and interactive visualization to make complex data analytics accessible to everyone."

A typical Orange Data Mining workflow. The workflow from the figures shows the genes of a social amoeba Dictyostelium discoideum positioned in the t-SNE plot according to their expression. The user can also select a gene set of choice and see if its genes group together in the t-SNE plot.

What sets Orange apart is its emphasis on educational applications. Crafted to blend machine learning and data visualization effortlessly, Orange allows easy explanation of data science concepts and enables the design of experimental workflows. With over two decades of development, nearly a million lines of code, and over 50,000 monthly users, Orange is likely the most extensive open-source software developed in Slovenia. Its educational influence extends to YouTube (http://youtube.com/orangedatamining), where video courses introducing data science through Orange have garnered over a million views. This tool is a data mining software and a comprehensive data science education platform that students can utilize throughout their academic journey and beyond.

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
franc.jager@fri.uni-lj.si

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
aleksandar.jurisic@fri.uni-lj.si

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
matija.marolt@fri.uni-lj.si

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 on-line streaming data processing, big data and machine learning in medicine and health, biosignal processing. The work performed also overlaps with the area of Computer Science Education, Medical Informatics and Data Science in Medicine and Healthcare.

Dr. Andrej Brodnik
andrej.brodnik@fri.uni-lj.si

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 to cross-lingual embeddings, complex analysis of written and spoken Slovene, analysis of big data and networks, monitoring and analysis of energy exchange trading, web-user profiling, applying evolutionary computation to data mining, modeling of sport games, heuristic search methods in clickstream mining, multi-view learning, learning and data fusion from data streams, various data mining subtasks in medical decision problems and medical diagnosis, Bayesian statistics and statistical computation, learning and concept drift detection in data streams, incremental semi-supervised learning, text summarization, data fusion.

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
marko.bajec@fri.uni-lj.si

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, and radio-based localization.

Prof. Dr. Branko Šter
branko.ster@fri.uni-lj.si

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's location), parallel computation (algorithm mapping and scheduling, algorithms in parallel systems, hardware supported multithreading, dataflow computing), 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
borut.robic@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

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. Based on the demand of our industry partners we recently also focused on digital transformation of enterprises, specifically on key Industry 4.0 areas: smart factory, smart operations, smart products, data-driven services and digital organization.

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

Bioinformatics Laboratory

Bioinformatics lab researches ways to combine 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 data mining suite that features visual programming, workflows, and interactive data analytics. Orange is powerful yet simple to use and is our contribution to the democratization of data science.

Prof. Dr. Blaž Zupan
blaz.zupan@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).

Assoc. Prof. Dr. Peter Peer
peter.peer@fri.uni-lj.si

Artificial Intelligence Laboratory

The laboratory carries out basic and applied research in artificial intelligence, specifically machine learning (including argument based machine learning), heuristic search, qualitative reasoning, intelligent robotics, game playing, and intelligent tutoring systems (ITS for programming and game playing, automated hint generation). Members of the laboratory also participate in several applicative projects, primarily focusing on applying artificial intelligence methods in medicine, e.g. for monitoring of Parkinson's disease or early detection of dyslexia.

Assist. Prof. Dr. Aleksander Sadikov
aleksander.sadikov@fri.uni-lj.si

Laboratory for Integration of Information Systems

The laboratory has established a 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 architecture, edge and fog computing, 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
matjaz.juric@fri.uni-lj.si

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

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.).

Sen. Lect. Igor Rožanc
igor.rozanc@fri.uni-lj.si

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, algebraic topology, computational topology, topological data analysis, nonlinear dynamical systems, Brownian motion, martingales and scientific computing. On the discrete side of the mathematical spectrum, however, we deal with problems in graph theory, particularly the structural and colouring problems of graphs, which are also connected to problems in computational geometry.

Assist. Prof. Dr. Žiga Virk
ziga.virk@fri.uni-lj.si

Computer Communications Laboratory

Computer Communications Laboratory is focused on research in the area of communication networks and protocols, cloud architectures and services, cloud and network security, virtualization and conteinerisation, computer supported learning systems, and mobile computing. Besides technical aspects, the laboratory is investigating human aspects related to networked computing (e.g. psychology of cybersecurity and human-computer interaction). The laboratory's portfolio includes a number of projects with industry (e.g. ISKRATEL - platform architecture for next generation telecommunication services), government agencies (e.g. AKOS - network measurement data analysis with the Slovenian communication regulator), as well as EU research framework projects (e.g. RICERCANDO - mobile broadband data analysis toolkit development) and national and EU digital education projects (Digital UL and HUBLINKED).

Assoc. Prof. Dr. Mojca Ciglarič
mojca.ciglaric@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.

Industrial projects

The Faculty is participating on 28 projects funded by different institutions and industry partners, including: Slovenian Research Agency • Amazon.com services, Inc. • AMZS d.d. • ARNES • BSP Regionalna Energetska Borza d.o.o. • C-Path • Dars d.d. • Forum Ljubljana • Garex Adria, napredne informacijske storitve, d.o.o. • IPMIT d.o.o. • ISKRATEL, telekomunikacijski sistemi, d.o.o. • Kolektor Group d.o.o. • Mladinska Knjiga Založba d.d. • Nela razvojni center d.o.o. • Pressclipping d.o.o. • Revelo d.o.o. • Slovenia control, Slovenian Air Navigation Services, Ltd • Slovenian Environment Agency • Slovenian Society of Cardiology • Smart Blood Analytics Swiss SA • Synchrotron SOLEIL • Telekom Slovenije d.d. • U-blox AG • UCS d.o.o. • XLAB, razvoj programske opreme in svetovanje d.o.o. • Best Solutions d.o.o. • Društvo za digitalno pismenost • Insurate, raziskave in razvoj d.o.o. • Zebra BI informacijske rešitve d.o.o.

Our industry partners are also key to strengthening our DataScience@UL-FRI initiative and helping us provide a complete learning experience for our students. These six companies share our vision and were the first to support our initiative: Siemens, Zemanta, Celtra, Lexpera, In516ht, Garex.

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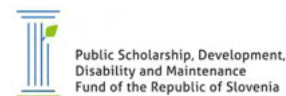
Current programmes, basic research and applied projects, bilateral and other projects funded by the Slovenian Research Agency

- Interactive visualisations for analysis of the genetic expressions of individual cells
- The inverse problem of own values for a graph
- Mobile computing for effective dissemination of information in emergency situations
- New algorithms for insertion and textual interpretation of data-rich knowledge networks in *biomedicine*

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

EkoSMART: A Smartcity Ecosystem

Project Type:
Structural Funds Project

Financed by:
European Regional Development Fund and Slovenian Ministry of Education, Science and Sport

Project Coordinator:
Marand d.o.o., 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 was 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 focused on three key pillars for smart cities (health, active life and mobility) and was strategically linked with municipalities and other important smart city domains, such as energy, smart buildings, citizen involvement and engagement, and smart communities. In economic terms, the vision of the EkoSMART programme was to enable Slovenian smart city innovations and products to enter the global market. Based on a high-quality consortium of advanced partners, the programme placed 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

Financed by:
European Regional Development Fund and Slovenian Ministry of Education, Science and Sport

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

Financed by:
European Regional Development Fund and Slovenian Ministry of Education, Science and Sport

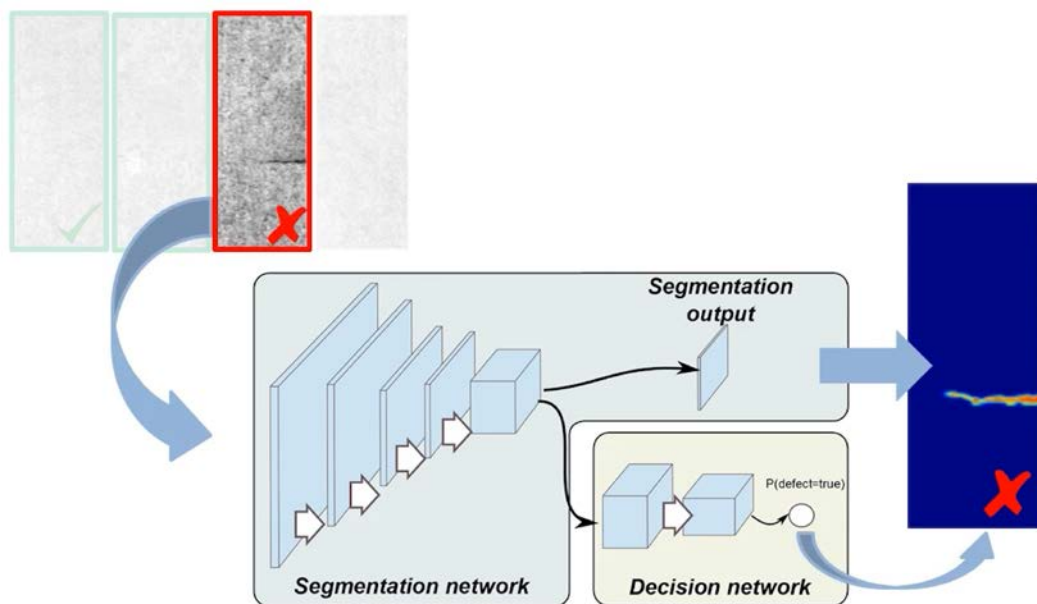**Project Coordinator:**
The Jožef Stefan Institute

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

Project duration:
2016–2020

Collaborating Laboratory:
Visual Cognitive Systems Laboratory

In GOSTOP, a total of 13 companies and 6 research organisations, which had compatible research and development programmes in the Factories of the Future concept, joined forces to push forward its development and to provide solutions to the current needs of Slovene industry. Four areas were identified in which decisive breakthroughs could be achieved: control technologies, tooling, robotics and photonics.

We are collaborating in the area of robotics. The main goal is to develop flexible and adaptable technologies for fast and simple adaptation of the production process to a new product. Our goal is to develop efficient machine vision algorithms coupled with machine learning approaches, which allows for fast and flexible adaptation of visual inspection systems to deal with novel quality control problems. Our research is based on the latest developments in deep learning and 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 exemplar images.

Data-driven deep-learning-based surface defect detection

Tourism 4.0: Enriched Tourist Experience

Tourism is growing rapidly. With more than 1.3 billion tourists yearly around the world a small change in the sector can have a huge impact on the whole of society. 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. Our goal is to unlock the innovation potential in the tourism sector by creating an ecosystem in which the infrastructure, people and technology behind it merge into one seamless experience of many personalized outputs. With the help of key technologies from Industry 4.0, such as IoT, Big Data, Blockchain, AI, VR and AR, we plan to develop tools to manage tourist flows while respecting users' data privacy and easing the negative impact of tourism on the local community and environment. 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 a lead in the development of Tourism 4.0 and make Slovenia its testbed.

1 = Climate change
2 = Land use
3 = Growth and economic development
4 = Value creation
5 = Smart destinations
6 = Management of technological development
7 = Destination websites
8 = Collaboration for technological development
9 = Travel experiences
10 = ICT for destination management

Marginal topic distribution
2%
5%
10%

Thesaurus of Modern Slovene: By the Community for the Community

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

Financed by:
Ministry of Culture

Project Coordinator and Principal Investigator at FRI:
Dr. Špela Arhar Holdt
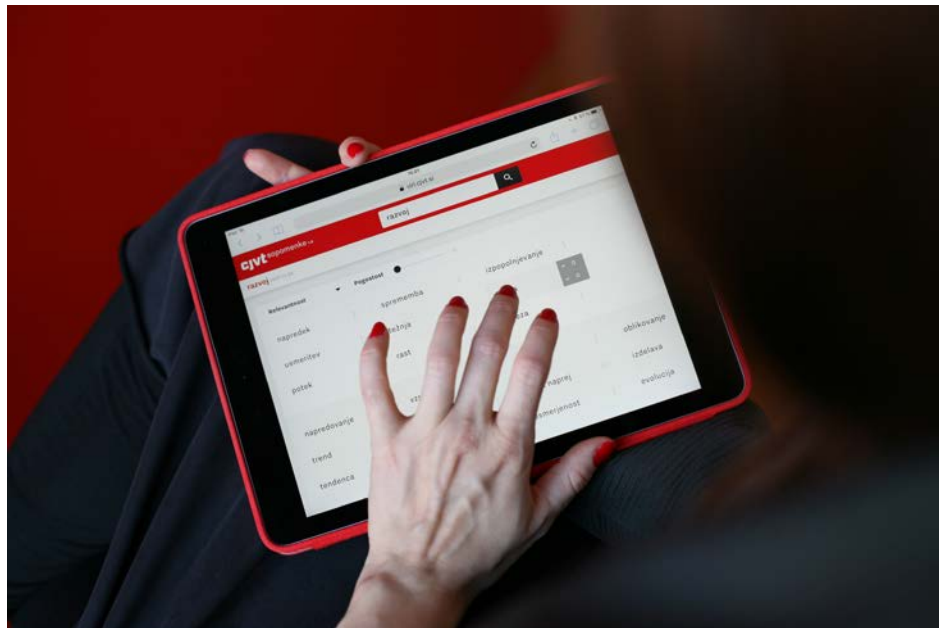spela.arhar@cjvt.si

Project duration:
2018–2019

Collaborating Laboratories:
Laboratory for Cognitive Modelling
Centre for Language Resources and Technologies

The Thesaurus of Modern Slovene [http://viri.cjvt.si/sopo-menke/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 was to promote this new type of resource among potential users, with emphasis on the user groups that find synonym information invaluable in their work. Within the project, a number of promotional events were organized, resulting in open-access educational materials [https://www.cjvt.si/promocija-sopo-menk/]. In addition, user feedback on the 'responsive concept' was collected and analyzed, and the methodology for user involvement was upgraded.

User participation in the Thesaurus: evaluating automatically obtained synonyms for the word 'development'.

EMBEDDIA: Cross-Lingual Embeddings for Less-Represented Languages in European News Media

Project Type:
EU project – H2020

Financed by:
European Commission

Project Coordinator:
The Jožef Stefan Institute

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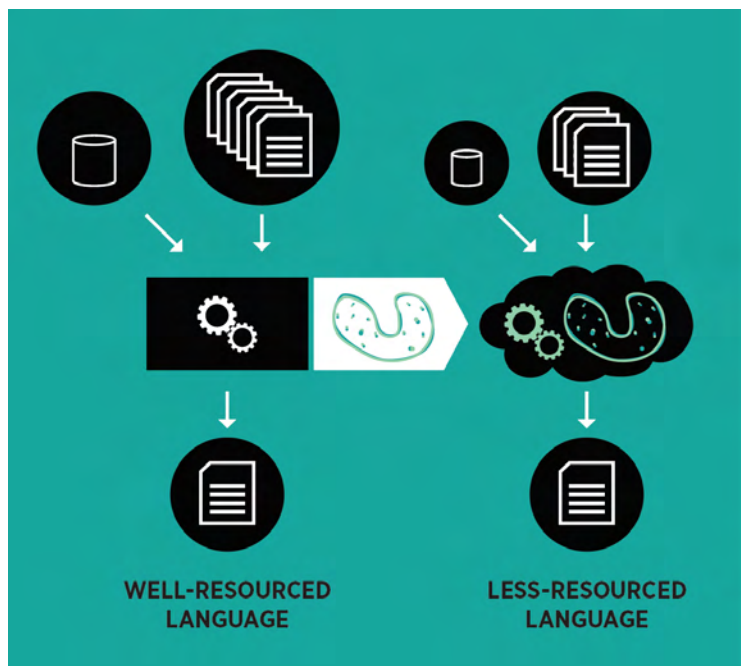Prof. Dr. Marko Robnik-Šikonja
marko.robnik@fri.uni-lj.si

Project duration:
2019–2021

Collaborating Laboratory:
Laboratory for Cognitive Modelling

Project partners:
Queen Mary University of London
Universite de la Rochelle
Helsinki University
University of Edinburgh
Texta OU
Ekspress Media
Trikoder (Styria Media Group)
Finnish News Agency STT

The use of deep neural networks significantly increased the success of artificial intelligence approaches in natural language. However, the success of deep learning relies on the availability of large annotated datasets in the required language. Modern machine learning models for language represent words as numeric vectors, called embeddings, which transform semantic similarities between words into distances. By aligning embeddings for different languages, we get a common cross-lingual representation. Cross-lingual mappings provide great potential for less-resourced languages: machine learning tools can be developed using one language's resources but can operate on another.

The EMBEDDIA project develops cross-lingual embeddings coupled with deep neural networks to allow existing monolingual resources to be used across languages. In three years, the project's six academic and four industry partners will develop novel solutions for under-represented languages, and test them in real-world news and media production contexts.

WELL-RESOURCED LANGUAGE   LESS-RESOURCED LANGUAGE

The idea of using cross-lingual embedding for model transfer.

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

Project Type:
EU project – H2020

Financed by:
European Commission

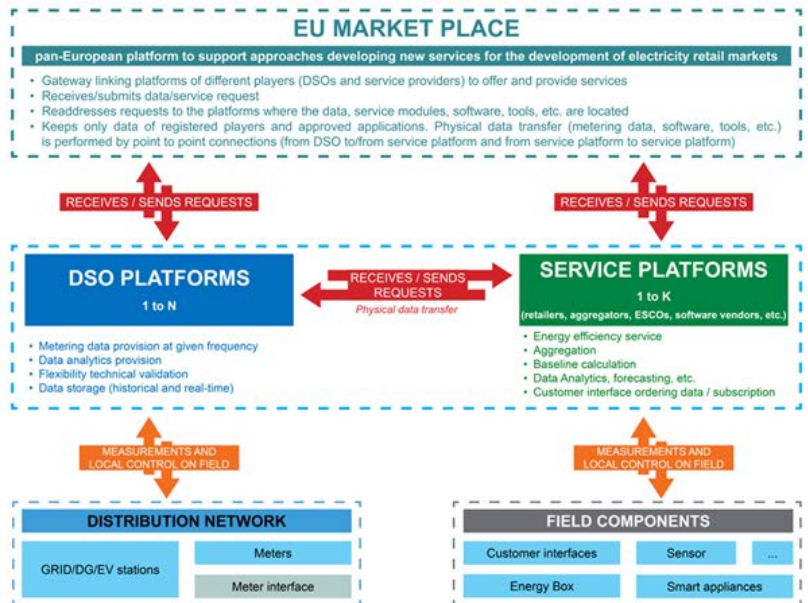**Project Coordinator:**
Enel Distribuzione s.p.a., Italy

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

Project duration:
2015–2019

Collaborating Laboratory:
Laboratory for Integration of Information Systems

Project partners:
E-Distribuzione Spa, EDISTRIBUCIÓN, Redes Digitales, S.L., Enedis, Vattenfall Eldistribution AB, European Distribution System Operators for Smart Grids, Verbund AG, Enel Energia S.p.a., Endesa S.A., Vattenfall AB, Ayuntamiento de Málaga, SAP SE, cyberGRID GmbH & Co KG, Siemens SPA, Assets Europe AB OY, VAASAETT LTD AB OY, Fundacion CIRCE CENTRO DE INVESTIGACION DE RECURSOS Y CONSUMOS ENERGETICOS, Univerza v Ljubljani, Kiwi Power Ltd.

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 CO_2 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 covered research and development activities on the EU Market Place – management of regulated and non-regulated 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

Financed by:
European Commission

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

Project partners:
ETRA Investigación y Desarrollo, S.A. (ETRA I+D), Centrul Roman al Energiei – CRE, Compania nationala de transport alenergiei electrice transelectrica SA, Institute Of Communications And Computer Systems, Independent Power Transmission Operator SA, Hellenic Electricity Distribution Network Operator S.A, Public Power Corporation SA, COBRA Instalaciones Y Servicios S.A., The VARTA Storage GmbH (VS), Elektroenergien Sistemen Operator EAD, Elektromreza Srbije AD, Security Coordination Centre SCC ltd Belgrade, Nezavisni Operator sistema u BiH, University of Manchester, Hrvatski operator prijenosnog sustava d.o.o., KONCAR – inzenjering za energetikui transport dd, Sveuciliste u Zagrebu fakultet elektrotehnike i računarstva, Univerza v Ljubljani, ELPROS, elektronski in programski sistemi, Crnogorski Elektroprenosni Sistem AD, Operator na elektroprenosniot sistem na Makedonija
Ss Cyril and Methodius University in Skopje, Faculty of Electrical, Engineering and Information Technologies, AD Elektrani na Makedonija Skopje - Direkcija, cyberGRID GmbH

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 crossborder 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.

XFLEX: Integrated Energy Solutions and New Market Mechanisms For an eXtended FLEXibility of the European Grid

Project Type:
EU project – H2020

Financed by:
European Commission

Project Coordinator:
ETRA Investigacion y desarrollo sa

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

Project duration:
2019–2023

Collaborating Laboratory:
Laboratory for Integration of Information Systems

Project partners:
Faculty of Electrical Engineering, Elektro Celje d.d., ETRA Investigacion y desarrollo sa, Institute of, Communication and Computer Systems , Diacheiristis Ellinikou Diktyou Dianomis Elektriki, Elektroenergien Sistemen Operator EAD, Petrol d.d., Albena AD, Suite5 data intelligence solutions limited

The X-FLEX project proposes a set of efficient, cost-effective, integrated solutions that will facilitate the optimum combination of decentralised flexibility assets, both on the generation (DER) side and on the demand side (V2G, power-to-heat/cold/gas, batteries, demand response), enabling all parties, including final prosumers, to offer their flexibility in the market creating benefits to all the actors in the smart grid value chain. X-FLEX will develop four complementary products that will offer services to all the energy stakeholders: SERVIFLEX tool – Integrated flexibility management tool, GRIDFLEX tool – Advanced tools for automatic control and observability, MARKETFLEX tool – Market platform and new market mechanisms and X-FLEX platform – Flexible and scalable integrated platform. These X-FLEX project solutions will be tested in real conditions at four pilot sites in three EU Member States (Bulgaria, Slovenia and Greece), with different needs and socioeconomic and technological boundaries, involving multiple existing flexibility assets (batteries, power to heat/cold, V2G and other storage solutions) and all complementary actors of the energy network (DSO, TSO, microgrid operator, utilities, flexibility providers, local communities).

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

Project Type:
EU project – H2020

Financed by:
European Commission

Project Coordinator:
BioIRC Ltd, Serbia

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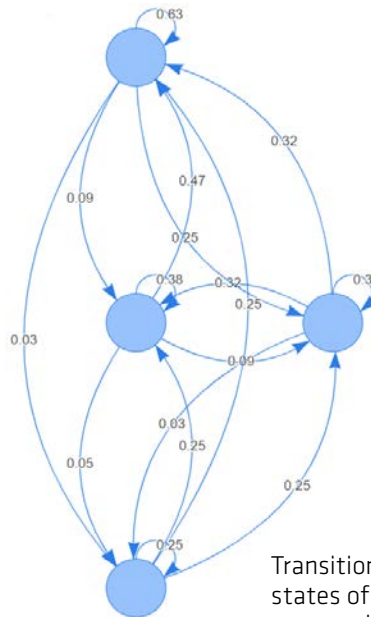Prof. Dr. Zoran Bosnić
zoran.bosnic@fri.uni-lj.si

Project duration:
2018–2021

Collaborating Laboratory:
Laboratory for Cognitive Modelling

Project partners:
Bioengineering Research and Development Center– BioIRC doo (RS), Illinois Institute of Technology (USA), University of Kent (UK), Newcastle University and Newcastle upon Tyne Hospitals NHS Foundation Trust (UK), Unit Cardiomiopatie Azienda Ospedaliero, Universitaria Careggi (IT), Institute of Cardiovascular, Diseases, Vojvodina (RS), University Hospital Regensburg, Department of Internal Medicine II (DE), University of Ioannina (GR), Barcelona Supercomputing Center – Centro Nacional de Supercomputación (ES), Univerza v Ljubljani (SI), Steinbeis Advanced Risk, Technologies (DE), University of Washington (USA), Seven Bridges Genomics Inc. (USA), Faculty of Medicine, University of Belgrade (USA)
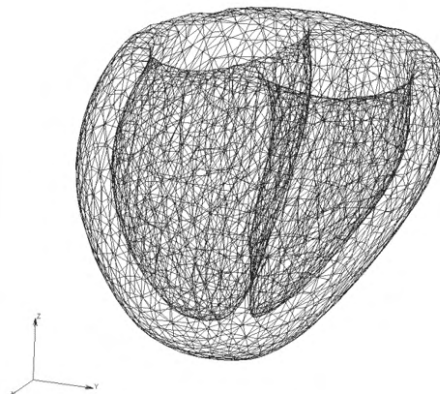
Cardiomyopathies are defined as abnormalities of the heart that are unexplained by the most frequent heart diagnoses. Familial cardiomyopathies (FCM) are most commonly diagnosed. Novel diagnoses and therapies need to be developed to affect the disease process and time course more fundamentally. Within 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 threatening 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.

Transition diagram between states of cardiomyopathy progression

Simulated heart geometry model

Quantitative MR-based Imaging of Physical Biomarkers

Project Type:
EU project – EMPIR (Health/Joint Research Project)

Financed by:
Euramet

Project Coordinator:
Istituto Nazionale di Ricerca Metrologica (INRIM), Torino, Italy

Principal Investigator at FRI:
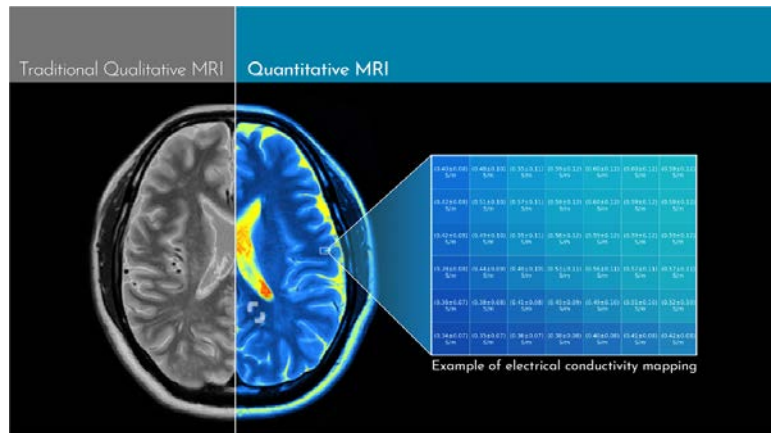Assist. Prof. Dr. Aleksander Sadikov
aleksander.sadikov@fri.uni-lj.si

Project duration:
2019–2022

Collaborating Laboratory:
Artificial Intelligence Laboratory

Project partners:
Instituto Nazionale di Ricerca Metrologica, Institut za mjeriteljstvo Bosne i Hercegovine , LGC Limited, Laboratoire national de métrologie et d´essais, Physikalisch-Technische Bundesanstalt, Turkiye Bilimsel ve Teknolojik Arastirma Kurumu, Charite - Universitaetsmedizin Berlin, Fondazione, Stella Maris, Technische Universität Dresden

Standard MRI (magnetic resonance imaging) results mostly have a qualitative nature that limits their objectivity and comparability. To overcome this, the project's aim is to evaluate the suitability of two MR-based emerging techniques, Electric Properties Tomography (EPT) and Magnetic Resonance Fingerprinting (MRF), to become clinical tools. During the project lifetime, EPT and MRF will undergo a full metrological characterisation, to provide the clinical community with a quantification of their reliability.

Moreover, two clinical studies, one focused on brain and the other on cardiac MRI (where specific attention is given to motion-compensation techniques, to maximize the quality of the acquisitions in the presence of breathing and heartbeat), will be performed on human subjects. The collected clinical data will be processed to explore the possibility of detecting pathological anomalies in the produced quantitative maps of the biomarkers, and to train models for diagnostic decision support systems.

Quantitative versus qualitative MRI

MiCREATE: Migrant Children and Communities in a Transforming Europe

Project Type:
EU project – H2020

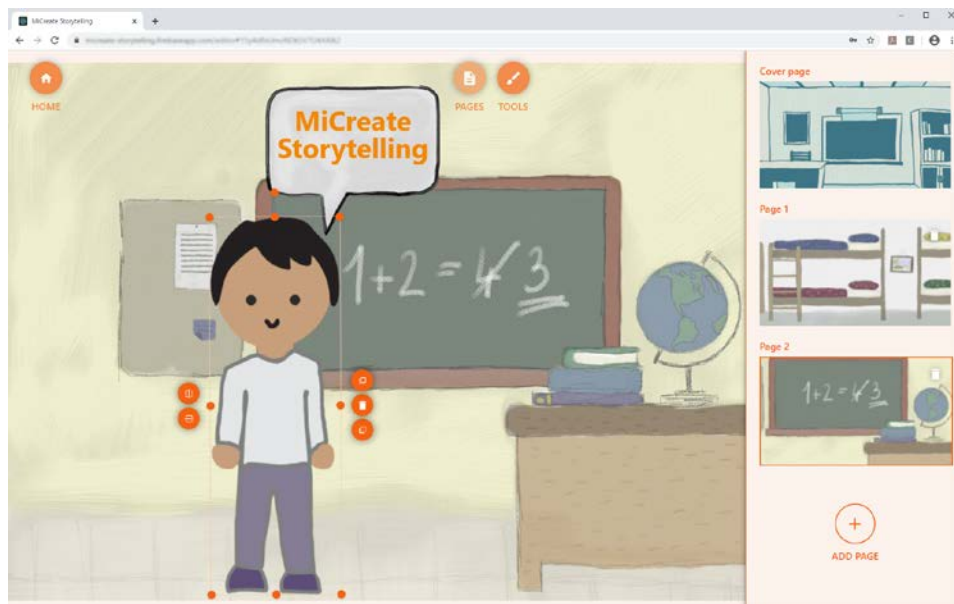**Financed by:**
European Commission

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).

COMMON: a Platform for Monitoring Society's State of Mind

Project Type:
Industrial project

Financed by:
Pressclipping d.o.o.

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

Project duration:
2019–2020

Collaborating Laboratory:
Laboratory for Data Technologies

The Common project aims to develop a platform for automatic analysis of news and information published in various media. It was initiated by a company that offers press clipping services to its customers. A number of different text and natural language processing services will be developed to support the company's existing services as well as to extend them beyond its current level. In support of smart city initiatives and principles, the Common project is also seeking to provide a special tool and associated dashboard for monitoring society's state of mind, i.e., to capture how specific society subgroups, such as students, the elderly, employees, disabled and other groups are feeling in the city, what are their opinions in relation to specific societal issues, what problems they might confront, what ideas they might have, etc., all based on social network and media analysis.

Data Mining and Visualization of Parkinson's Disease Progression

Project Type:
Structural Funds Project

Financed by:
European Regional Development Fund and Slovenian Ministry of Education, Science and Sport

Principal Investigator at FRI:
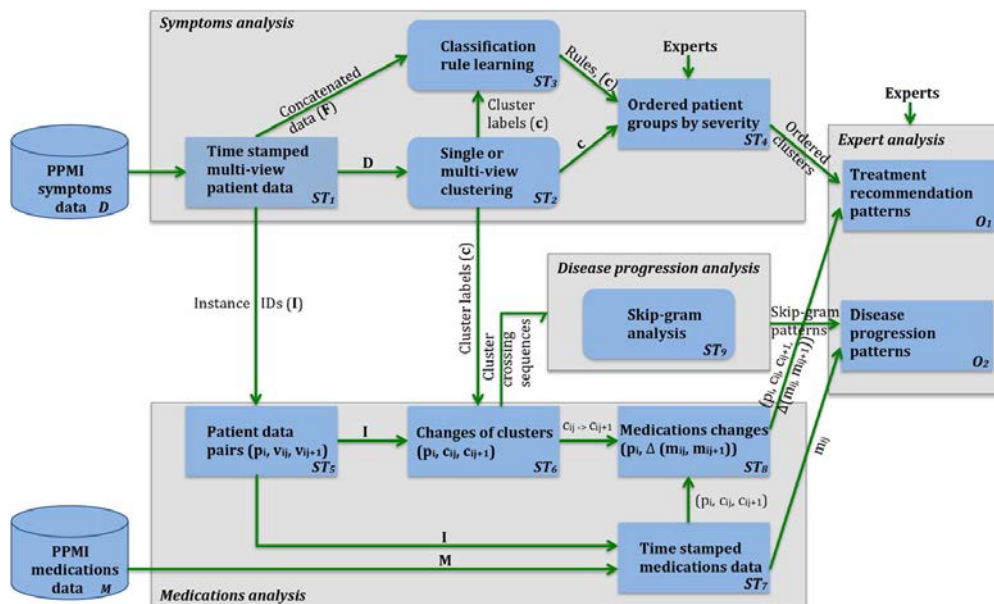Assist. Dr. Anita Valmarska
anita.valmarska@fri.uni-lj.si

Project duration:
2019–2022

Collaborating Laboratory:
Laboratory for Cognitive Modelling

Project partners:
3fs Računalniški studio d.o.o.

Parkinson's disease (PD) is a neurodegenerative disease affecting people worldwide. In addition to motor symptoms, Parkinson's disease patients all experience a range of other symptoms, including psychological, cognitive and behavioural problems, which affect the quality of life of the patients and their families. Parkinson's disease is a chronic disease whose management is directed towards the treatment of the underlying symptoms.

The project focuses on discovering groups of Parkinson's disease patients through the development and application of advanced multi-view clustering approaches. The detection of groups of patients who share similar symptoms at the time of diagnosis and similar patterns of disease progression is an important step towards the development of personalized treatment of PD patients. The second phase of the project consists of the development of an interactive tool for visualization of Parkinson's disease patients' longitudinal status and their respective treatments.

Outline of the approach to Parkinson's disease quality of life data analysis

Algebraic Footprints of Geometric Features in Homology

Project Type:
Basic research project

Project Code:
N1-0114

Financed by:
Slovenian Research Agency

Principal Investigator at FRI:
Assist. Prof. Dr. Žiga Virk
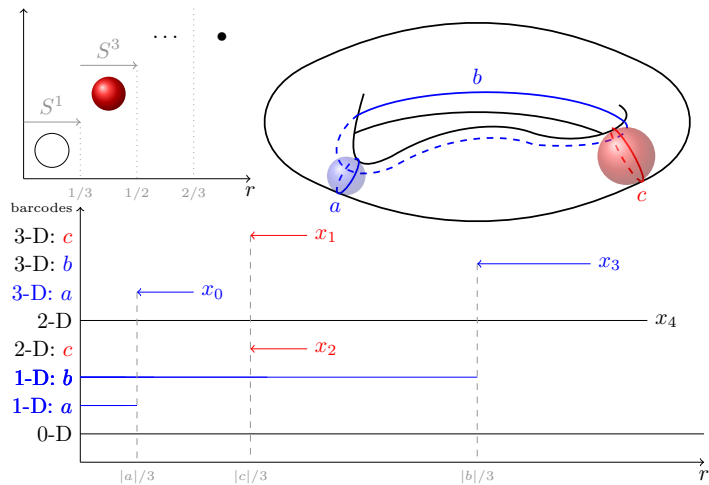ziga.virk@fri.uni-lj.si

Project duration:
2019–2022

Collaborating Laboratory:
Laboratory for Mathematical Methods in
Computer and Information Science

Project partners:
Faculty of Mathematics and Physics
IST Austria

Simplicial complexes represent triangulations of spaces of arbitrarily high dimension. They may describe the geometric shape of an object, a combinatorial structure, etc. In the topological context they are often analyzed using homology, which extracts encoded qualitative information: components, holes, voids, etc. In the past two decades, a parameterized version of homology was introduced within the field of topological data analysis. The additional structure allowed for a convenient description in terms of persistence diagrams, which summarize geometric and topological properties of a filtered simplicial complex in a stable sense.

With this project we plan to develop an extensive theory of geometric interpretation of persistence diagrams, linking the computable output to geometric features of a triangulated space. Particular emphasis is placed on interpretation of higher-dimensional points in persistence diagrams which encode lower-dimensional features such as geodesics.

Rips complexes of geodesic circles (for example, of loops a, b, and c on the torus above right) attain homotopy types of even-dimensional spheres according to the scheme above left. The corresponding persistence diagram (below) thus contains higher-dimensional bars indicating lower dimensional features (loops) in a space.

FaceGEN - Face Deidentification with Generative Deep Models

Project Type:
Basic research project

Project Code:
J2-1734

Financed by:
Slovenian Research Agency

Principal coordinator:
University of Ljubljana,
Faculty of Electrical Engineering,
Assoc. Prof. Dr. Vitomir Štruc
vitomir.struc@fe.uni-lj.si

Principal Investigator at FRI:
Assoc. Prof. Dr. Peter Peer
peter.peer@fri.uni-lj.si

Project duration:
2019–2022

Collaborating Laboratory:
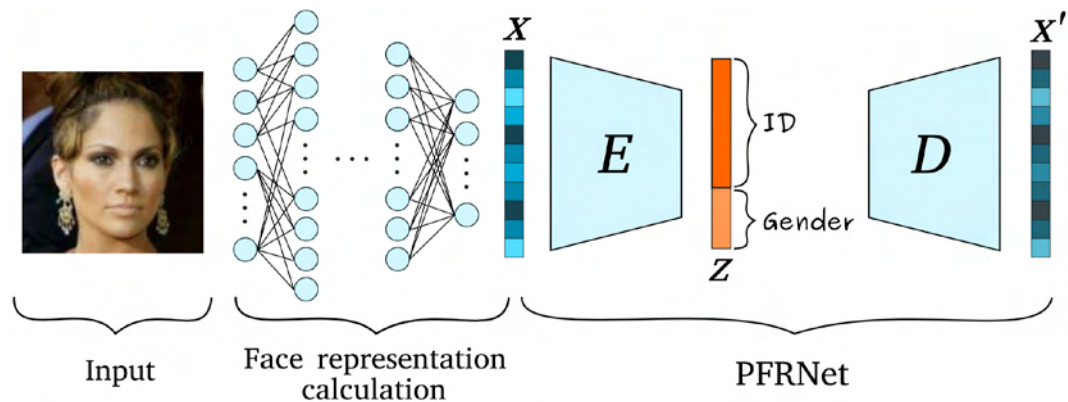Computer Vision Laboratory

Project partners:
Faculty of Electrical Engineering
Alpineon d.o.o.

The research project Face Deidentification with Generative Deep Models (FaceGEN), strives to conduct research on deidentification technology with a particular focus on deep learning, which has recently been shown to be a highly effective tool for various computer vision and machine learning problems. Our goal is to develop deep generative models and conditional face synthesis techniques that can be used for deidentification with still images, but also with video, where multiple faces in cluttered and unconstrained scenes may appear in the data. The main tangible results of the project will be novel generative deep models and input-conditioned image synthesis techniques that are able to deidentify all parts of the facial data photo-realistically. Within the project we also address the problem of soft-biometric privacy-enhancement and present PFRNet – a neural network capable of suppressing soft-biometric attributes, such as gender, in face representations without compromising identity cues.

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.

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.

Marija Ivanovska, Blaž Bortolato, Peter Rot, Janez Križaj, Peter Peer, Damer Naser, Philipp Terhoerst, Vitomir Štruc (2020), Learning privacy-enhancing face representations through feature disentanglement, IEEE FG 2020.

Input   Face representation calculation   PFRNet

PFRNet disentangles the input face representations in such a way that attributes and identity are encoded separately in the latent space. It is also a step closer to explainable AI. [3]

Detection of Inconsistencies in Complex Visual Data Using Deep Learning

Project Type:
Basic research project
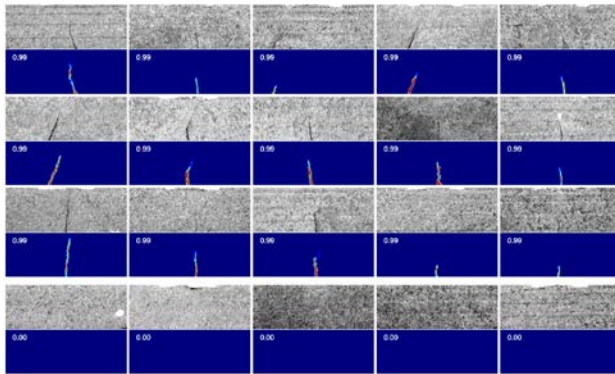
Project Code:
J2-9433

Financed by:
Slovenian Research Agency

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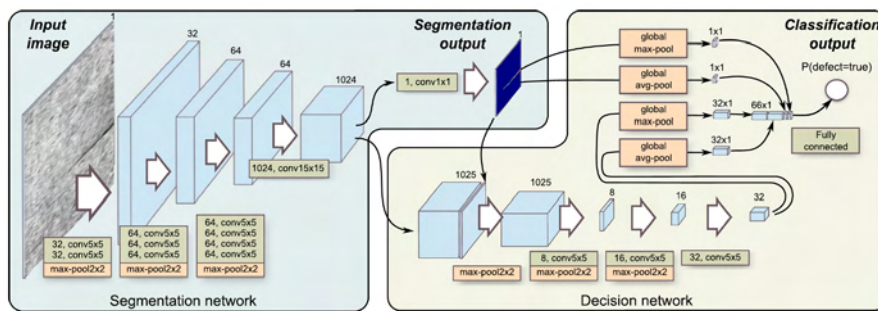Assoc. Prof. dr. Danijel Skočaj
danijel.skocaj@fri.uni-lj.si

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.

Surface with (or without) defects and automatically segmented defects.

Two-stage end-to-end deep learning architecture for weakly supervised surface-defect detection.

Deep Generative Appearance Modelling in Visual Tracking

Project Type:
Postdoctoral research project

Project Code:
Z2-1866

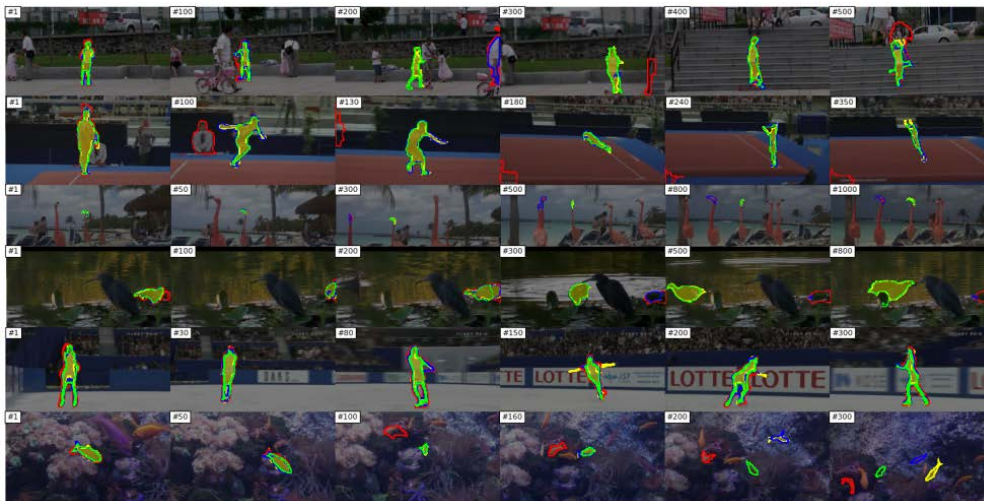**Financed by:**
Slovenian Research Agency

Principal coordinator and Investigator at FRI:
Assist. Prof. Dr. Luka Čehovin Zajc
luka.cehovin@fri.uni-lj.si

Project duration:
2019–2021

Collaborating Laboratory:
Visual Cognitive Systems Laboratory

Predicting object state in video streams is one of the fundamental challenges of computer vision. Knowing where the object is in a video can help autonomous vehicles avoid obstacles, analyze performance in professional sport, discover the behaviour of animals, or help robots learn actively. Currently, visual object tracking is an ill-posed problem without prior information about the object, and it cannot be solved by an online learning method alone. Humans, on the other hand, can solve complex tracking scenarios by relying on a massive amount of a-priori information about categories of objects, and their possible deformations and appearance variations which are crucial for a stable representation of the tracked object. In machine learning terms, we can say that this knowledge is contained in a generative model of the object's appearance. We investigate the robust design of such a generative model, its training and application in visual tracking. We believe that a generative appearance model of the object is a crucial step towards grounding visual object tracking in high-level semantic concepts.

Results of co-segmentation method for visual object tracking.

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 2019, our researchers were involved in several projects, out of which, in 4 they were also principal investigators. In the rest of these projects, they collaborated as academic mentors.

Frequency-Modulated Continuous Wave Radar

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

Frequency-Modulated Continuous Wave Radar (FMCW Radar) is a particular type of radar that changes its operating frequency during transmission, generally in a sweep across a set bandwidth. The reflected signal is mixed with the emitted signal. The frequency difference between the reflected and emitted signals is then used to measure the speed of the target and the distance of the target from the radar.

The goal of this project was to develop a prototype system to test the FMCW radar circuit. The existing FMCW radar circuit does not have built-in signal frequency detection functions. These algorithms were developed and then implemented in an FPGA (Field Programmable Gate Array) circuit to ensure real-time data processing speed.

Development of mQuiz pilot

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

Modern education represents a high cost for everyone involved. Printed books, which were the main learning material in the past, are being replaced with digital media and web applications. Acquiring knowledge remains expensive, requires great mental effort and is most often practiced inefficiently. A significant obstacle for students is maintaining a high level of motivation. Most online resources do not pay a lot of attention to this aspect of learning.

The pilot application mQuiz was developed in collaboration with partner organizations. The aim of this application is to educate users in a more efficient way by ensuring a constant level of high motivation. In previous projects, we have developed the application eQuiz, which provides e-teaching material. The novelty of mQuiz is in the motivational aspect. By solving various puzzles, users can now test their knowledge of a chosen topic, receive feedback from the application and have the ability to provide feedback to the application. This way the developers and educators gain very useful information for future development, which benefits both users and developers. Our application is structured into different levels and the user has to gain knowledge from one level before moving to the next level.

Study and implementation of visualisation enrichments

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

With the transition to the information society, visualisation of data is becoming increasingly important. Organisations gather more data than ever before, and its access is becoming easier. On the other hand information presentation is often inefficient, vague and does not deliver value to its consumers. In collaboration with the Zebra BI company we tried to address some of these problems.

The main goal of the project was to study and refine various kinds of visualisations through advanced techniques and to test its feasibility and efficiency. We implemented bubble charts as well as scatter plots to visualise multi-dimensional data in a two-dimensional plane, where each point also presents additional dimensions through various attributes. Moreover, we tested some interactive elements such as drag & drop functionality, automatic resolving of attributes such as size of bubbles, colour scheme generation, mouse hover behaviour and drop-down menus. We also experimented with algorithms for determining the positions of elements such as labels in order to minimise their overlapping. The algorithms were mainly based on two approaches: simulations of forces and genetic algorithms. Finally, we also prototyped and studied how our solutions may be integrated into some well-known visualisation platforms such as PowerBI, Tableau, QlikView and QlikSense.

Virtual machine accelerator for embedded systems

Principal Investigator:
Prof. Dr. Branko Šter
branko.ster@fri.uni-lj.si

Due to the increasing number of microcontrollers on the market that specialize in a growing number of tasks, companies such as iSYSTEM Labs have to adapt more and more software. As microcontrollers become increasingly more complex, software customization is becoming difficult to manage. Therefore, only the most widespread microcontrollers and most used functionalities are usually supported. The ability to run application programs at the emulator level allows customers, as well as microcontroller manufacturers, to add support for their microcontrollers, even if they are not yet supported by the company software.

The goal of the project was to implement an accelerator for the virtual machine that translates commands from the ARM instruction set into the native processor commands ahead of execution. In this way, the execution of ARM programs can be sped-up significantly. Such acceleration is important when programs need to be run in the protected sandbox of the virtual machine, and on weaker microcontrollers used in their emulators. Users of the company's products can extend the functionality of their tools without compromising the working of the existing emulator assemblies in the event of errors.

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 2019 our researchers were involved in several projects, out of which, in 3 they were also principal investigators. In the rest of these projects, they collaborated as academic mentors.

Interactive e-Crypto Book

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

The dependence of our society on computers, the internet and smart devices is growing continuously. Using these media in a secure way is of vital importance, and users must be educated on the basics of computer security. The main goal of cryptography is to provide a secure and authorized communication between two users over a non-protected channel (mobile phone, computer network, smart device), which prevents an unauthorized person from listening to or changing the exchanged messages. Most cryptographic systems are based on efficient methods for encryption, signing, random number generators, cryptographic protocols and mathematical problems that are hard to solve in real time.

The aim of the project was to present a basic knowledge of cryptography through interactive tasks, which motivate the user to solve problems and learn new cryptographic concepts. In the previous project, we developed the portal Cryptogram, where classic codes, visual schemes for sharing secrets, secure passwords and time stamps were presented. In this project, we developed an interactive e-book, where users can learn the basics of each topic and then try to solve interactive exercises. Users can comment and share their opinions with other users.

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 100 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.

Online information on cultural events and historical sites

Principal Investigator:
Assist. Prof. Dr. Jure Žabkar
jure.zabkar@fri.uni-lj.si

Cultural tourism accounts for 40% of tourism in Europe. These tourists are among the most desirable. They are better consumers, stay longer and have a positive attitude towards local offerings. The situation in Slovenia is different. The survey conducted by Tourism Ljubljana shows that only three percent of tourists chose culture as a reason for visiting Ljubljana. This is due to unsystematic work in this segment, insufficient offers of high-quality cultural programmes, and ineffective promotion among consumers of cultural and artistic content at the local and international level. Imago Sloveniae Foundation is an NGO focused on revitalizing the building cultural heritage and developing cultural tourism in Slovenia. Concerts organized by Imago Sloveniae take place in city squares, atriums, sacral buildings and other historical locations. Over the course of 30 years, Imago has developed a number of internationally acclaimed cultural and tourism projects, including the Summer in Old Ljubljana Town and Nights in Old Ljubljana Town festivals.

We have developed an online platform (https://noci.imagosloveniae.net) that provides presentations of concert locations, cultural and historical sites and information on cultural events in Ljubljana's city center. Visitors can filter the events based on dates, locations, name or can choose them on the map.

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 users.

An eye-tracking computer system for dyslexia screening

Principal Investigator:
Assist. Prof. Dr. Jure Žabkar
jure.zabkar@fri.uni-lj.si

Dyslexia is a neurodevelopmental disorder. Dyslectic people have difficulties understanding what they read. Despite normal intelligence, dyslectics most often experience learning problems in school. Traditional tests for dyslexia include memory and phonological tests (the ability to comprehend oral instructions) as well as reading skills. Testing usually comes as a response to learning problems. Late diagnosis prevents early treatment (adjusted teaching methods) and stigmatizes dyslectic children. Early screening for dyslexia is thus important because it substantially improves the quality of life of dyslectic people in adulthood.

The goal of the project was to develop a computer system for screening for dyslexia based on eye-tracking. A child is presented with a series of tasks, which include understanding of oral language and reading skills. While solving the tasks, the eye-tracking device is used to record the eye movements. We can analyse the data off-line to assess the child's capabilities of solving the tasks correctly. Our system is not a registered diagnostic tool but serves as an objective assessment of potential reading disorders.

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 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 thus 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 utilizes 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. Moreover, the system still needs further testing (especially the automated components) under artificial lighting conditions (for night competitions).

Polona Stefanič,
doctoral student

"Doctoral studies demand a lot of creativity, innovation and vision. The most outstanding experience is the international collaboration with worldwide recognized experts and research groups. Although the doctoral study requires significant dedication and commitment, it opens new career opportunities in Academia and Industry as well.

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 man provided with paper, pencil, and rubber, and subject to strict discipline, is in effect a universal machine."

Alan Turing

Long-Term Visual Object Tracking with Discriminative Correlation Filters

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

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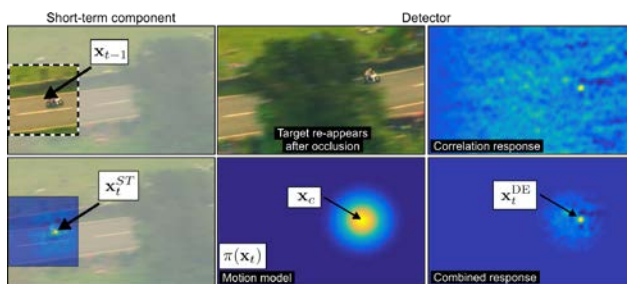Assoc. Prof. Dr. Matej Kristan
Visual Cognitive Systems Laboratory

"FuCoLoT maintains several target appearance models and transforms them into a detector for efficient target localization and re-detection."
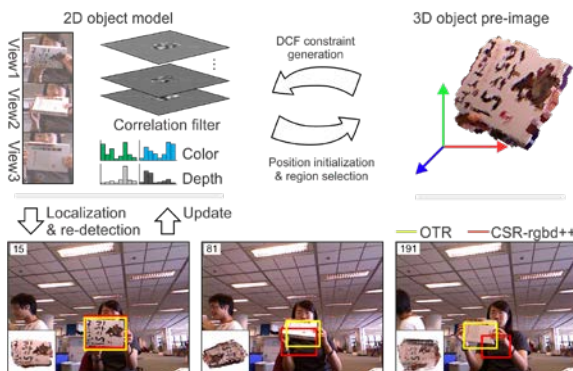
The task in visual object tracking is to localize a target in a video given a single target annotation in the first frame. In long-term tracking, the target often leaves the field-of-view and re-appears later in the video. A tracking algorithm has to detect when the target is not visible and has to re-localize it after it reappears. We developed a fully correlational long-term tracker (FuCoLoT), which exploits the novel DCF constrained filter learning to design a detector that is able to re-detect the target in the whole image efficiently. FuCoLoT maintains several correlation filters, trained on different time scales, that act as detectors. A novel mechanism based on the correlation response is used for tracking failure estimation. FuCoLoT was extended to videos combining two modalities: RGB and depth images. The proposed method, called OTR (Object Tracking by Reconstruction), performs online 3D target reconstruction to robustly learn a set of view-specific discriminative correlation filters (DCFs). The 3D reconstruction improves performance by (i) generation of an accurate spatial support for constrained DCF learning from its 2D projection and (ii) point-cloud based estimation of 3D pose change for selection and storage of view-specific DCFs, which robustly localizes the target after out-of-view rotation or heavy occlusion.

Alan Lukežič, Luka Čehovin Zajc, Tomáš Vojíř, Jiří Matas and Matej Kristan (2018) FuCoLoT - a fully-correlational long-term tracker. Asian Conference on Computer Vision (ACCV).

Ugur Kart, Alan Lukežič, Matej Kristan, Joni-Kristian Kamarainen, Jiří Matas (2019) Object tracking by reconstruction with view-specific discriminative correlation filters. IEEE Conference on Computer Vision and Pattern Recognition (CVPR).

The tracker localizes the target by combining its visual and motion information. A detector is used to perform target re-detection over the entire image.

The Object Tracking by Reconstruction (OTR) model consists of a set of 2D view-specific filters and of an approximate 3D object reconstruction. The OTR (yellow region) copes with out-of-view rotation and with a significant aspect change better than a state-of-the-art tracker (red region), which drifts and fails.

Dr. Andrej Čopar
andrej.copar@fri.uni-lj.si

Supervisors:
Prof. Dr. Blaž Zupan
Assist. Prof. Dr. Marinka Žitnik
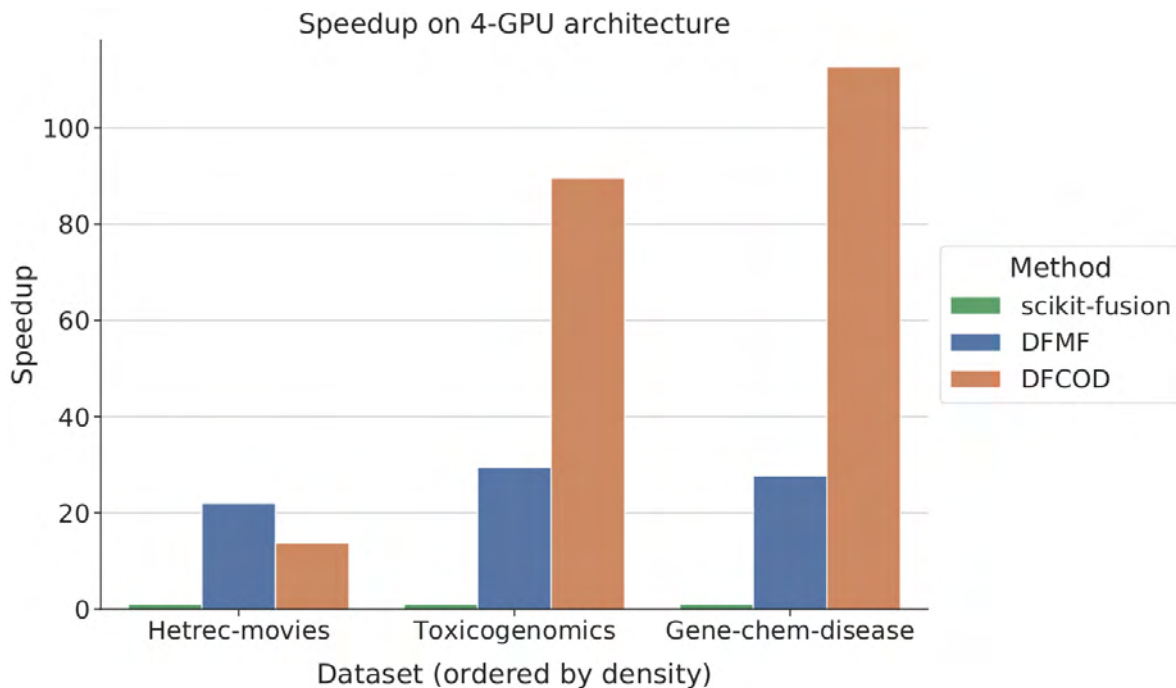Bioinformatics Laboratory

"Over a hundred times faster data fusion approach."

Scalable Matrix Factorization for Data Fusion

Data fusion is used in machine learning to improve the performance of clustering and classification by integrating data from several different sources. However, such datasets can be very large and existing methods are too slow for practical applications. We improve the efficiency of data fusion by increasing parallelization and lowering the computational complexity of matrix tri-factorization, its core component. We first developed a block-wise formulation of matrix tri-factorization, which can run efficiently in highly parallel environments, such as multi-processor and multi-GPU systems. The resulting multi-GPU implementation is over 200 times faster compared to a serial approach. Next, we developed three alternative optimization techniques for non-negative matrix tri-factorization based on alternating least squares, projected gradients and coordinate descent. We found that coordinate descent-based technique is the fastest and can converge twenty times faster compared to the existing multiplicative update-based approach. Finally, we employed block-wise parallelization and convergence improvements to accelerate data fusion. Our data fusion method can run over 100 times faster compared to an existing approach running on 16 processes.

Andrej Čopar (2019) Scalable matrix factorization for data fusion, doctoral dissertation. University of Ljubljana, Faculty of Computer and Information Science.

Andrej Čopar, Blaž Zupan, Marinka Žitnik (2019) Fast optimization of non-negative matrix tri-factorization. PLoS ONE, 14(6): e0217994.

Existing data fusion approach on 16 threads (scikit-fusion), speedup on 4-GPUs (DFMF), and speedup of our new method on 4-GPUs (DFCOD).

Polona Štefanič
stefanic.polona@gmail.com

Supervisor:
Assoc. Prof. Dr. Vlado Stankovski
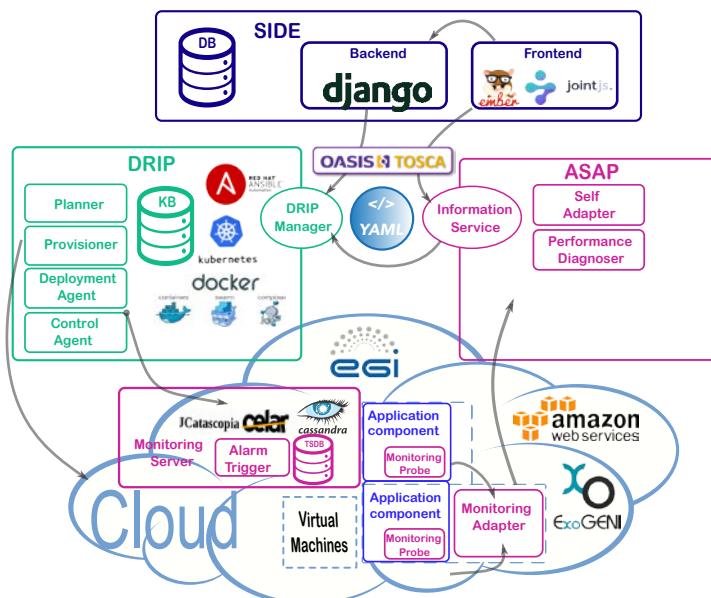Laboratory for Data Technologies

"Co-engineering of microservice-based applications and underlying infrastructure environment for full and QoS-aware life cycle support."

Component-based Software Engineering of IoT Applications

With the emergence of IoT-based applications with time-critical requirements that generate an enormous amount of raw data, more data-centric and event-driven approaches of Quality of Service (QoS)-aware application engineering are needed to cope with varying peaks of dynamic load and reconfigurability of on-demand compute resources. Current Platform-as-a-Service-based engineering tools lack the support for QoS-aware micros-ervice-based application creation including self-adaptation, pro-visioning and graphical application components modelling, and mostly offer only multi-cloud infrastructure deployment without considering fog nodes placed towards the network edge. We propose a flexible co-programming architecture that provides support for the abstraction application layer and an underlying infrastructure environment, which can help to specify and support the life cycle of microservice-based applications with time-critical requirements. The architecture and application components designed as middleware tools are applied to three time-critical real-world use cases, such as disaster early warning system, live event broadcasting and business communication platform. As an interoperable exchanging data format we use OASIS Topology and Orchestration Specification for Cloud Applications (TOSCA), which we extend with dynamic mappings of QoS and runtime attributes related to an application and its underlying architecture. We then can enable the execution of distributed application components within the Edge-Fog-Cloud environment.

Polona Štefanič et al. (2019) SWITCH workbench: A novel approach for the development and deployment of time-critical microservice-based cloud-native applications. Future Generation Computer Systems, 99: 197-212.

Polona Štefanič, Matej Cigale, Louise Knight, Andrew C. Jones, Ian J. Taylor (2019) Support for full life cycle cloud-native application management: Dynamic TOSCA and SWITCH IDE. Future Generation Computer Systems, 101: 975-982.

Overall tripartite co-programming architecture that provides support for the abstraction application creation and an underlying infrastructure environment is depicted. Switch Interactive Development Environment - SIDE; Dynamic Real-time Infrastructure Planner - DRIP; Autonomous System Adaptation Platform (ASAP).

Characterization of Viable Parameter Regions of Synthetic Biological Systems

Žiga Pušnik
ziga.pusnik@fri.uni-lj.si

Supervisor:
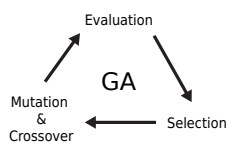Assist. Prof. Dr. Miha Moškon
Computer Structures and Systems
Laboratory

"Design of synthetic biological systems relies on the identification of the most robust topologies before experimental work is conducted."
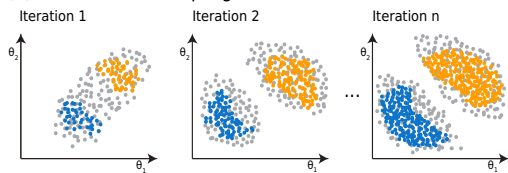
Applications of synthetic biology range from healthcare to bio-manufacturing. The development of reliable and robust systems is consequently of vital importance. The design of such systems can be problematic, especially when different topological and dynamical properties exhibit similar behaviour. For this reason, we propose a global methodology for the robustness assessment of mathematical models of gene regulation in biological systems. The methodology assesses the viable volume, which can provide an insight into systems robustness. We first estimate the viable solution space of parameter regions which is further refined with efficient local sampling. Secondly, we assess the size of the viable volume with Monte Carlo integration. The proposed methodology was demonstrated on models of the repressilator, the AC-DC circuit and the D flip-flop in a master-slave configuration. We showed that Michaelian degradation and noncompetitive binding at promoter levels increase the viable solution space in the D flip-flop model. Furthermore, we provide a computational framework, which allows the user to straightforwardly apply the proposed methodology on an arbitrary topology.

Žiga Pušnik, Miha Mraz, Nikolaj Zimic, Miha Moškon (2019) Computational analysis of viable parameter regions in models of synthetic biological systems. Journal of Biological Engineering, 13: 75, [pdf].

The outline of the proposed methodology and its main results. (a) The analysis performed on the AC-DC circuit model reveals that the system can exhibit different modes of behaviour, i.e. oscillations and bistability. (b) Results of the methodology are consistent with the results of the deterministic and stochastic modelling.

Gregor Pirš
gregor.pirs@fri.uni-lj.si

Supervisor:
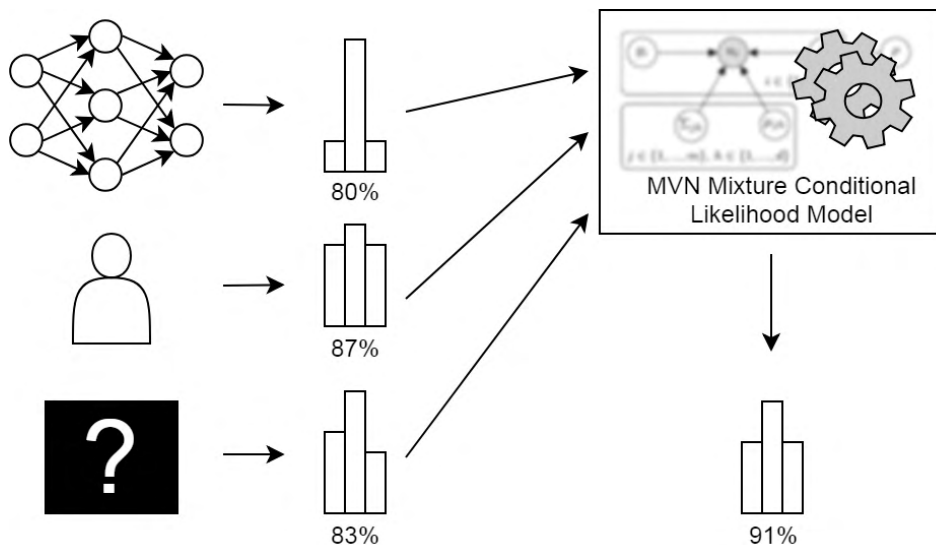Assoc. Prof. Dr. Erik Štrumbelj
Laboratory for Cognitive Modelling

"Learning complex patterns in classifiers allows us to combine them better."

Combining Classifiers with Latent Multivariate Normal Mixtures

Ensemble methods are a powerful tool, often outperforming individual prediction models. Generally, we can divide methods for combining classifiers into two groups. First, methods that evaluate the performance of each classifier by performance, and then weight them accordingly. Second, methods which learn the latent structure of the classifications and use it to provide probabilistic predictions. We developed a method that estimates the latent structure of classifiers in the ensemble with multivariate normal mixtures, and makes the probability of the true class conditional on the estimated distribution. Additionally, we developed a regularization step to discredit detrimental dimensions, by increasing their variance. By learning the latent structure that produced the classifications, the method is especially suitable for combining biased classifiers or classifiers with systematic errors. It is robust and requires practically no tuning. Empirical results show that the method is useful, especially in a case study of combining several machine learning models and human expert predictions for air-pollutant concentration prediction.

Gregor Pirš and Erik Štrumbelj (2019) Bayesian combination of probabilistic classifiers using multivariate normal mixtures. Journal of Machine Learning Research, 20(51): 1-18.

Deep Learning for Large-Scale Traffic-Sign Detection and Recognition

Domen Tabernik
domen.tabernik@fri.uni-lj.si

Supervisor:
Assoc. Prof. Dr. Danijel Skočaj
Visual Cognitive Systems Laboratory

———

"A novel dataset with over 200 traffic-sign categories and 7000 images enables deep learning for large-scale detection of traffic signs."

———

Current approaches for visual recognition and detection of traffic signs are well suited for advanced drivers-assistance and autonomous systems. However, automated detection of a select few traffic signs (around 50 categories) is not suitable for automating the management of all traffic-sign inventory with several hundred categories. We addressed the issue of detecting and recognizing a large number of traffic-sign categories suitable for automating traffic-sign inventory management. A convolutional neural network (CNN) approach, the Mask R-CNN, with several improvements for the traffic-sign domain, has been employed to address the full pipeline of detection and recognition with automatic end-to-end learning. A significant effort has been made to collect and annotate the dataset with over 200 traffic-sign categories represented in our novel public dataset with over 7000 high-resolution images. A novel dataset provided the necessary data for deep network training and enabled comprehensive analysis of the deep learning methods for the detection of traffic signs with large intra-category appearance variation. An error rate below 3% has been demonstrated with the proposed approach, which is sufficient for deployment in practical applications of traffic-sign inventory management.

Examples of detected traffic signs on the left, with the variety of traffic sign categories on the right.

Management

Dean
Assoc. Prof. Dr. Mojca Ciglarič

Vice Dean for Education
Prof. Dr. Gašper Fijavž

Vice Dean for Research
Assist. Prof. Dr. Tomaž Curk

Vice Dean for Quality and International Affairs
Assoc. Prof. Dr. Damjan Vavpotič

Vice Dean for Economic Affairs
Assoc. Prof. Dr. Peter Peer

Secretary-General
Nives Macerl

Chair Heads
(as of 1 October 2018)

Head of Theoretical Computer Science Chair
Prof. Dr. Borut Robič

Head of Computer Systems Chair
Prof. Dr. Miha Mraz

Head of Information Systems and Technologies Chair
Prof. Dr. Marko Bajec

Head of Artificial Intelligence Chair
Prof. Dr. Marko Robnik Šikonja

Head of Multimedia Chair
Prof. Dr. Franc Jager

Head of General Topics Chair
Assoc. Prof. Dr. Polona Oblak

Researchers

Laboratory for Biomedical Computer Systems and Imaging

Prof. Dr.	Franc Jager (Head)
Assist. Prof. Dr.	Aleš Smrdel

Laboratory for Computer Graphics and Multimedia

Assist. Dr.	Ciril Bohak
Senior Lecturer Dr.	Alenka Kavčič
Assist.	Žiga Lesar
Assoc. Prof. Dr.	Matija Marolt (Head)
Assist. Dr.	Matevž Pesek
	Vid Klopčič

Laboratory of e-media

Assist. Dr.	Aleks Huč
Assist. Dr.	David Jelenc
Prof. Dr.	Denis Trček (Head)
Assist. Prof. Dr.	Mira Trebar

Laboratory for Data Technologies

Prof. Dr.	Marko Bajec (Head)
Assist Dr.	Neli Blagus
	Jernej Cvek
Assist.	Sandi Gec
Dr.	Marko Janković
Jr. Res.	Petar Kochovski
	Jure Lokovšek
Assist. Prof. Dr.	Dejan Lavbič
	Mitja Rizvič
Assist. Prof. Dr.	Lovro Šubelj
	Gregor Weiss
Senior Lecturer Dr.	Aljaž Zrnec
Assist. Prof. Dr.	Slavko Žitnik

Laboratory for Cryptography and Computer Security

Assist.	Mia Filić
Prof. Dr.	Aleksandar Jurišić (Head)
Assist.	Klemen Klanjšček

Laboratory for Ubiquitous Systems

	Katarina Bebar
Assist. Dr.	Andrej Brodnik (Head)
Assist. Dr.	Gašper Fele Žorž

Laboratory for Cognitive Modelling

Assist. Dr.	Špela Arhar Holdt
Prof. Dr.	Zoran Bosnić
Assist. Dr.	Jaka Čibej
Assist. Dr.	Jana Faganeli Pucer
	Teja Goli
	Enja Kokalj
Assist.	Gregor Pirš
Assist.	Martin Jakomin
Prof. Dr.	Igor Kononenko (Head)
Dr.	Jan Kralj
Assoc. Prof. Dr.	Matjaž Kukar
Dr.	Nikola Ljubešić
	Kristian Miok
	Matej Martinc
	Aleš Papič (MR)
Assist. Dr.	Matej Pičulin
Assist.	Gregor Pirš
Prof. Dr.	Marko Robnik Šikonja
	Tim Smole(TS)
Assoc. Prof. Dr.	Erik Štrumbelj
	Matej Ulčar
Assist. Dr.	Anita Valmarska
Assist. Dr.	Petar Vračar
Assist. Dr.	Aleš Žagar
Assist. Dr.	Bojan Žunkovič

Laboratory for Adaptive Systems and Parallel Processing

Assoc. Prof. Dr.	Patricio Bulić
Assist.	Rok Češnovar
Assist. Dr.	Nejc Ilc
Assoc. Prof. Dr.	Uroš Lotrič
	Matija Rezar
Assist.	Davor Sluga
Prof. Dr.	Branko Šter (Head)

Laboratory of Algorithmics

Assist. Dr.	Uroš Čibej
Assist. Prof. Dr.	Tomaž Dobravec
Assist.	Peter Gabrovšek
Assist. Prof. Dr.	Matej Guid
Assist. Prof. Dr.	Jurij Mihelič
Prof. Dr.	Borut Robič (Head)
Senior Lecturer Dr.	Robert Rozman
Assist. Prof. Dr.	Boštjan Slivnik

Information Systems Laboratory

Assist.	Damjan Fujs
Assoc. Prof. Dr.	Tomaž Hovelja
Assist. Prof. Dr.	Rok Rupnik
Assoc. Prof. Dr.	Damjan Vavpotič (Head)

Computer Vision Laboratory

Senior Lecturer Dr.	Borut Batagelj
Assoc. Prof. Dr.	Narvika Bovcon
	Assist. Žiga Emeršič
	Niko Gamulin
Assist. Prof. Dr.	Aleš Jaklič
Assist. mag.	Bojan Klemenc
Assist.	Blaž Meden
Assoc. Prof. Dr.	Peter Peer (Head)
Prof. Dr.	Franc Solina
Assist. Prof. Dr.	Luka Šajn
	Matej Vitek (MR)

Laboratory for Integration of Information Systems

Assist. Dr.	Aleš Frece
Assist.	Anton Zvonko Gazvoda
Prof. Dr.	Matjaž Branko Jurič (Head)
	Benjamin Kastelic
Assist.	Miha Nagelj
Assist.	Rok Povše
Assist. Dr.	Vid Podpečan
	Luka Šarc
	Marko Škrjanec

Visual Cognitive Systems Laboratory

Assist.	Borja Bovcon
Assist. Prof. Dr.	Luka Čehovin Zajc
Assoc. Prof. Dr.	Matej Kristan
Prof. Dr.	Aleš Leonardis
Assist	Alan Lukežič
Assist.	Jon Mukovič
Assist.	Anže Rezelj
Assoc. Prof. Dr.	Danijel Skočaj (Head)
Assist.	Domen Tabernik
Assist.	Vitjan Zavrtanik

Software Engineering Laboratory

Assist. Dr.	Luka Fűrst
Assist. Dr.	Marko Poženel
Prof. Dr.	Viljan Mahnič (Head)
Senior Lecturer Dr.	Igor Rožanc

Bioinformatics Laboratory

Assist. Prof. Dr.	Tomaž Curk
Assist. Dr.	Andrej Čopar
Prof. Dr.	Janez Demšar
	Aleš Erjavec
Assist.	Primož Godec
Assist.	Rok Gomišček
Assist. Dr.	Tomaž Hočevar
	Amra Omanović
Assist. Res. Dr.	Ajda Pretnar
Assist. Dr.	Martin Stražar
Assist.	Vesna Tanko
Assist. Dr.	Marko Toplak
Prof. Dr.	Blaž Zupan (Head)
Assist. Dr.	Lan Žagar
Assist. Prof. Dr.	Marinka Žitnik

Computer Structures and Systems Laboratory

Assist. Prof. Dr.	Jure Demšar
Assist. Dr.	Miha Janež
	Miran Koprivec
Assoc. Prof. Dr.	Iztok Lebar Bajec
Assist.	Lidija Magdevska
Assist. Prof. Dr.	Miha Moškon
Prof. Dr.	Miha Mraz
Assist.	Žiga Pušnik
Prof. Dr.	Nikolaj Zimic (Head)

Artificial Intelligence Laboratory

Prof. Dr.	Ivan Bratko
Assist. Dr.	Dejan Georgiev
Assist. Dr.	Vida Groznik
	Ana Herzog
Assist. Dr.	Timotej Lazar
	Teodora Matić
Assist. Dr.	Martin Možina
Assist. Prof. Dr.	Aleksander Sadikov (Head)
Assist. Prof. Dr.	Jure Žabkar

Computer Communications Laboratory

Assoc. Prof. Dr.	Mojca Ciglarič (Head)
Assist.	Miha Grohar
	Ivan Majhen
Assist. Dr.	Matjaž Pančur
Assist. Prof. Dr.	Veljko Pejović

Laboratory for Mathematical Methods in Computer and Information Science

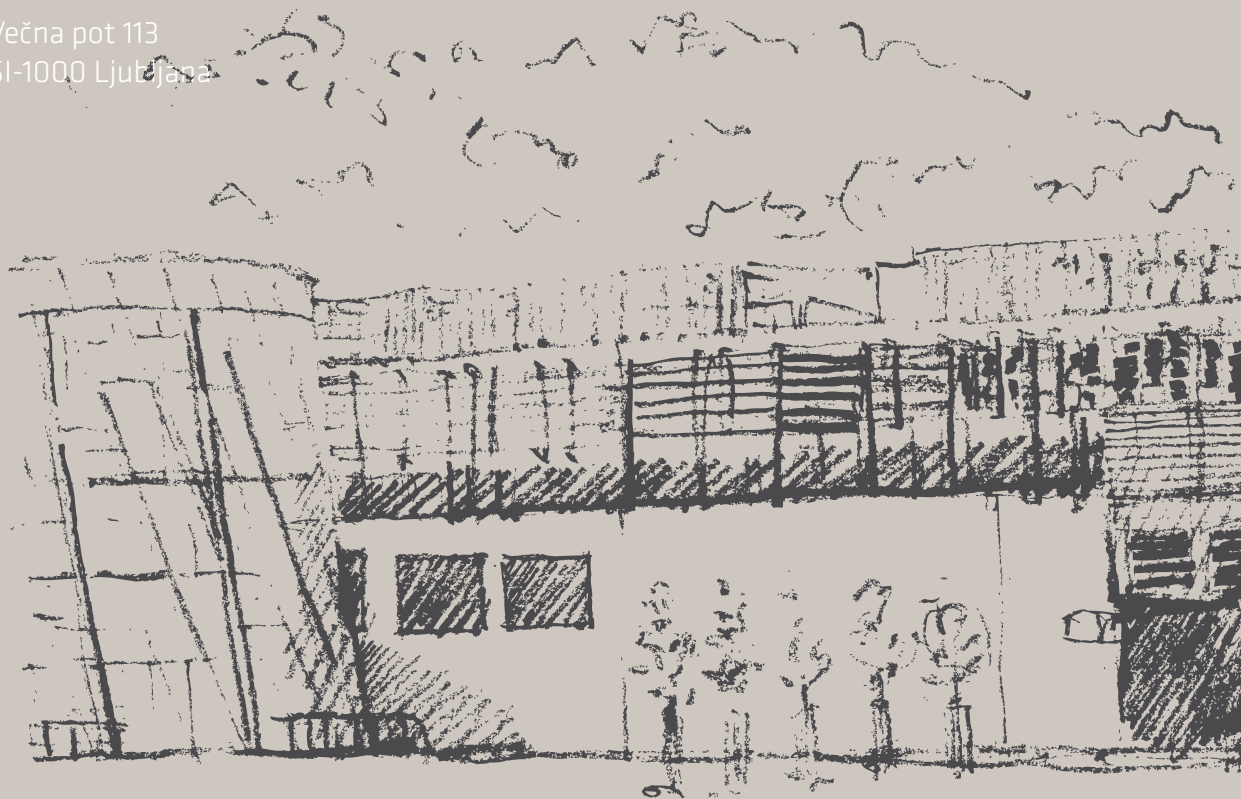|	
Assist. Dr.	Marko Boben
Prof. Dr.	Gašper Fijavž
Assist. Dr.	Aleksandra Franc
Assist. Dr.	Damir Franetič
Assist. Dr.	Gregor Jerše
Assist. Dr.	Peter Marijan Kink
Assist. Dr.	Jelena Klisara
Prof. Dr.	Nežka Mramor Kosta
Assoc. Prof. Dr.	Polona Oblak
Prof. Dr.	Bojan Orel
Assist. Prof. Dr.	Žiga Virk (Head)
Assist. Dr.	Martin Vuk
Assist. Dr.	Aljaž Zalar

Univerza v Ljubljani,
Fakulteta za računalništvo in informatiko

University of Ljubljana,
Faculty of Computer and Information Science

Večna pot 113
SI-1000 Ljubljana

www.fri.uni-lj.si

f Fakulteta za računalništvo in informatiko

Research Office: srd@fri.uni-lj.si
Public Relations: pr@fri.uni-lj.si
International Office: international.office@fri.uni-lj.si