

# Survey



University of Ljubljana  
Faculty of Computer and Information Science



## Remarks by the Dean

The Faculty of Computer and Information Science at the University of Ljubljana is the leading institution in the field of computer and information science in Slovenia. Since its first study programme in computer science began in 1973, it has had a lengthy roster of alumni, many of whom have achieved distinction in academic and professional circles in Slovenia and abroad.

In recent years we have been expanding research competences of our Faculty to fit a wider spectrum of promising technical areas by attracting experienced researchers and teachers. We are also intensifying cooperation with related institutions in neighbouring and other countries. We implemented the double master degree program in Computer Science with Graz University of Technology and we are working towards establishment of further double degree studies. This year our Faculty has also been awarded with the ASIIN accreditation for three core study programmes in computer and information science. The accreditation confirms the quality of study and the value of our graduates and postgraduates. The accreditation is important because it acknowledges the quality of study programmes that are internationally comparable. Therefore it creates new opportunities for international cooperation, increases the value of our graduates in a very competitive high-tech environment and speeds up the process of certifying accomplished education abroad.

In addition to computer science, which is our core programme, we enable an interdisciplinary approach through interdisciplinary study programmes, designed according to the Bologna principles and offered jointly with selected other faculties of the University of Ljubljana and other European universities. These programmes are meant to attract students from diverse educational and geographical backgrounds. We also aim to further open our studies and make them accessible to international students, as can be seen in the Doctoral Programme which is entirely conducted in English. Particular attention is also given to attracting promising international doctoral students.

Please explore this survey of research activities at our Faculty, find out more about our research and research opportunities we have encountered. Whether you are a prospective student, a potential industrial partner, a future research collaborator, an alumni or friend, or just someone curious about computer science as a discipline, we are positive that you will be able to find something of interest in this booklet.

–Prof. Nikolaj Zimic, PhD  
Dean



## Remarks from the Vice-Dean for Research

Computer Science and informatics are inseparably linked with modern life. At work, studying, keeping in touch with your friends and family, on the road, in your free-time and even at everyday chores we are constantly linked with high tech and complex information systems. And if these systems and equipment work, our jobs are sufficiently done.

The Faculty has a number of active research groups that attract funding from various EU and other international and national programmes as well as funding from Slovenian and foreign industry. In addition to fostering basic and applied research, our Faculty is using the momentum of the new building to establish and deepen the collaboration with the industry. We are constantly improving knowledge and technology transfer between the academy and the industry with new partnership models and we are inviting leading high-tech companies to strengthen the collaboration with the Faculty. Special attention has been given to the innovation segment. In the last few years, our students have achieved excellent results in various competitions and developed ground-breaking projects. In the new building, we are offering the working space and mentoring support to the best and most innovative students, which will potentially lead to innovative projects, start-ups and spin-offs. With all these activities, our aim is to make study and research at our Faculty more appealing.

Due to the high demand for computer and information science graduates, the interest for studies on the Faculty is steadily growing. We actively promote computer and information science study by offering free summer workshops and similar outreach events for secondary and primary school students. During the academic year, we also provide assistance to selected secondary as well as primary schools in the form of after-class activities.

I hope that this booklet will form new links with the international computer science community, which is a prerequisite for the Faculty to successfully continue its mission. I am inviting readers who find material in this booklet interesting to establish a contact with our Faculty members.

–Assist. Prof. Danijel Skočaj, PhD  
Vice Dean for Research

# Research Laboratories

Research at the Faculty of Computer and Information Science at the University of Ljubljana (UL) is conducted in 20 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 Algorithms and Data Structures

We conduct research in the areas of approximation and randomised algorithms, algorithms for problems in 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, data-flow 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. Borut Robič, PhD  
borut.robic@fri.uni-lj.si

## Laboratory for Computer Graphics and Multimedia

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.

Prof. Franc Jager, PhD;  
franc.jager@fri.uni-lj.si

## Information Systems Laboratory

The focus of the research here includes software development methodologies and business process evaluation. We offer efficient approaches to the evaluation of information systems, specific information solutions and specific IT related processes. The approaches break down IT products or IT processes into key elements and evaluate them through a comprehensive set of criteria. We have excellent references in the areas of information system strategic planning and context aware applications, where we have developed a context engine prototype.

Assist. Prof. Rok Rupnik, PhD;  
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## Laboratory for Adaptive Systems and Parallel Processing

Our main 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. We are also involved in digital logic design of arithmetic circuits, processing on GPUs, and smart wireless sensor networks.

Prof. Branko Šter, PhD  
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## Bioinformatics Laboratory

The Bioinformatics Laboratory carries out research in data mining, machine learning, big data analysis and data fusion. We apply computational methods to solve practical problems and focus on systems biology and biomedicine. The laboratory also develops practical software tools, such as Orange (<http://orange.biolab.si>) for data mining and visual programming, and collaborate in development of cool web-based data exploration platforms like dictyExpress (<http://dictyexpress.org>) for gene expression analytics.

Prof. Blaž Zupan, PhD  
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## Laboratory for Integration of Information Systems

The laboratory has established strong foundation in service and cloud computing and conducts research in the field of the integration and interoperability of applications, 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 novel authentication and location algorithms.

Prof. Matjaž Branko Jurič, PhD;  
matjaz.juric@fri.uni-lj.si

## Laboratory for Cognitive Modelling

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

Prof. Igor Kononenko, PhD;  
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## 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.

Prof. Franc Jager, PhD  
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## Laboratory of e-media

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

Prof. Denis Trček, PhD  
denis.trcek@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. Aleksandar Jurišić, PhD;  
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### Laboratory for Mathematical Methods in Computer and Information Science

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

Assoc. Prof. Gašper Fijavž, PhD;  
gasper.fijavz@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.).

Assoc. Prof. Viljan Mahnič, PhD;  
viljan.mahnic@fri.uni-lj.si

### Artificial Intelligence Laboratory

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

Prof. Ivan Bratko, PhD;  
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### 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. Marko Bajec, PhD;  
marko.bajec@fri.uni-lj.si

### Computer Communications Laboratory

The research focus here is on communication networks and protocols, cloud architectures and services, cloud and network security, virtualisation, ICT sustainability, computer supported learning systems and the use of agile methodologies. We have researched the building automation (orchestration) of complex virtual environments, examined SDN and NFV and their use in cloud environments, and developed our own virtual cloud laboratory. Our latest project focuses on carrier-grade cloud solutions for large telco providers, including identity management, AAA and remote administration.

Assist. Prof. Mojca Ciglaric, PhD;  
mojca.ciglaric@fri.uni-lj.si

### Computer Structures and Systems Laboratory

The laboratory is focused on the computational methods for modelling, simulation and analysis of three fundamentally different system families. Their applications are directed towards computational approaches in systems and synthetic biology, towards the analysis of coordinated behaviour in biological systems and towards the design of Quantum-dot Cellular Automata processing structures. Laboratory therefore consists of three groups, i.e. the Computational Biology Group, the Collective Behaviour Group and the Quantum-dot Cellular Automata group.

Prof. Nikolaj Zimic, PhD;  
nikolaj.zimic@fri.uni-lj.si

### Computer Vision Laboratory

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

Prof. Franc Solina, PhD;  
franc.solina@fri.uni-lj.si

### Visual Cognitive Systems Laboratory

The Visual Cognitive Systems Laboratory is involved in basic and applied research of visually enabled intelligent systems. We have extensive experience with visual object tracking, object detection and categorisation, incremental visual learning, as well as with systems for human-robot interactive learning and the development of computer vision solutions for smart mobile devices. Our experience has been accumulated in collaboration with a variety of research partners in a number of the EU, national and industry funded projects which address these research issues.

Assist. Prof. Danijel Skočaj, PhD;  
danijel.skocaj@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. The work performed also overlaps with the area of Computer Science Education.

Andrej Brodnik, PhD;  
andrej.brodnik@fri.uni-lj.si

# International Collaboration

Great diversity and interdisciplinary approaches distinguish the research work of the Faculty of Computer and Information Science. We conduct intensive research on artificial intelligence and related fields, such as machine learning, data mining and computer vision, and applying this knowledge in the fields of bioinformatics, cognitive modelling and intelligent robotics. Data acquisition and management is an important area of research, as is the integration of systems. Our research addresses a number of other 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.

Making data is like cooking, you have to make recipes. These are expensive tasks, though in my opinion not so mentally demanding. The most difficult part is when you have to analyze the data.

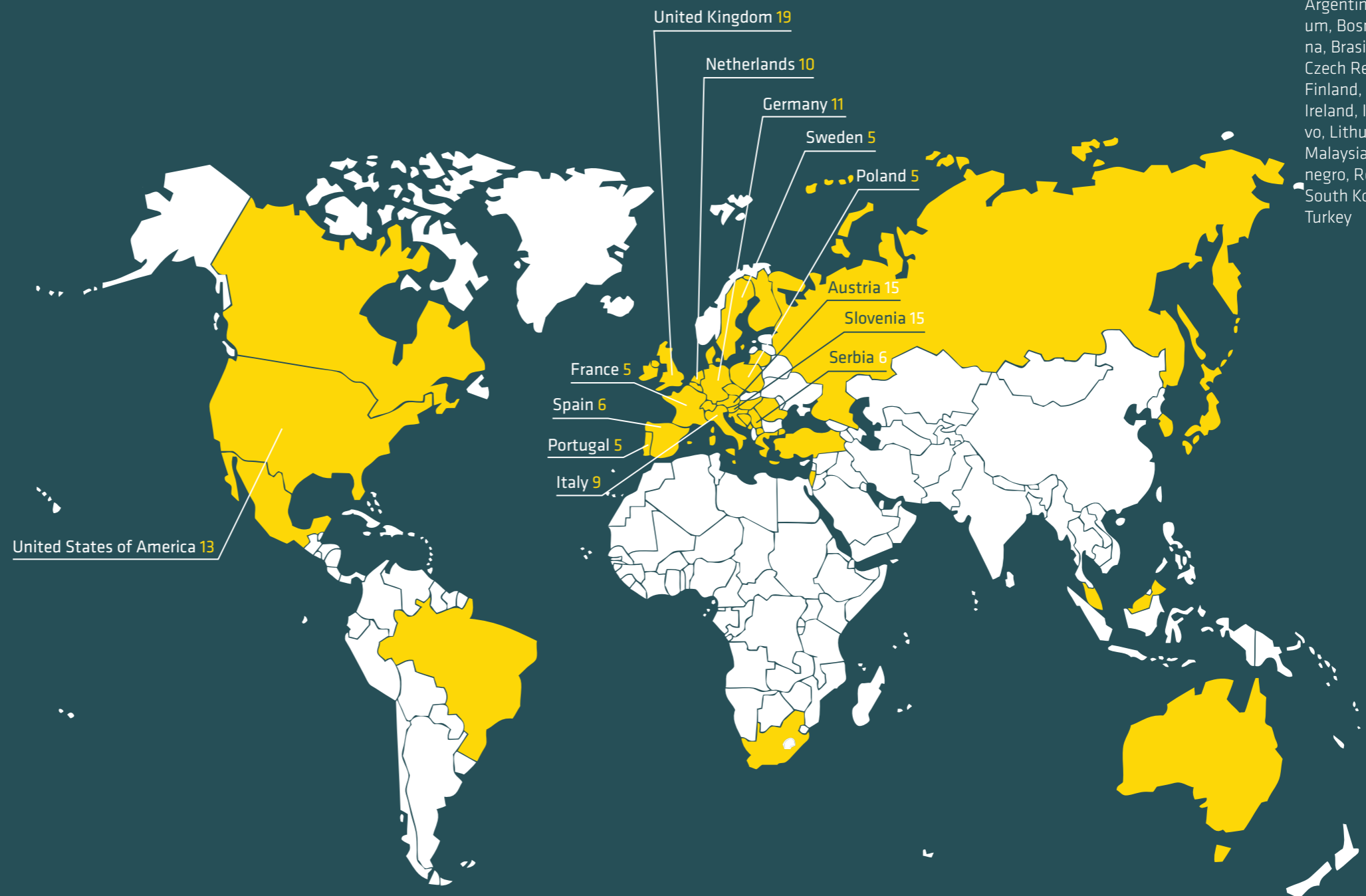
–Prof. Jernej Ule, PhD

Total number of collaborations

# 174

Other collaborations:

Argentina, Australia, Belgium, Bosnia and Herzegovina, Brasil, Canada, Croatia, Czech Republic, Denmark, Finland, Greece, Hungary, Ireland, Israel, Japan, Kosovo, Lithuania, Macedonia, Malaysia, Mexico, Montenegro, Romania, Russia, South Korea, Switzerland, Turkey



## Highlights and Selected Publications

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.

**Current Basic research and application projects funded by the Slovenian Research Agency:**

Metabolic and inborn factors of reproductive health, birth • Artificial intelligence and intelligent systems • Computer Vision • Synergy of the technological systems and processes • Pervasive Computing • Parallel and distributed systems • Conquering the Curse of Dimensionality by Using Background Knowledge • Posttranscriptional regulatory networks in neurodegenerative diseases • Model for Domain-Specific Trend Prediction based on Semantic Enrichment of Unstructured Patterns Epidemiology and Biodiversity Studies of Plant Pathogens • Maintenance of large databases based on visual information using incremental learning • Designed cellular logic • Automatic annotation of medical video sequences • Computer based modelling in bioinformatics for gene based cancer classification focused on reliability and machine learning • Development of new e-learning models for game-based learning using mobile technologies • Supervised and unsupervised learning from imbalanced datasets for assistance in movement of persons with low vision • Trust Management and Reputation Systems • Data Fusion in Systems Biology of a Social Amoeba Dictyostelium

**Projects funded by the European Commission:**

FLEXICIENCY – Energy services demonstrations of demand response, flexibility and energy efficiency based on metering data • SWITCH – Software workbench for interactive, time-critical and highly self-adaptive cloud applications • CREA – Network of summer academies for improving entrepreneurship in innovative sectors • AGROIT – Increasing farming efficiency through an AgrolT platform based on open standards • SALUS – Security and interoperability in next generation PPDR communication infrastructures • AXLE – Advanced analytics for extremely large European databases • CARE-MI – Cardio repair European multidisciplinary initiative

Additionally to these projects the Faculty is participating on more than 30 projects funded by different institutions and industry partners including Akrapovič, CBSR, Celtra, CHS, Datalab, FMC, Guru Namig, HTTPPOOL, Informatika, Iskratel, Iskra Impuls, IBM Slovenija, Kopa, Mega M, Optilab, Prosplet, PB Slovenije, RC IRC Celje, Stacklabs, SRC, SŽ, TMG-BMC, UCS, XLAB and others.

## CARE-MI, Cardio repair european multidisciplinary initiative

**Project Type:**  
EU project

**Project Coordinator:**  
Fundación centro nacional de investigaciones  
cardiovasculares carlos III (CNIC), Spain

**Principal Investigator at FRI:**  
Prof. Blaž Zupan, PhD

**Collaborating Laboratories:**  
Bioinformatics Laboratory

CARE-MI was a five year EU FP7 project whose aim was the use stem cells to repair heart muscle after infarction. The project goal was research in stem cells development and design of a clinically applicable therapy. The project successfully finished in October 2015 with a start of the clinical trial. The role of UL was to provide bioinformatics support for the research. Our aim was to design a tool that can consider plethora of very different data sets from molecular biology and construct models that could benefit in accuracy from collective data treatment. The data fusion method we have devised is based on large-scale, collective matrix factorization (IEEE TPAMI 2015, PLoS Comp Biol 2015). We have also delivered our biomedical data mining approaches within Orange (<http://orange.biolab.si>), a data mining framework with attractive visual programming interface.



## AXLE, Advanced Analytics for Extremely Large European Databases

**Project Type:**  
EU project

**Project Coordinator:**  
2nd Quadrant Limited, Birmingham, UK

**Principal Investigator at FRI:**  
Assoc. Prof. Janez Demšar, PhD

**Collaborating Laboratories:**  
Bioinformatics Laboratory

What advances in hardware are needed to handle relational databases with tens of terabytes of data? How should a database be organized? How to do analytics and make decisions on such extremely large data? How to resolve the related security and privacy issues? AXLE brought together a diverse group of researchers covering hardware, database kernel and visualisation experts all focused on solving the needs of extremely large data analysis.



## SALUS, Security And Interoperability in Next Generation PPDR Communication InfrastructureS

**Project Type:**  
EU project

**Project Coordinator:**  
Instituto de Telecomunicacoes, Portugal

**Principal Investigator at FRI:**  
Prof. Denis Trček, PhD

**Collaborating Laboratories:**  
Laboratory of e-media



Public Protection and Disaster Relief (PPDR) agencies in EC member states are relying on digital Private Mobile Radio (PMR) networks for mission-critical voice and data communication. These networks are highly resilient and properly dimensioned to cope with crisis and emergency handling, and are well protected against monitoring and intrusion by means of encryption, authentication and integrity. The two main standards for digital PMR networks in Europe are TETRA (TErrestrial Trunked RAdio) and TETRAPOL. The majority of these networks are based on mature technology, requiring old-fashioned synchronous links (backbone), and using proprietary hardware solutions that eventually become obsolete. These networks also provide limited inter-technology coverage providing very ineffective management of emergency events, both at the national level and in cross-border regions. The main goal of SALUS is to design, implement and evaluate a next generation communi-

cation network for Public Protection and Disaster Relief (PPDR) agencies, supported by network operators and industry, which will provide security, privacy, seamless mobility, QoS and reliability support for mission-critical PMR voice and broadband data services. The project covers the full techno-economic scope regarding development and deployment of the next generation PPDR networks by focusing on the integration with / migration to 4G wireless communications developments targeting three critical scenarios 1) city security, 2) disaster recovery, and 3) temporary protection. Salus will address key research challenges such as enterprise architectures, economic and business analysis, and a number of technical aspects concerning QoS, resilience, inter-systems handover (secure, seamless and fast), enhanced security, privacy mechanisms in heterogeneous network infrastructure, and multicast broadband PPDR services.

## Increasing the efficiency of farming through on open standards based AgrolT platform

**Project Type:**  
EU project

**Project Coordinator:**  
Datalab Tehnologije d.d.

**Principal Investigator at FRI:**  
Assist. Prof. Damjan Vavpotič, PhD  
Assoc. Prof. Zoran Bosnić, PhD  
Prof. Matjaž Branko Jurič, PhD

**Collaborating Laboratories:**  
Information Systems Laboratory  
Laboratory for Integration of Information Systems  
Laboratory for Cognitive Modelling

AgrolT is an EU funded project that will implement an open platform based on open standards. Project will deliver applications and services to various stakeholders: farmers, local communities, state institutions, consulting institutions in farming (government founded and private) and EU institutions. Integrated platform will enable farmers to get all applications they need: ERP for SME's (with all accountancy functionalities), mobile applications for easier data entry and report review, decision support system for better farm management and automatic data collection through sensors and other devices on the farm.



## SWITCH, Software Workbench for Interactive, Time Critical and Highly self-adaptive cloud applications

**Project Type:**  
EU project

**Project Coordinator:**  
Universiteit van Amsterdam, Netherlands

**Principal Investigator at FRI:**  
Prof. Marko Bajec, PhD

**Collaborating Laboratories:**  
Laboratory for Data Technologies

## CREA, Network of summer academies for the improvement of entrepreneurship in innovative sectors

**Project Type:**  
EU project

**Project Coordinator:**  
Politecnico di Milano (POLIMI), Italy

**Principal Investigator at FRI:**  
Andrej Brodnik, PhD, Assist. Prof. Matija Marolt, PhD

**Collaborating Laboratories:**  
Laboratory for Ubiquitous Systems,  
Laboratory for Computer Graphics and Multimedia



The SWITCH project addresses the urgent industrial need for developing and executing time critical applications in Clouds. Time critical applications such as disaster early warning, collaborative communication and live event broadcasting can only realise their expected business value when they meet critical requirements for performance and user experience. The very high requirements on network and computing services, particularly for well-tuned software architecture with sophisticated data communication optimisation, mean that development of such time critical applications is often customised to dedicated infrastructure, and system performance is difficult to maintain when infrastructure changes. This fatal weakness in the existing architecture and software tools yields very high development cost, and makes it difficult fully to utilize the virtualised, programmable services provided by networked Clouds to improve system productivity. SWITCH aims at improving the existing development and execution model of time critical applications by introducing a novel conceptual model: application-infrastructure

co-programming and control model, in which application Quality of Service (QoS)/Quality of Experience (QoE), together with the programmability and controllability of the Cloud environments, can all be included in the complete lifecycle of applications.

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

CREA aims to promote ICT development and creativity as new drivers able to produce specific structural changes and arrangements in the European entrepreneurial base, to influence the future paths of social change and innovation to a large extent. CREA project wants to validate a new European Model of Summer Academy for students who want to develop business ideas focus on creativity and ICT and able to explore innovation in advanced fields: new products for new markets, social innovation, meaning drive innovation in old sectors, service innovation, technology driven innovation etc. CREA will test 2 edition of Summer Academy simultaneously organized in 6 European Cities (Milan, Stuttgart, Ljubljana, Newcastle, Tallin, Utrecht), which will end with an international event (CREA ICT Business Idea Contest) for the presentation of results to international investors and the awarding of a prize. The project includes training courses, mentoring activities and the incubation program for

start up companies that will be able to use the opportunities of ICT and Creativity to propose new business model with a European vision.

The general objectives of CREA project are: (a) To create European wide system of Summer Academies for university and last year high school students entirely focused on ICT entrepreneurship; (b) To create a model of Summer Academy action oriented with a strong focus on ICT and entrepreneurial skills development and a rich offer of mentoring, support for business planning, matchmaking opportunities and generation of ICT related business idea; (c) To stimulate the development of new start up business ideas boosting on ICT and creativity; (d) To complement and extend similar existing Summer Academy program while strongly focusing on ICT and creativity entrepreneurship; (e) To organize and promote ICT Business Idea Contests.



## FLEXICIENCY, Energy services demonstrations of demand response, FLEXibility and energy efficiency based on metering data

**Project Type:**  
EU project

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

**Principal Investigator at FRI:**  
Prof. Matjaž Branko Jurič, PhD

**Collaborating Laboratories:**  
Laboratory for Integration of Information Systems

## Posttranscriptional regulatory networks in neurodegenerative diseases

**Project Type:**  
Basic Research Project funded by the Slovenian Research Agency

**Project Leader:**  
Assist. Prof. Jernej Ule, PhD

**Principal Investigator at FRI:**  
Assist. Prof. Jernej Ule, PhD  
Assist. Prof. Tomaž Curk, PhD

**Collaborating Laboratories:**  
Bioinformatics Laboratory



The four year project, launched in early 2015, is part-funded by the European Commission's Horizon 2020 research programme, with the aim of addressing flexibility and efficiency within the European energy market, putting focus on consumers and making use of data from smart metering. More specifically, the project's mission is to create new opportunities for energy business and expand the DSO's market facilitator role for new services. As neutral players in the market, they can support the creation of new business opportunities and innovative services for end users, based on consumer data collected by smart

meters. The initiative marks an important step towards the achievements of 2020 energy consumption and CO2 emissions targets through the development of advanced energy services and the implementation of new policies and market regulations that promote the creation of smart grids, in the process boosting jobs and growth in Europe. Besides UL, 17 partners from 10 EU countries participate in the project, including four of the continent's leading Distribution System Operators: Italian's Enel, French company ERDF, Swedish company Vattenfall and Spain's Endesa Distribucion.

Recent years have seen intensive developments of new methods for understanding the function of RNA-binding proteins that are based on high-throughput sequencing. Due to the large quantities of sequencing data, new computational tools are needed to analyze and integrate various data sources on protein-RNA interactions. In this ARRS project, we are developing tools to understand the principles and mechanisms of gene expression regulation on the RNA level and their role in neurodegenerative diseases. The developed software tools are used to map sequencing data collected in iCLIP experiments on protein-RNA interaction assays, to quantify, model and visualize sites of protein-RNA interaction, and to model gene expression regulation. In particular, we are interested in the regulatory roles associated with neurodegenerative diseases of two proteins: TDP-43 and FUS.

\* SIBLEY, Christopher R., EMMETT, Warren, BLAZQUEZ, Lorea, FARO, Ana, HABERMAN, Nejc, BRIESE, Michael, TRABZUNI, Daniah, RYTEN, Mina, WEALE, Michael E., HARDY, John, MODIC, Miha, CURK, Tomaž, WILSON, Stephen W., PLAG-

NOL, Vincent, ULE, Jernej. Recursive splicing in long vertebrate genes. *Nature*, ISSN 0028-0836. [Print ed.], May 2015, vol. 521, no. 7552, str. 371-375, [15] str. pril., graf. prikazi. <http://www.nature.com/nature/journal/v521/n7552/full/nature14466.html>, doi: 10.1038/nature14466. [COBISS.SI-ID 1536358339]

\* STRAŽAR, Martin, ŽITNIK, Marinka, ZUPAN, Blaž, ULE, Jernej, CURK, Tomaž. Orthogonal matrix factorization enables integrative analysis of multiple RNA binding proteins. *Bioinformatics*, 2016 (accepted).

\* HAUER, Christian, CURK, Tomaž, ANDERS, Simon, SCHWARZL, Thomas, ALLEAUME, Anne-Marie, SIEBER, Jana, HOLLERER, Ina, BHUVANAGIRI, Madhuri, HUBER, Wolfgang, HENTZE, Matthias W., KULOZIK, Andreas E. Improved binding site assignment by high-resolution mapping of RNA-protein interactions using iCLIP. *Nature communications*, ISSN 2041-1723, Aug. 2015, vol. 6, str. 1-13, ilustr. <http://www.nature.com/ncomms/2015/150811/ncomms8921/full/ncomms8921.html>, doi: 10.1038/ncomms8921. [COBISS.SI-ID 1536523459]



## Model for Domain-Specific Trend Prediction based on Semantic Enrichment of Unstructured Patterns

**Project Type:**  
Basic Research Project funded by the Slovenian Research Agency

**Project Leader:**  
Prof. Matjaž Branko Jurič, PhD

**Collaborating Laboratories:**  
Laboratory for Integration of Information Systems

Project “Model for Domain-Specific Trend Prediction based on Semantic Enrichment of Unstructured Patterns” deals with the possibility of forecasting trends based on the semantic enrichment of unstructured patterns. With the expansion of the Internet new sources of mostly unstructured data constantly arise. The results of trend forecasting based on simple searches in search engines are surprising and show that the potential is huge. Additionally, a significant progress in the field of analysis of large amounts of unstructured data has also contributed to the successful extraction of formal knowledge from this data. However, due to abundance of unstructured data and the absence of adequate methodological support, pattern recognition and trend forecasting is still too demanding of both time and financial terms. Currently, time advances in cloud computing, processing large amounts of

data and large number of transactions allows the development of such solutions without building costly data centers. Thus we believe that it is possible to develop an automated model that will not only recognize patterns, but will also be able to use them to forecast trends within a particular domain by leveraging methods of data acquisition, analysis and data sampling from heterogeneous data sources. Our approach exploits the existing models for obtaining formal knowledge, introduces an innovative consensus-based decision model for pattern recognition using methods of artificial intelligence and an innovative mathematical model for trend forecasting. The proposed common solution can be adapted to particular domains, which can provide greater relevancy and accuracy of forecasts in shorter time with fewer resources.

## Maintenance of large databases based on visual information using incremental learning

**Project Type:**  
Application Research Project funded by the Slovenian Research Agency

**Project Leader:**  
Assist. Prof. Danijel Skočaj, PhD

**Collaborating Laboratories:**  
Visual Cognitive Systems Laboratory

We live in the era of information abundance. However, rather than quantity, the central concern is becoming the quality and credibility of the acquired data. This is especially true for visual information databases. Although the field of computer vision has achieved significant progress recently, the methods for automatic image interpretation are still not reliable enough to be used for autonomous annotation and maintenance of image and video databases (e.g. databases of detected objects). On the other hand, manual annotation of video sequences with relevant objects is very time consuming, expensive, as well as tedious and therefore prone to errors.

In this project, we aspire to combining two approaches: computer-based automation of image interpretation that is necessary for database

maintenance as well as suitable introduction of a human verifier into the loop. Such combination is of central importance for developing a methodology suitable for semiautomatic maintenance of traffic signalization records, which is partially our project’s practical goal. Even the database of such records for only state roads in the Republic of Slovenia may contain more than 250.000 entries along with additional information. Automation is therefore crucial for continuous maintenance of such databases. The main goal of the project is to develop a framework for semi-supervised incremental learning as well as specific methods for visual learning and recognition that will increase the quality and efficiency of large visual information databases maintenance.





Kaj je novega?



Kaj manjka?



Zaporedja



Sestavi me



Skriti predmeti

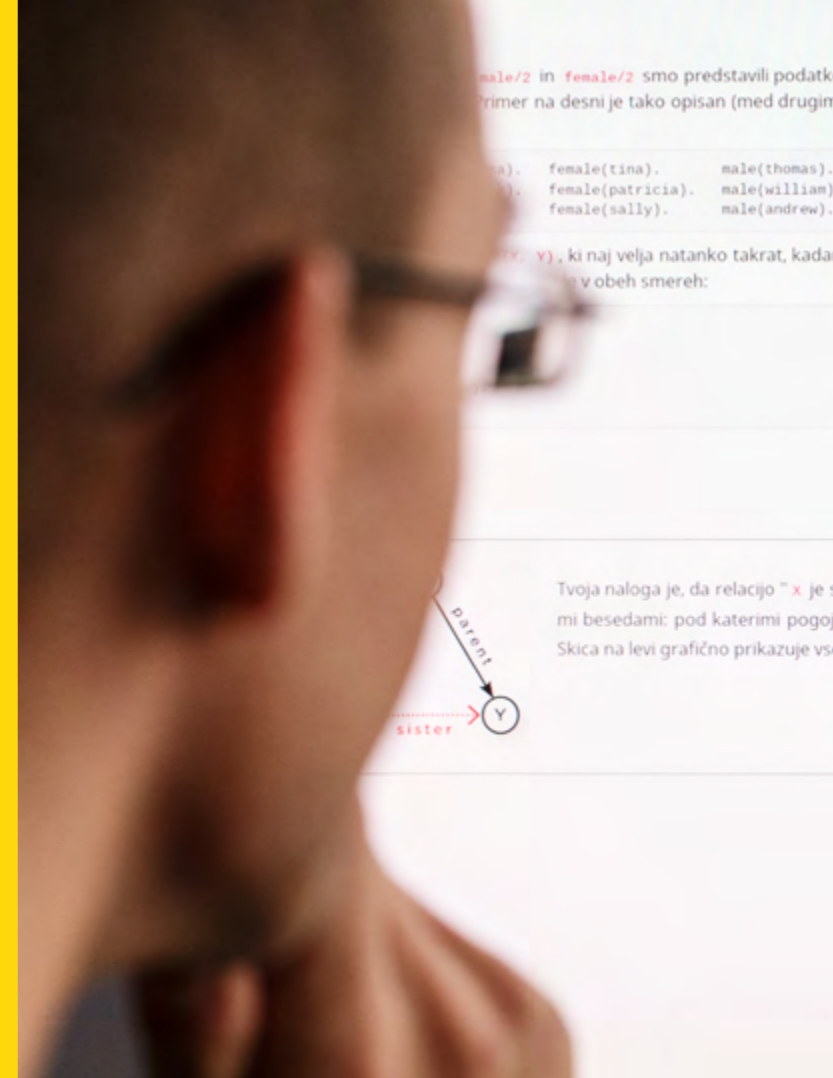
VEČ IGER  
(splet)

## CODE Q, Learning programming with automatically generated tips

**Project Type:**  
Structural Funds Project

**Project Leader:**  
Lecturer Aleksander Sadikov, PhD

**Collaborating Laboratories:**  
Artificial Intelligence Laboratory



## PerceiveConceive: an application for ICT-supported inclusion of blind and visually impaired youth in society

**Project Type:**  
Structural Funds Project

**Project Leader:**  
Institute for the Blind and Partially Sighted Youth  
Ljubljana

**Principal Investigator at FRI:**  
Assist. Prof. Matija Marolt, PhD

**Collaborating Laboratories:**  
Laboratory for Computer Graphics and Multimedia

The project involves the development of a web-mobile solution, which will be appropriated for the learning process of the blind and visually impaired, while remaining useful to the wider audience, for example pre-school children, eLaboratory of e-mediaentary school students and people, who lost vision later in life. The project is composed of two parts: The first is intended to familiarize a blind or visually impaired adolescent with standard and appropriated peripherals (keyboard and Braille line), teaching ten-finger typing to blind students, as well as Braille symbols. Likewise the solution is useful for adolescents learners without visual impairment, who wish to learn blind-typing. The second part, which is directly useful as a teaching aid for all adolescents, is intended for vision, memory and precise movement exercises in the form of memory games, as well as others which involve sorting, pair identification, image understanding and description and object navigation, controlled with fingers or keys.

Code Q is a web platform and an application for teaching programming through exercises. Besides a collection of carefully prepared programming exercises, Code Q offers automatic testing of the correctness of solutions, an interpreter to run instructions, queries, and programs, and foremost the ability to provide immediate feedback tailored specifically for the individual student. This type of communication is of vital importance for learning – Code Q strives to offer it to each and every one student. By giving appropriate hints and explanations, the application facilitates self-learning and simultaneously prevents a drop of motivation.

Feedback is provided by an advanced expert module that draws hints, advice and other information from various sources. Apart from deliberately predefined explanations and clues, the module uses a state-of-the-art method, developed at the Artificial Intelligence Laboratory at the Faculty of

Computer and Information Science in Ljubljana, for automatic detection and correction of common programming errors based on the analysis of previously submitted solutions to the exercises. The application also facilitates the running of selected groups of programs on Lego Mindstorms robots. Robot's performance serves as a visual hint of either the correctness or probLaboratory of e-medias with the solution, and also provides additional motivation for younger students.

CODE Q is freely available and can be used either for self-learning or as a suppLaboratory of e-mediaent in class. It currently offers a beginner's programming course in Python and Prolog programming languages and a beginner's course in programming a Lego Mindstorms robot. New exercises and other materials are planned and will be added in due course.

The main objective of this applied project is to develop an application for measuring the size of a foot with smart mobile devices. The project is application-oriented, requiring the development and implementation of robust and accurate computer vision algorithms. Due to the highly heterogeneous target platforms and non-constrained conditions of use, as well as due to high requirements imposed, the project is complex and challenging, both, from the research and the application point of view.

## FootScApp, development of an application for measuring feet with smart mobile devices

**Project Type:**  
Industrial Project

**Project Leader:**  
Assist. Prof. Danijel Skočaj, PhD

**Collaborating Laboratories:**  
Visual Cognitive Systems Laboratory

## Projekt Sentinel2AgriSlovenia

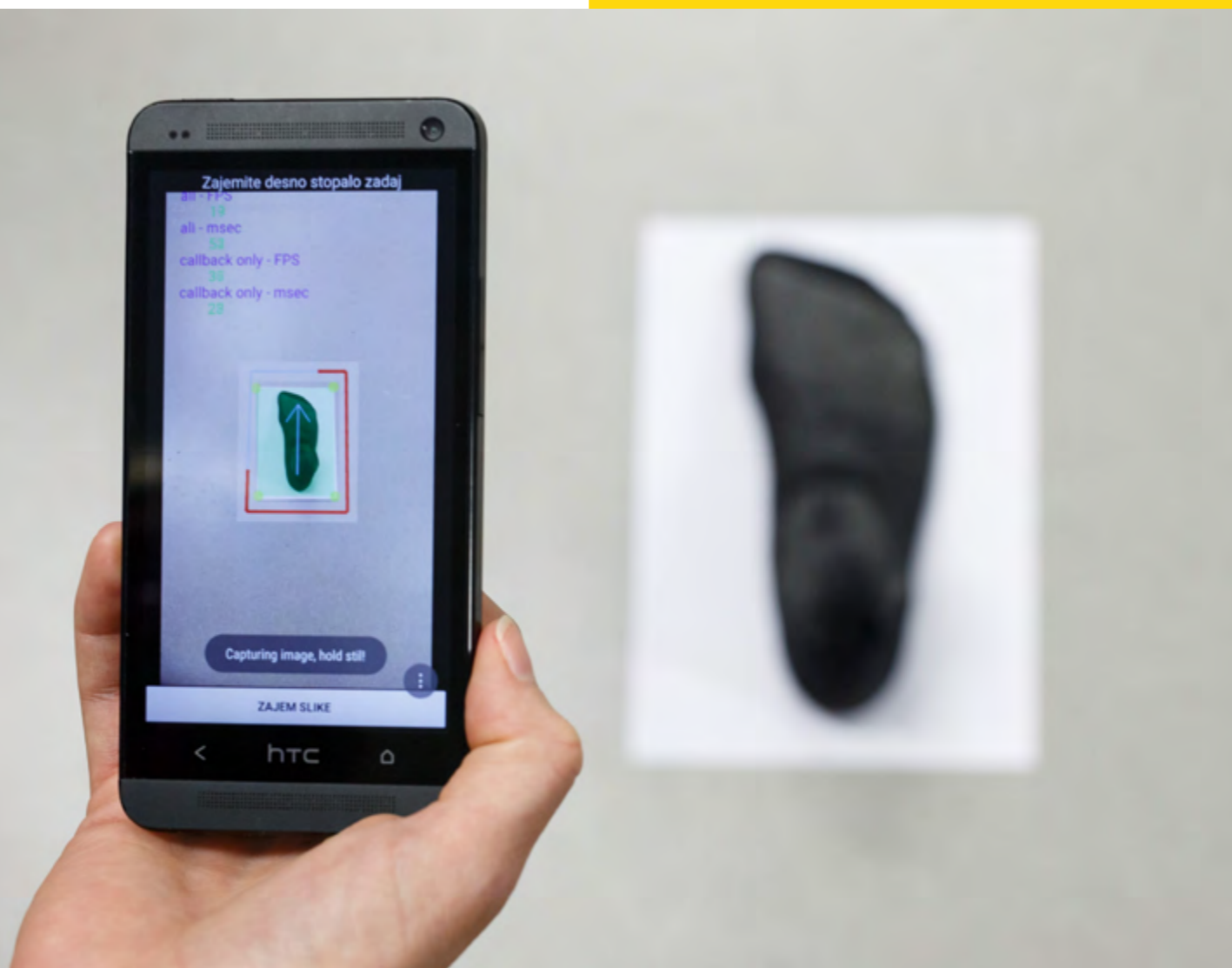
**Project Type:**  
Industrial Project


**Project Leader:**  
Andrej Brodnik, PhD

**Collaborating Laboratories:**  
Laboratory for Ubiquitous Systems

Today, agriculture is facing many challenges worldwide. In Slovenia, several demonstration studies have shown the potential of satellite remote sensing in the field of agriculture. The motivation for this project is an interest and a strong need to develop more enhanced, robust, consistent, harmonised and product-oriented infrastructure for crop dynamics observation that has been shown by Slovenian Ministry of Agriculture and the Environment (MKO), Slovenian Environmental Agency (ARSO) and the Agency for Agricultural Markets and Rural Development (ARSKTRP).

The proposed project has a scientific and technical objective to study satellite image time series for the purpose of the crop mask determination, crop area estimation, crop identification and crop stress dynamics monitoring along with the development of the product dissemination tool. The outcomes of the project could serve as an indicator for the agricultural productivity and food security infrastructure at different regional levels and at the national level considering also a strategic market potential role of crop production yields and could also provide information needed for policy making.





## “ Creative Path to Practical Knowledge ”

*A successful measure which connects knowledge and experience for a successful transition from the educational system into work environment is carried out with the support of the European Social Fund and the 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 the central role as experts in small scale projects from all academic fields and use their theoretical knowledge and apply it towards research and practical solutions. With the help of an academic mentor and a mentor from business, the students are solving individual businesses and society challenges which are the most actual at the moment, using specific theoretical knowledge from educational process and business work approach and their infrastructure.

In 2015 our Research Staff was involved in several projects, 7 of which were projects where our Researchers were Principal Investigators in the rest of these projects their collaboration role was Teaching Mentor. All of these projects are described below.

### Automatic analysis of the technical quality of mammography images

**Principal Investigator:**  
Assoc. Prof. Janez Žibert, PhD

**Teaching Mentor:**  
Andrej Brodnik, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

The purpose of the project was to develop a system for the automatic detection of irregularities in the mammographic image to automate quality control protocols of mammography systems, which are used under the DORA project (national screening program for breast cancer).

### E-content in education

**Principal Investigator:**  
Prof. Aleksandar Jurišić, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

The projects objective was the further development of a previously developed application called »Kvizko«, which is used for e-learning. It included statistical methods to encourage quiz rescuers. We also looked at the security mechanisms on mobile devices such as smartphones and tablets. The main focus of the project was to work on software for e-learning, interactive and challenging acquisition of new knowledge.

### Tourist guide on the basis of a treasure hunting game

**Principal Investigator:**  
Assoc. Prof. Zoran Bosnić, PhD

**Project Duration:**  
01.03.2015 - 31.07.2015

The main objective of this project was to develop a mobile and web application, intended for mobile learning through teaching. The application, called FR1step is based on the principle of a treasure hunting game. This game guides the player to search different consecutive points in one place and at every point the »hidden treasure« presents an educational riddle which educates the player.

### Human Resources management in translation industry

**Principal Investigator:**  
University of Ljubljana, Faculty of Arts

**Teaching Mentor:**  
Andrej Brodnik, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

In a bussiness of translation the most valuabel resource represent human translators. The goal of this project is to build the environment for efficient monitoring and management of human resources in a atranslation process.

### Integration of IoT devices and SaaS applications

**Principal Investigator:**  
Prof. Matjaž Branko Jurič, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

In the recent period, the development of technology resulted in wide appearance and popularity of smart devices, including smart phones and low-power computing devices supported by small sensors that operate either in authonomous way or provide an extension of conventional devices and thus make them »smart«. Such devices correspond to IoT (Internet-of-Things) paradigm, where all of them have common property - they are continuously connecting to world wide web and are using it as a communication channel to send and receive data about several quantities (i.e. location, movement, temperature, etc.), where these interconnected devices act as a whole. Nowadays, integration of such devices becomes of great importance also in business environment since consideration of data acquired in real-time enables implementation of new and advanced functionalities that were not applicable before. Thus, such real-time collected data can significantly improve services in terms of business and process management, customer relationship management, logistics, automatization, localization, security, as well as other information systems. Project is focused on integration of IoT smart sensors and devices by SaaS (Software-as-a-Service) and by exploiting and joining positive properties of both aspects, one of the main objectives is to build a prototype platform that provides similar level of self-service and automatization in the field of the integration of IoT devices by SaaS services.

## Modern approaches of informatics in healthcare

**Principal Investigator:**  
University of Ljubljana, Faculty of Economics

**Teaching Mentor:**  
Andrej Brodnik, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

The company C-Astral is one of the market leaders in the small unmanned systems (UAS) and services field. It has a global presence, a robust research and development program and advanced integration/customization capacities. Students will learn to design an unmanned aircraft, from design based on the user's requirements to the adjustment of the structure and the components. They will model an aircraft in 3D modeler, create a structure array and integrate all electronic and mechanical systems. Besides that, they will compose and set an airplane, consequently test it in the laboratory and on field, and finally carry out a prescribed task.

## A study in the advanced distributed analytics

**Principal Investigator:**  
Assist. Prof. Boštjan Slivnik, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

The project, carried out by undergraduate students and in cooperation with XLAB d.o.o, was focused on finding out how much certain methods for analysis of massive data about prospective customers can be sped up by using distributed and heterogeneous computing. By implementing several analytical methods on different heterogeneous systems enhanced by GPUs or Intel Xeon Phi subsystems the students demonstrated that the data, acquired by XLAB mostly from various social networks, can be analysed an order of magnitude faster compared with the existing XLAB sequential implementation.

## An unmanned aerial vehicle (UAV) for control and surveillance

**Principal Investigator:**  
Prof. dr. Milan Batista

**Teaching Mentor:**  
Lecturer Borut Batagelj, PhD

**Project Duration:**  
02.02.2015 - 31.07.2015

It is about a close cooperation among three faculties of University of Ljubljana (Faculty of Mechanical Engineering, Faculty of Maritime Studies and Transport and Faculty of Computer and Information Science) on one hand and the C-Astral company on the other. The company C-Astral is one of the market leaders in the small unmanned systems (UAS) and services field. It has a global presence, a robust research and development program and advanced integration/customization capacities. In the first part students learned to design an unmanned aircraft, from design based on the user's requirements to the adjustment of the structure and the components. They modeled an aircraft in 3D modeler, created a structure array and integrated all electronic and mechanical systems. Besides that, they composed and set an airplane, consequently tested it in the laboratory and on field, and finally carried out a prescribed task. In the second part, the student's team constructed a drone for observing and practical usage. As engineers we faced different challenges such as: satisfactory construction solidity of the aircraft while flying and maneuvering, its sufficient autonomy and reliability, the ability of wireless connection, operational limitations and the camera usage for quality videos.

## Smart glasses

**Principal Investigator:**  
University of Ljubljana, Faculty of Electrical Engineering

**Teaching Mentor:**  
Prof. Marko Bajec, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

Using smart glasses we have developed a system that enables the operator in a production line to receive required documentation in front of his eyes as soon as possible, without using his hands. Furthermore we have enabled the worker to make a recording of the forwarding or error correcting process and thereby enabling effective transfer of experience onto staff.

## Web-based application for identifying and providing information on sexual transmitted infections

**Principal Investigator:**  
Prof. Mojca Matičič, MD

**Teaching Mentor:**  
as. Gašper Fele Žorž, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

The goal of this project was to spread awareness of sexually transmitted infections (STIs) among the young. To facilitate this, a web-site with containing an on-line quiz and various information regarding STIs has been deployed at [aspo.mf.uni-lj.si](http://aspo.mf.uni-lj.si).

## Innovative musical instruments cases

**Principal Investigator:**  
Assoc. Prof. Patricio Bulić, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

The projects aim was the development of an innovative and functional smart suitcase for instruments, specifically a harmonic.

## Analysis and visualization of impact factors on organization visits

**Principal investigator:**  
Assist. Prof. Jurij Mihelič, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

The project is focused on the design and development of a software-based system for the visualization and analysis of impact factors on visits of organisations. We process data about two kinds of organizations, first private ones (focused on profit) such as shopping centers and, second, public ones such as museums and galleries. We split the impact factors into endogenous and exogenous factors. We develop several types of visualizations such as geo-visualization of visits, time- correlated rain dependency, analysis of age-related groups, comparison of planned and realized visits, etc.

## A pilot study of placement and design for cyclists counter

**Principal Investigator:**  
Prof. dr. Ilka Čerpes

**Teaching Mentor:**  
Lecturer Borut Batagelj, PhD

**Project Duration:**  
02.02.2015 - 31.07.2015

The Placement and Design Pilot Study was implemented in the context of Parenzana Cycling Trail along Slovenian Adriatic coast. By connecting the physical and the digital, a better cycling traffic quality and popularity can be achieved. Students were practically involved in the development and testing data of the devices for counting cyclists. They also worked on computer applications for capturing and collecting data about the number of cyclists and applications for further statistical and analytical data processing.

## Visualization and analysis of public finance networks

**Principal Investigator:**  
as. Uroš Čibej, PhD

**Project Duration:**  
01.02.2015 - 31.07.2015

The goal of the project is to develop a visualization tool for data publicly available by the Slovenian Commission for the Prevention of Corruption. The commission already provides a visualization tool called Supervizor, but the visualization offered by it is rather local. We develop an online application that will enable a global (network) view of the slovenian financial system and make it available for general public.





## Naslov “Posebni dosežki” mogoče?

## Robust detection of heart beats in simultaneous physiological signals

### Project Leader:

Prof. Franc Jager, PhD; franc.jager@fri.uni-lj.si

### Collaborating Laboratories:

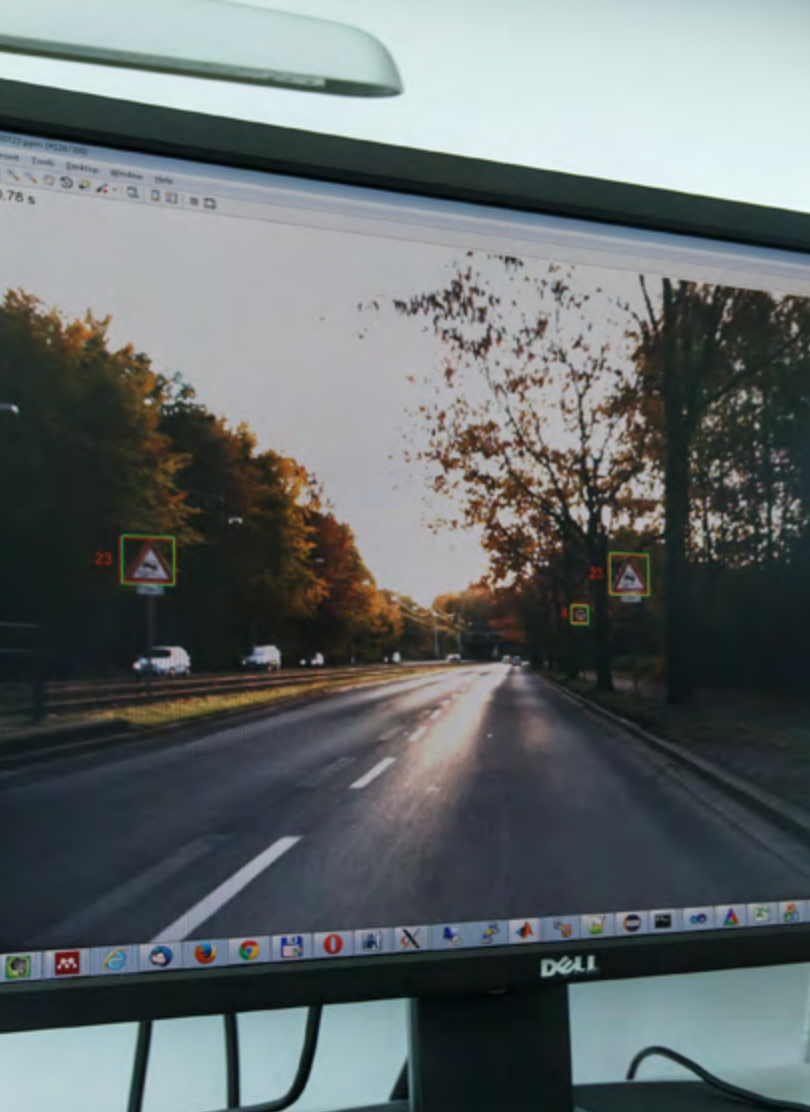
Laboratory for Biomedical Computer Systems and  
Imaging



The Laboratory for Biomedical Computer Systems and Imaging (Bioinformatics Laboratory CSI) is, among other things, engaged in the development of techniques and algorithms for automatic analysis of electrocardiograph (ECG) signals. A Bioinformatics Laboratory CSI team competed at the Robust Detection of Heart Beats in Multimodal Data international competition. The competition was held in the scope of the scientific challenge of the international Computing in Cardiology Conference. The problem of accurate automatic detection of heart beats is older than computer science and is still not sufficiently solved. Among 47 international teams, during the last phase of the competition in April 2015, the competing team from the Bioinformatics Laboratory CSI obtained first place. The developed heartbeat detector is capable of robust detection of heart beats in ECG signals only, in pulsatile signals only, or in both. The develop-

ment strategy behind the developed detector is to analyse ECG signals as accurately as possible, to estimate noise intervals in the ECG signals, and after that to map the positions of the detected heart beats in the selected pulsatile signal into the noise intervals and intervals with ECG signal loss. The novelties of the developed robust heart beat detector may be summarised as follows: an attempt to unify the problem of seeking for optimal convolution kernel to extract features of signals, original procedures to improve the shape of detection functions and to detect intervals with severe noise that are based on morphological algorithms, an original and reliable procedure to detect presence of pacemaker pattern.

The results have been published in the *Physiological Measurement* journal.



## Visual Object Tracking

### Project Leader:

Assist. Prof. Danijel Skočaj, PhD; danijel.skocaj@fri.uni-lj.si

### Collaborating Laboratories:

Visual Cognitive Systems Laboratory

## Data handling

### Project Leader:

Andrej Brodnik, PhD; andrej.brodnik@fri.uni-lj.si

### Collaborating Laboratories:

Laboratory for Ubiquitous Systems

The task of visual object tracking is localisation of a selected object in a sequence of images. This is a highly challenging problem since the tracking algorithm is required to learn object appearance and perform accurate localisation despite the possible variation in appearance due to illumination changes, occlusion and non-rigid object deformation. Our recent work has focused on development of part-based models for visual tracking and fast optimisation methods for learning and localisation [1]. The developed trackers exhibit robust performance and we have applied them to several application domains, ranging from traffic-sign tracking and automatic video-conferencing devices to people following by autonomous drones. Apart from development of new tracking algorithms, our research also focuses on approaches for tracker performance evaluation. We are the founding members of the Visual object tracking (VOT) initiative [2], within which

we have organised several visual object tracking challenges and have established the most advanced performance benchmarks in visual tracking to date [2] as well as the most advanced supporting methodology for performance evaluation [3].

### Selected Publications:

- [1] Luka Čehovin, Matej Kristan, and Aleš Leonardis, Robust Visual Tracking using an Adaptive Coupled-layer Visual Model, IEEE Transactions on Pattern Analysis and Machine Intelligence, 2013
- [2] <http://www.votchallenge.net/>
- [3] Matej Kristan, Jiri Matas, Aleš Leonardis, Tomas Vojir, Roman Pflugfelder, Gustavo Fernandez, Georg Nebehay, Fatih Porikli, and Luka Čehovin, A Novel Performance Evaluation Methodology for Single-Target Trackers, IEEE Transactions on Pattern Analysis and Machine Intelligence, 2016

The prime research interest of the Laboratory for Ubiquitous Systems is efficient data handling, in particular in distributed pervasive environments. The distributed environments store tera-bytes of data which presents a challenge in at least two areas: how to efficiently store the data and how to efficiently handle the data. Furthermore, the distributed environment is inherently capable of parallel processing, which requires proper data and work distribution.

Currently, our research is concentrated on three areas: unstructured text handling, data deduplication and on-line streaming data processing. The unstructured text is nowadays the most common data one can find. It includes everything from the (human) genome, protein banks, stock prices, signals and all the way to the natural text. Our interest is to efficiently construct an index of such data and how to query the text through the index. The measure of efficiency includes cache hierarchy and possibility of a parallelism. Our research spans from theory to practical ap-

plication. This span is also heavily present in the data deduplication research. Here we are primarily interested in on-line deduplication systems. In particular, we want to use the possibility of parallel processing whilst preserving the balance of stored data. The research results shall be applied to the distributed data storage systems such as open-source CEPH. The third area of research, the streaming data processing, is primary concentrated on satellite pictures coming to the Earth. The pictures need to be processed for use in agriculture.

Last but not least, our research area is also Computer Science Education, where we focus on what and how to teach Computer Science. Target groups are pupils in secondary school. We have written a new textbook for Informatics in secondary school. Furthermore, we are organising and co-organising national competitions in Computer Science for K12 education and also for college students.

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## Theoretical Computer Science

**Project Leader:**  
Prof. Viljan Mahnič, PhD; viljan.mahnic@fri.uni-lj.si

**Collaborating Laboratories:**  
Software Engineering Laboratory

## 3D documentation of cultural heritage

**Project Leader:**  
Prof. Franc Solina, PhD; franc.solina@fri.uni-lj.si

**Collaborating Laboratories:**  
Computer Vision Laboratory

The Computer Vision Laboratory is active in 3D documentation of cultural heritage, in particular in under-water archaeology. We are active in particular in multi-image photogrammetry which can generate, even under-water, large clouds of 3D points which can then be used for visualisation and for further reconstruction of more compact volumetric models. We study how the under-water environment influences the precision that can be obtained with photogrammetrical methods. We collaborated with underwater archaeologists and cultural heritage professionals, for example in documenting a Roman barge in the Ljubljanica river near Vrhnika and in modelling stone sarcophagi in a Roman wreck off the island Brač in Croatia. We are also engaged in the development of novel database approaches in digital heritage, for example the Arches project. Another project in this area that we are participating in is the establishment of a 3D digital Glyptothek.

In the field of Theoretical Computer Science, members of the Software Engineering Laboratory deal with agile and lean software development, graph grammars, and graph theory.

In Lean software development, the members of the Software Engineering Laboratory presented a capstone course in software engineering which exposes students to Lean principles advocated by Kanban. The course introduces the most important Kanban concepts, i.e., visualisation of the workflow and limitation of the work in progress in two ways: in combination with Scrum (as Scrumban) or as a “pure” Kanban (omitting some of the Scrum activities considered waste). In the published paper, the use of different Kanban boards and work in progress limits is described. There is also an analysis of the students’ progress in reducing lead time. A survey among students has shown that they liked both approaches and were overwhelmingly positive about the course. The results of this work were published in the International Journal of Engineering Education.

In Graphs Theory, the members of the above mentioned Laboratory also presented a method to convert a metamodel in the form of a UML class diagram into context-sensitive graph grammar whose language comprises precisely the set of model graphs (UML object diagrams) that conform to the input metamodel. Results were published in Software and System Modelling.

Another focus the Laboratory adopted this year is the maximum exploratory equivalence in trees. The focus is on a type of vertex equivalence, called exploratory equivalence, which has a great potential to speed up such algorithms. It is an equivalence based on graph automorphisms and can, for example, help in solving the subgraph isomorphism problem, which is a well-known NP-hard problem. In particular, if a given pattern graph has nontrivial automorphisms, then each of its nontrivial exploratory equivalent classes gives rise to a set of constraints to prune the search space of solutions. The results of this study are published in the International Journal of Engineering Education.

**Selected Publications:**  
1. V. Mahnič. From Scrum to Kanban: Introducing Lean Principles to a Software Engineering Capstone Course. International Journal of Engineering Education, 31(4): 1106-1116 (2015).  
2. Luka Fürst, Marjan Mernik, Viljan Mahnič. Converting metamodels to graph grammars: doing without advanced graph grammar features. Software and System Modeling 14(3): 1297-1317 (2015).  
3. Luka Fürst, Uroš Čibej, Jurij Mihelič. Maximum exploratory equivalence in trees. In 2015 Federated Conference on Computer Science and Information Systems (FedCSIS 2015), Łódź, Poland, September 13-16, 2015, pages 507-518.



Computational analysis of biological systems is important in the context of both natural and synthetic biological systems. In-silico investigation of different synthetic designs is able to guide the implementation of biological systems with desired functionality. Analysis of natural systems is on the other hand important for understanding the underlying mechanisms that regulate several cellular responses and may lead to a better understanding of complex diseases and to the finding of novel possibilities for their treatment. Our group is working extensively on the establishment of novel computational approaches for modelling, design and analysis of biological systems that lead to efficient use of available computational resources, higher accuracy of obtained results and increased complexity of targeted systems.

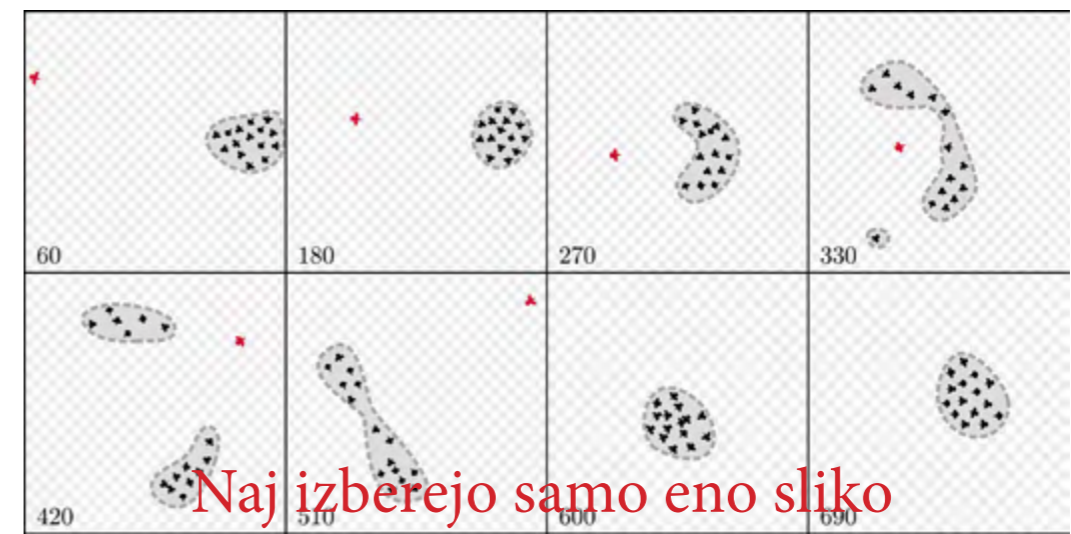
## Computational modelling, design and analysis of biological systems

### Project Leader:

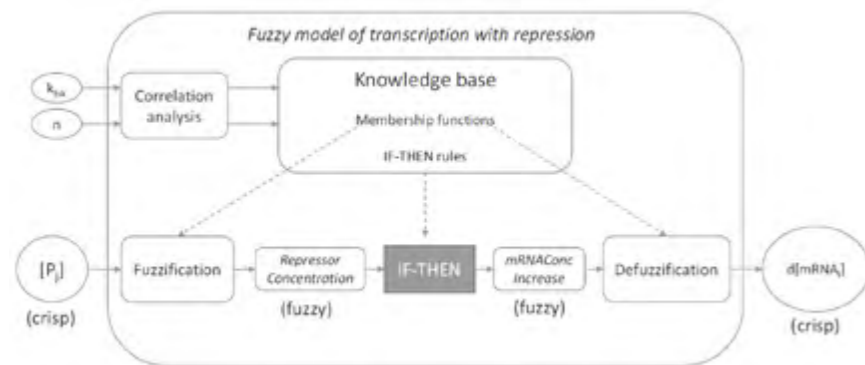
Prof. Nikolaj Zimic, PhD;  
nikolaj.zimic@fri.uni-lj.si

### Collaborating Laboratories:

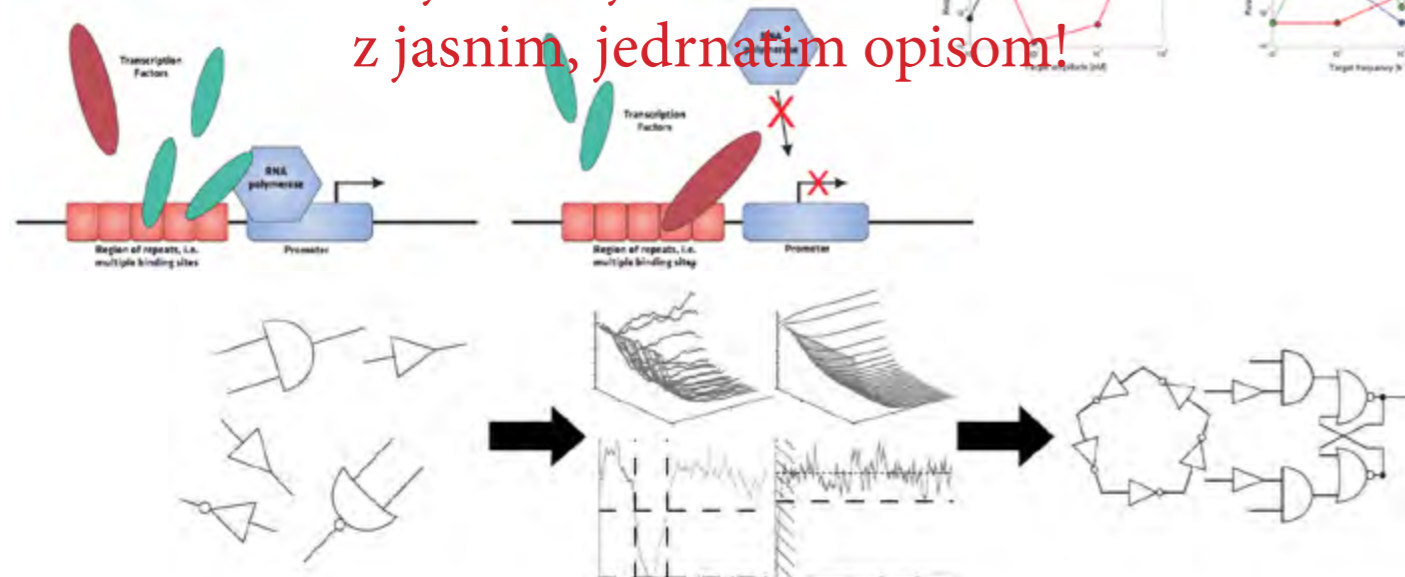
Computer Structures and Systems Laboratory



Naj izberejo samo eno sliko  
z jasnim, jedrnatim opisom!



Naj izberejo samo eno sliko  
z jasnim, jedrnatim opisom!



## Predatory attacks and self-organization in social systems

### Project Leader:

Prof. Nikolaj Zimic, PhD;  
nikolaj.zimic@fri.uni-lj.si

### Collaborating Laboratories:

Computer Structures and Systems Laboratory

A key question in self-organising social systems is how evolution may have shaped the prey-targeting system depending on the prey's self-organising/social behaviour. In the quest to elucidate the interplay between prey targeting, pursuit and evasion, we develop individual based predator-prey models. With the help of evolutionary rule based systems, we seek to gain insight into the evolution of both, the predator's target selection/pursuit methodology, and prey self-organisation.

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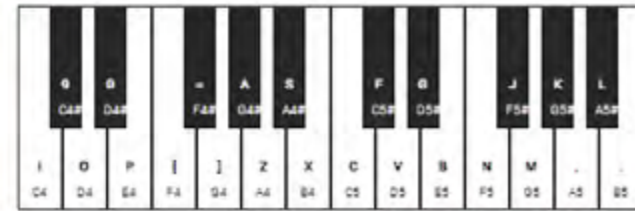
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About EtnoFletno

## Melody

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Results (10)



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## Robust detection of heart beats in simultaneous physiological signals

The University Prešeren Award

**Project Leader:**

Urška Pangerc

Prof. Franc Jager, PhD;

franc.jager@fri.uni-lj.si

**Collaborating Laboratories:**

Laboratory for Biomedical Computer Systems and Imaging

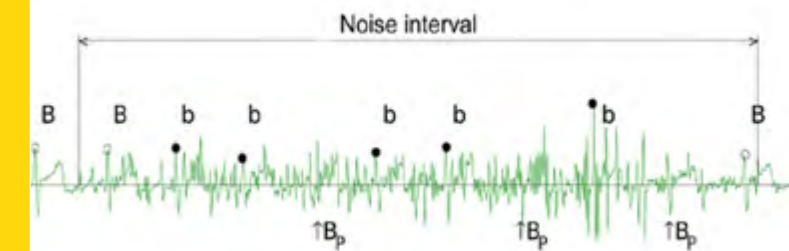


Figure above: Example of detecting a noise interval and detecting heart beats. B and b: Positions of correctly detected heart beats in ECG. Bp: Positions of correctly detected heart beats in simultaneously recorded pulsatile signal that were mapped into the noise interval.

The Laboratory for Computer Graphics and Multimedia is active in the area of music information retrieval, specifically in extraction of high level semantic descriptors from audio and music signals.

We are developing a Compositional Hierarchical Model for Music Information Retrieval, a deep architecture that processes music in audio or symbolic forms and can efficiently and in an unsupervised manner learn and encode relationships in music. It is a generative model, with a transparent structure which enables insight into the learned concepts. The architecture is multi-layered, where lower layers encode basic musical concepts (harmonics, tones), while higher layers represent more complex entities such as chords and motives. The model can be used for music transcription, chord estimation or for detection of repeated patterns, where it achieved good results on the 2015 Music Information Retrieval Evaluation eXchange.

Specific focus is also given to extraction of information from ethnomusicological archives. In a series of projects in cooperation with Ethnomusicological Institute of Scientific Research Centre of Slovenian Academy of Sciences and Arts we developed methods for segmentation of ethnomusicological field recordings, as well as segmentation, classification and transcription of folk song and bell chiming recordings. We developed the EthnoMuse archive, containing the digitized collections of the Institute, as well as the web and mobile platforms ClickToHomeland ([www.klikvdomovino.si](http://www.klikvdomovino.si)) and EtnoFletno ([www.etnofletno.si](http://www.etnofletno.si)), exposing parts of the EthoMuse to general public.

## Music Information Retrieval

**Project Leader:**

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**Collaborating Laboratories:**

Laboratory for Computer Graphics and Multimedia

The first place obtained during the final phase (April 2015) of the Robust Detection of Heart Beats in Multimodal Data international competition.

The Laboratory for Biomedical Computer Systems and Imaging (Bioinformatics Laboratory CSI) is, among other things, engaged in the development of techniques and algorithms for automatic analysis of electrocardiograph (ECG) signals. A Bioinformatics Laboratory CSI team competed at the Robust Detection of Heart Beats in Multimodal Data international competition. The competition was held in the scope of the scientific challenge of the international Computing in Cardiology Conference. The problem of accurate automatic detection of heart beats is older than computer science and is still not sufficiently solved. Among 47 international teams, during the last phase of the competition, in April 2015, the competing team from the Bioinformatics Laboratory CSI obtained first place (see <http://physionet.org/challenge/2014/>). The paper describing the architecture and performances

of the developed detector as achieved on several international reference databases and on the competing database was published in the Physiological Measurement journal (1). The developed heartbeat detector is capable of robust detection of heart beats in ECG signals only, in pulsatile signals only, or in both. The development strategy behind the developed detector is to analyse ECG signals as accurately as possible, to estimate noise intervals in ECG signals, and after that to map the positions of the detected heart beats in the selected pulsatile signal into the noise intervals and intervals with ECG signal loss. The novelties of the developed robust heart beat detector may be summarised as follows: an attempt to unify the problem of seeking for optimal convolution kernel to extract features of signals, original procedures to improve the shape of detection functions and to detect intervals with severe noise that are based on morphological algorithms, an original and reliable procedure to detect presence of pacemaker pattern.

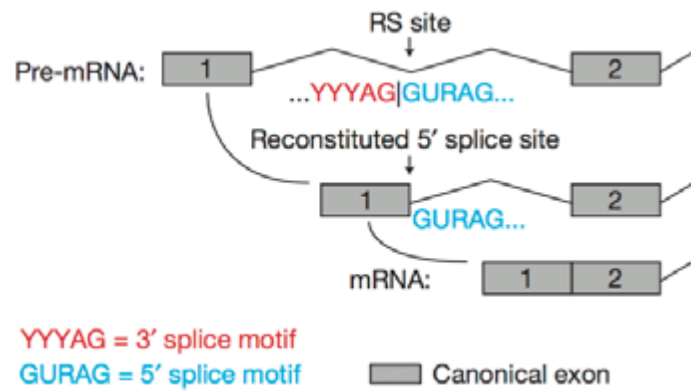


Figure 1: Model of recursive splicing mechanism.

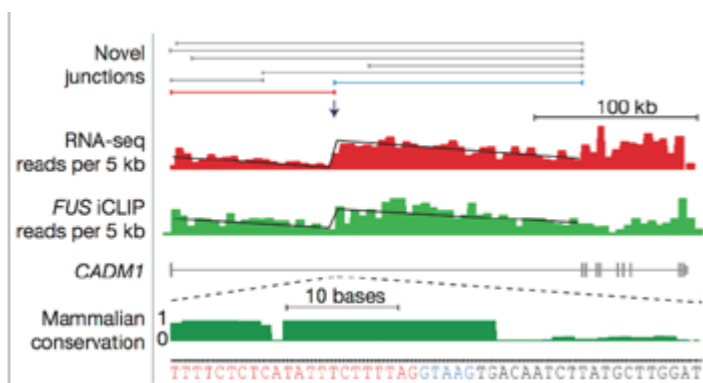


Figure 2: Model of recursive splicing mechanism. RNA-seq and iCLIP high-throughput sequencing data supporting novel junctions identified within CADM1 gene.

## Recursive splicing in long vertebrate genes

### Project Leader:

Assist. Prof. Tomaž Curk, PhD  
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### Collaborating Laboratories:

Bioinformatics Laboratory

## The Foundations of Computability Theory

### Project Leader:

Prof. Borut Robič, PhD; borut.robic@fri.uni-lj.si

### Collaborating Laboratories:

Laboratory for Algorithms and Data Structures

Splicing is a well-known and studied mechanism of gene regulation. The main goal of splicing is to remove the intronic parts and retain the protein-coding parts of pre-mRNA transcripts before they are sent off to ribosomes, where they are used as a template for protein synthesis. Splicing also allows the alternative selection of exons, which is the basis for the multitude of different proteins that can be produced from a limited number of genes. Understanding splicing is thus key to understanding gene regulation and the role of gene misregulation in disease.

By analysing high-throughput sequencing data, we have showed that genes that are active in the human brain have a tendency to be longer than in other tissues. For the first time, we have showed that recursive splicing, a mechanism previously only seen in *Drosophila*, is used to process some of the longest human genes. We discovered that long introns in these genes are recursively spliced - they are removed in two splicing steps. By performing sequence analysis, we found that

for recursive splicing to work, a recursive splice site (RS) signal is required. This site mimics a cryptic exon within an intron, and is normally removed without a trace. We have also found that when two cryptic exons are present, one may be retained, often resulting in an inactivated and destroyed isoform. We postulate that this may serve as a binary switch for the activation of new, cryptic isoforms, which may be an important driver of the evolution of gene expression regulation, which appears to be particularly important for the brain. Recursive splicing may also be of clinical importance, since many of the identified genes are linked to autism and other neurological disorders.

### Selected Publications:

Sibley CR, Emmett W, Blazquez L, Faro A, Haberman N, Briese M, Trabzun D, Ryten M, Weale ME, Hardy J, Modic M, Curk T, Wilson SW, Plagnol V, Ule J (2015) Recursive splicing in long vertebrate genes, *Nature*, 521(7552):371-375.

The book by Prof. Borut Robič, PhD, "The Foundations of Computability Theory": Original, informative view of the development of the fundamental concepts of computability theory. Avoids excessive formalism, offering instead intuitive understanding. Characterized by the appreciation of historical context and motivation of the logical development of the theory presented. This book offers an original and informative view of the development of fundamental concepts of computability theory. The treatment is put into historical context, emphasising the motivation for ideas as well as their logical and formal development. In Part I, the author introduces computability theory, with chapters on the foundational crisis of mathematics in the early twentieth century, and formalism; in Part II he explains classical computability theory, with chapters on the quest

for formalisation, the Turing Machine, and early successes such as defining incomputable problems, c.e. (computably enumerable) sets, and developing methods for proving incomputability. In Part III he explains relative computability, with chapters on computation with external help, degrees of unsolvability, the Turing hierarchy of unsolvability, the class of degrees of unsolvability, c.e. degrees and the priority method, and the arithmetical hierarchy. This is a gentle introduction from the origins of computability theory up to current research, and it will be of value as a textbook and guide for advanced undergraduate and graduate students and researchers in the domains of computability theory and theoretical computer science.

The increased prevalence of antibiotic-resistant bacteria urges us to explore alternative strategies to treat bacterial infections. Nature abounds with species that are highly resistant to pathogenic bacteria, including the popular model organism *Dictyostelium*, which is a bacterial predator. Uncovering its bacterial resistance pathways could improve our understanding of core resistance mechanisms and lead us to drugs that target such pathways in humans. But even in *Dictyostelium*, the experiments are expensive and take time. Our partners at Baylor College of Medicine took five years to discover four bacterial resistant genes. To speed-up the discovery process, we have developed a computational approach that can consider a vast array of data sets, including data on mutant-based phenotypes, gene expressions, protein interactions, gene functional annotations, literature, drugs, and effects of drug treatments. We represent each data set as a matrix, and collectively compress the matrices to get rid of noise and retain only the prevailing, true data patterns. The resulting compressed data system is then used to identify genes with high probability of a target phenotype. For bacterial resistance, we have predicted the role for nine new genes. For eight of these genes, our predictions were confirmed in the wet lab. This time, instead of five years for the discovery of the initial four genes, it took our partners only a month of lab time.

The results have been published in IEEE Transactions on Pattern Analysis & Machine Intelligence and PLoS Computational Biology by Blaž Zupan and Marinka Žitnik.

## Large-Scale Data Fusion

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**Collaborating Laboratories:**  
Bioinformatics Laboratory

## Orange, Data Mining Fruitful & Fun

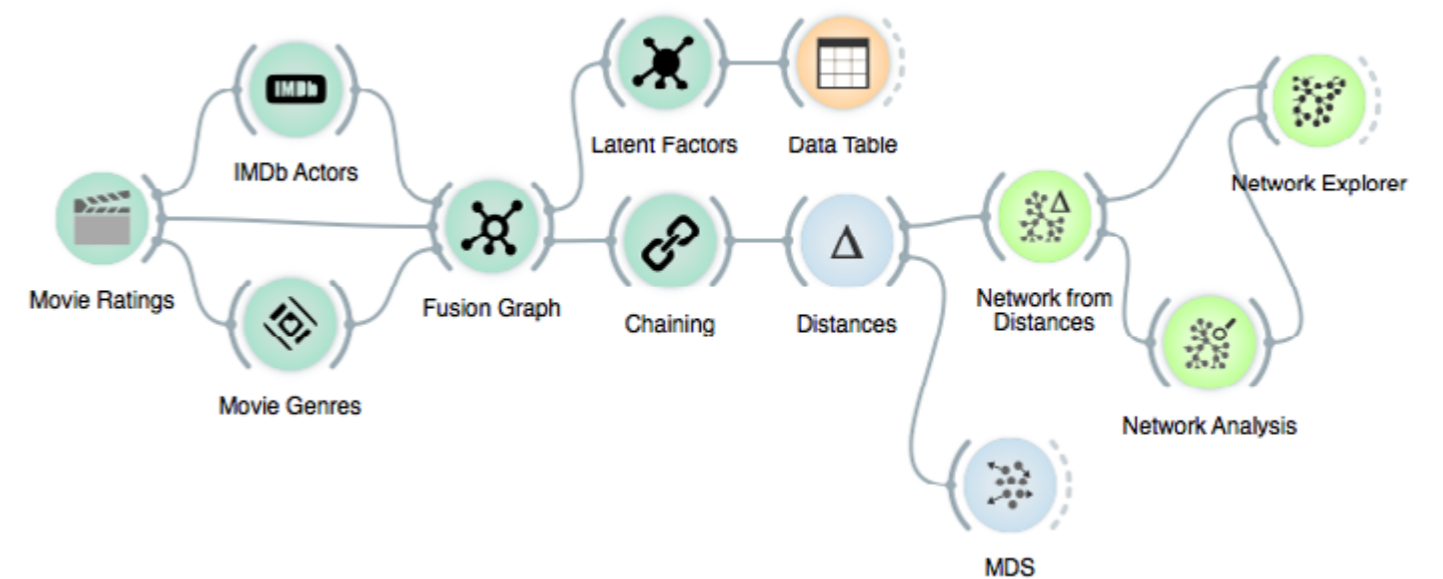
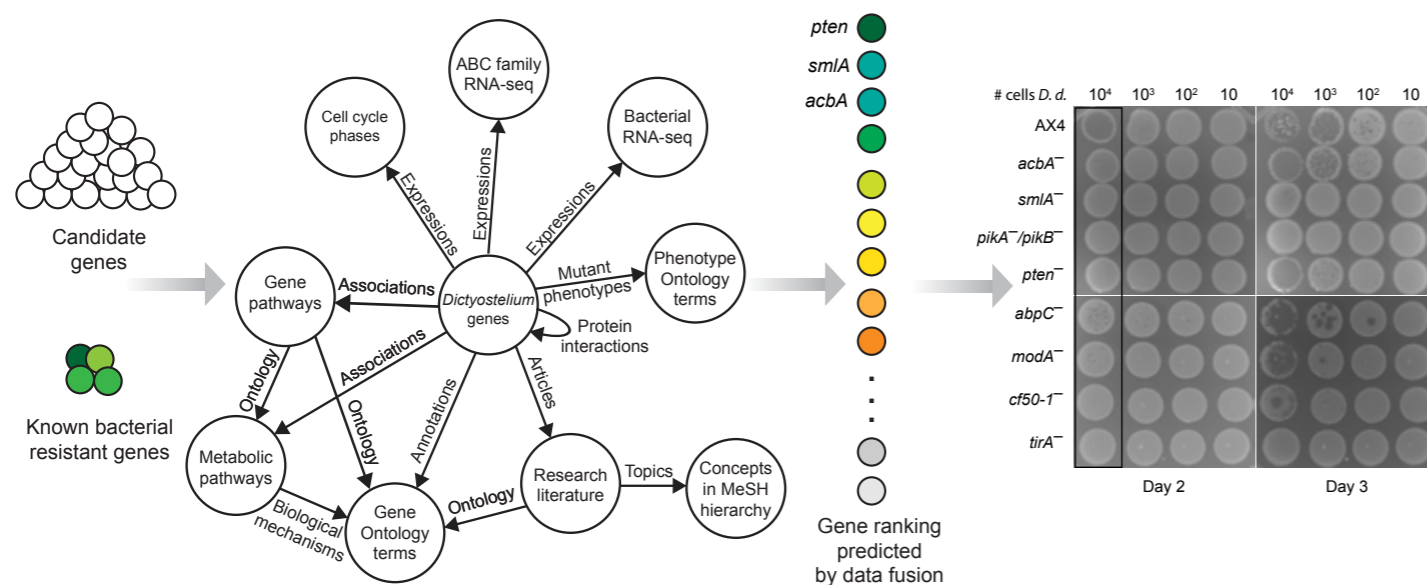
**Project Leader:**  
Prof. Blaž Zupan, PhD; blaz.zupan@fri.uni-lj.si

**Collaborating Laboratories:**  
Bioinformatics Laboratory

Orange is an open source data visualisation and data analysis framework for novices and experts. It features construction of data mining workflows through visual programming and a large toolbox of methods for data preprocessing, visualisation and machine learning. Developed in Biolab, it has been short-listed in virtually every top-10 open source data mining frameworks.

Figure below: A data mining workflow with data fusion and network analysis

Figures below: Knowledge inference through data fusion. Left: Data fusion schema consisting of fourteen considered data sets (edges in the schema) and biological entities (nodes) that the data sets relate on. Right: Lab results with responses of *Dictyostelium* mutants on the presence of bacteria, which confirm our predictions.



## 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 de-

voted 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 offers 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 and the Faculty of Mechanical Engineering).



In my opinion PhD students should endeavour to pursue cutting-edge research in a topic they are curious and passionate about. With that in mind, the study involved may be challenging and hard work, but is enjoyable and most of all rewarding. One can expect to gain substantial insight into a specific area of computer science and possibly contribute to its development.

– MARINKA ŽITNIK, PhD

**“DOCTORAL STUDY ENABLES ME TO WORK DURING THE DAY ON IDEAS THAT I DREAM ABOUT AT NIGHT.”**

– Assist. MATEVŽ PESEK

The doctoral programme has deepened my analytical and critical thinking. The ability to think analytically is vital when it comes to solving everything from small everyday problems to the most complex strategic business solutions. On the doctoral programme I was given the opportunity to work in very interesting areas of scientific research and, for me, this was also a real test of my perseverance. I also broadened my connections in Slovenia and abroad, meeting several interesting.

– ŠTEFAN FURLAN, PhD,  
Executive Director at  
Optilab d.o.o.







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