



REPUBLIC OF SLOVENIA  
MINISTRY OF EDUCATION,  
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Univerza v Ljubljani  
Fakulteta za računalništvo  
in informatiko

# Survey of Activities

in 2014

Faculty of  
Computer and  
Information  
Science  
University of  
Ljubljana

**Survey of  
Activities  
in 2014**

Ljubljana  
2015

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## Foreword

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 expanded our research competences to fit a wider spectrum of promising technical areas by attracting experienced researchers and teachers. In summer 2014 we moved to the new premises. In the new Faculty building, which was funded by EU, we have excellent working conditions that will allow us to prosper in our endeavours towards the realisation of our goals.

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. Part of the Master's Studies and the entire Doctoral Programme, are conducted in English and particular attention is given to attracting promising international doctoral students. In 2014, we also continued with our activities towards internationalisation of staff and hired two foreign teachers with internationally recognized research records and with a proven ability to direct research of highest quality. Furthermore, we are intensifying cooperation with related institutions in neighbouring and other countries. We implemented the double master's degree programme with Graz University of Technology and we are working towards the establishment of further double degree studies.

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.

**Nikolaj Zimic**  
Dean

Faculty of Computer and Information Science

# About FRI

## General Information

Dean **Prof Nikolaj Zimic, PhD**

Vice Dean for Education **Prof. Neža Mramor Kosta, PhD,**  
**Assoc. Prof. Zoran Bosnić, PhD** (since 1 October 2014)

Vice Dean for Research **Prof. Matjaž B. Jurič, PhD,**  
**Assist. Prof. Danijel Skočaj, PhD** (since 1 October 2014)

Vice Dean for Development **Assoc. Prof. Patricio Bulić, PhD**

Vice Dean for Economic Affairs **Prof. Marko Bajec, PhD**

Secretary General **Nives Macerl**

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(for all teaching and research staff)

## FRI

The Faculty of Computer and Information Science (FRI) was established in 1996 as an independent faculty of the University of Ljubljana. The undergraduate programme in computer science had commenced before, in 1973, when the faculty staff was engaged within the former Faculty of Electrical Engineering and Computer Science. The study programme first started as an elective programme after the second year of electrical engineering study. In 1982 an independent four-year programme in computer science began. In 2008 the first generation of students enrolled into the newly designed programmes for computer science at all degrees, which are internationally comparable and follow the Bologna guidelines.

At the FRI over 3681 students have completed undergraduate programmes in computer science and obtained an undergraduate university degree. At the graduate level, 401 master's degrees (MSc) and 158 doctoral degrees (PhD) in Computer and Information Science have been awarded. Currently, there are about 1273 undergraduate and graduate students at the Faculty. The Faculty has 161 employees, of which 131 are teaching and research staff.

## NEW PREMISES

In July 2014 the Faculty relocated to a new building in Ljubljana Brdo. This was the culmination of a several year-long project to build new facilities for the Faculty of Computer and Information Science and the Faculty of Chemistry and Chemical Technology. The new building offers 9,245 m<sup>2</sup> of modern premises and serves as a solid basis for the future growth and development of the faculty in all areas, including research, education and knowledge transfer. It is also the largest project in Slovenia to have been co-funded by the European Union and the largest investment in the history of the University of Ljubljana.

The new Faculty of Computer and Information Science has 9 lecture halls and 13 ICT lecture rooms with more than 170 PCs. There are 20 research laboratories, which are well equipped with a number of personal computers or workstations, and other specific hardware and software needed to conduct the research. The Faculty of Computer and Information Science and the Faculty of Chemistry and Chemical Technology share a large lecture hall as well as a library, which boasts an impressive collection of books and scientific journals and provides access to several on-line services and databases.

## How to get to Ljubljana

### BY AIR

The Ljubljana airport at Brnik is about 20 km north-west of the centre of Ljubljana (see Figure 2). It has fairly good connections with other European airports (Frankfurt, Munich, London, Zurich, Copenhagen, Paris, etc.) and is serviced by Adria, the national Slovenian air carrier, as well as number of other major European airlines.

### BY PASSENGER CAR

Ljubljana is connected to all neighbouring countries by a good highway system.

### BY AIR AND RAIL

*Via Austria:* By plane to Vienna, Graz or Klagenfurt airport and by car, shuttle (such as GoOpti.com) or train to Ljubljana (direct trains run twice daily on weekdays).

*Via Germany:* By plane to Munich or Frankfurt and by train, car, shuttle (such as GoOpti.com) or plane to Ljubljana (a direct train is available once every day; there are also two flights daily from Munich and Frankfurt to Ljubljana).

*Via Croatia:* By plane to Zagreb and by train, shuttle (such as GoOpti.com) or car to Ljubljana.

*Via Italy:* By plane to Venice or Trieste and by car or shuttle (such as GoOpti.com) to Ljubljana.

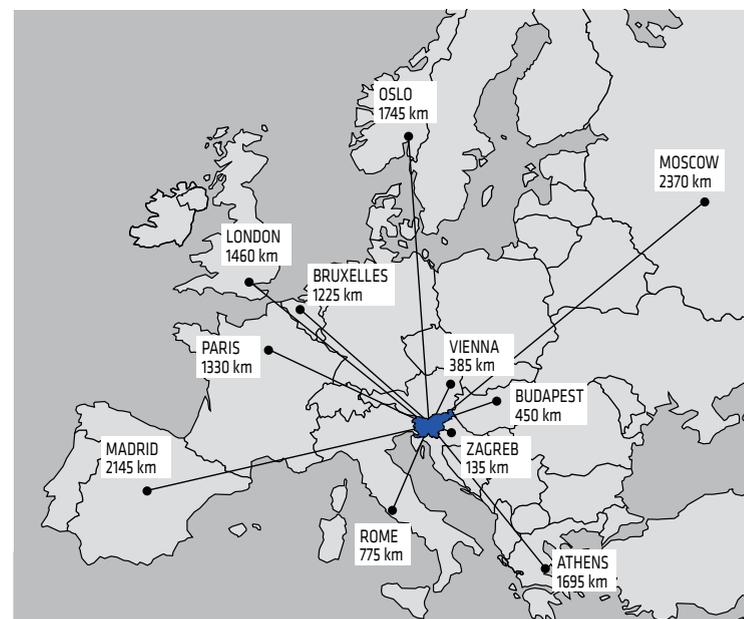
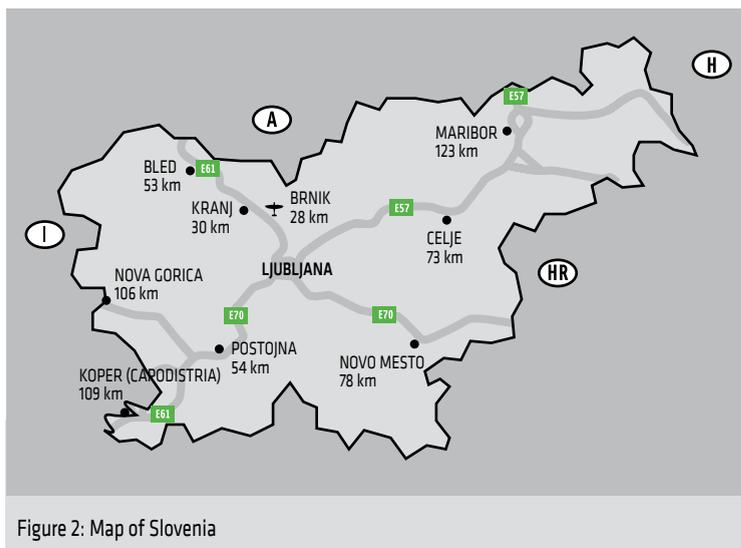


Figure 1: Slovenia in Europe

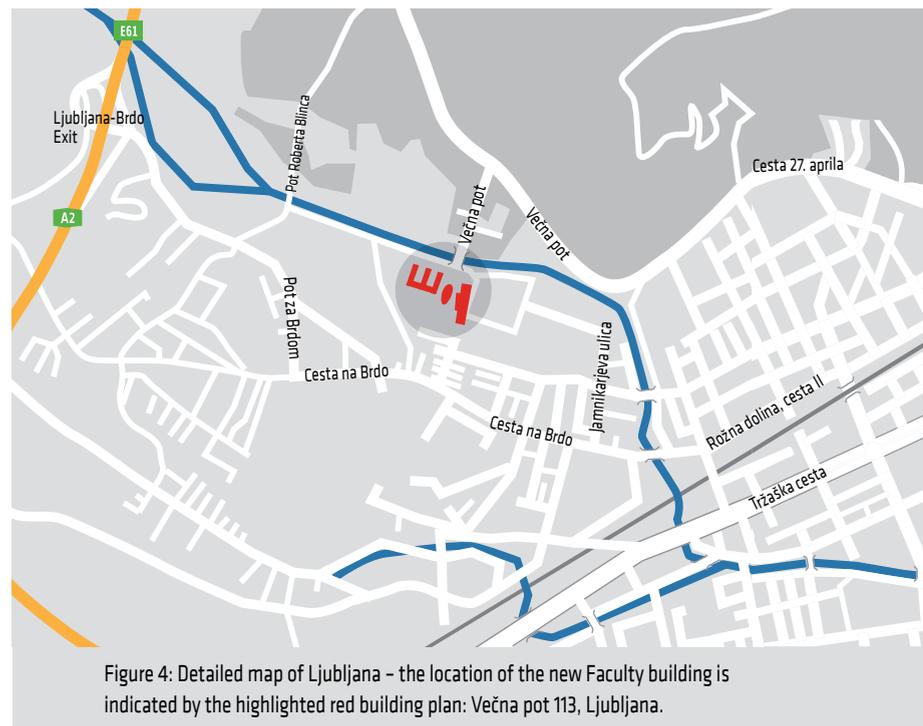
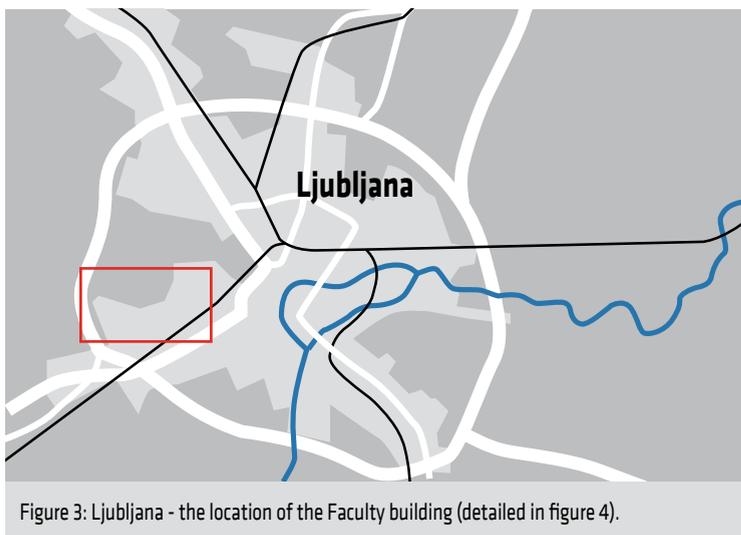


## BY RAIL

Ljubljana has good railway links with Austria (Vienna, Klagenfurt and Graz), Germany (Munich), Croatia (Zagreb, Rijeka) and Hungary (Budapest). These cities have good international connections with all large European cities. Traveling to Slovenia by rail from places further afield is of course less comfortable and not necessarily cheaper than air travel.

## LOCATION OF FRI IN LJUBLJANA

Until June 2014, the FRI had been located at Tržaška cesta 25. In July 2014 the FRI moved to a new building in Ljubljana Brdo at Večna pot 113. The FRI is located at the new site together with the Faculty of Chemistry and



Chemical Technology (UL FKKT). The faculty can be reached from the city centre by taking the bus lines 18 (direction "Center Stožice") or 14/14B (direction "Vrhovci" or "Bokalce"). The map in Figure 5 shows the location of the new building. Figures 5, 6, 7 and 8 show the new building.



Figure 5: Faculty of Computer and Information Science new building - rear view.



Figure 6: Faculty of Computer and Information Science new building - front view.



Figure 7: Faculty of Computer and Information Science - lecture room.

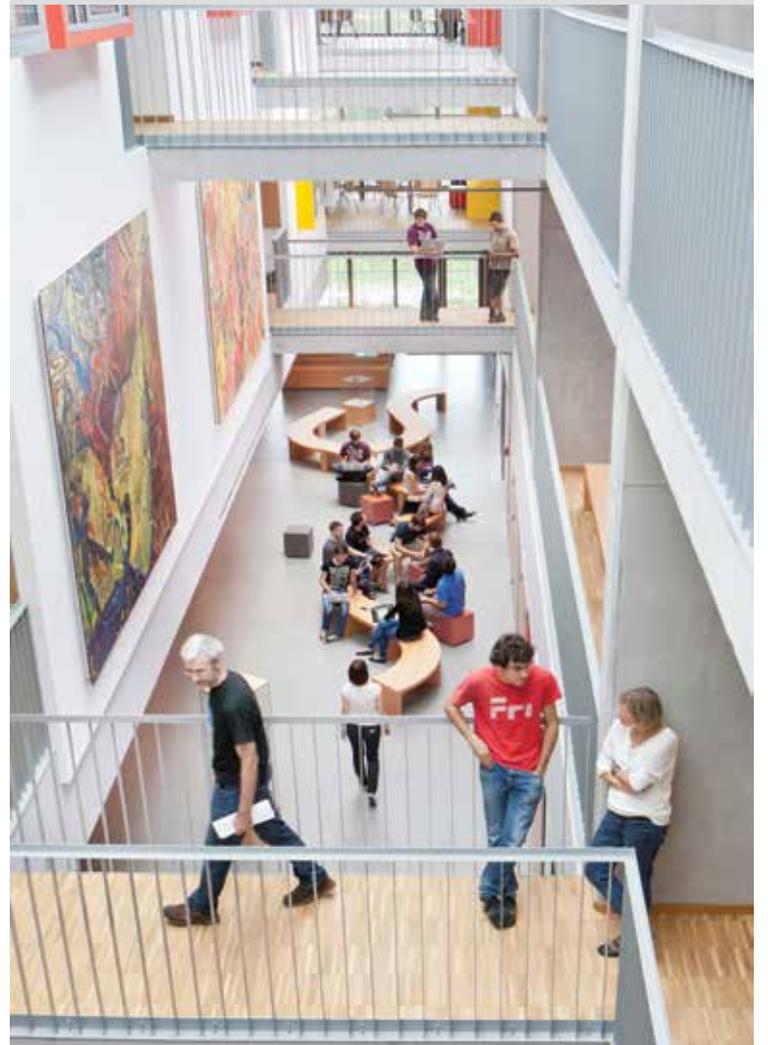


Figure 8: Faculty of Computer and Information Science new building - interior.

# Key Achievements

In 2014 the Faculty of Computer and Information Science was active in several fields, including the publishing of original scientific papers, research projects, awards and recognitions, and other achievements.

Although the total number of scientific papers published in SCI-Expanded indexed journals was less than for the previous year, a positive trend with a notable growth of the number of papers published in very high quality journals (from the first quarter) can be observed, as shown in the table below:

Period	Number of articles in A1 (first quarter)	Number of articles in A2 (second quarter)	Number of articles in A3 (third quarter)	Number of articles in A4 (fourth quarter)	Total
<b>5 Year Period</b>					
2007-2012	113	68	62	95	338
2008-2013	126	77	67	104	374
2009-2014	142	84	66	69	361
<b>1 Year Period</b>					
2012	23	16	10	18	67
2013	29	15	17	25	86
2014	34	16	14	14	78

Positive growth can be observed along with citations, in the particular citations in the Web of Science, as shown in the table below, which sets out the citations in the last eleven years:

Year	WoS Citations				Scopus Citations					Wos/Scopus Citations					
	TC	AC	CI	CI <sub>Au</sub>	NC	TC	AC	CI	CI <sub>Au</sub>	NC	TC	AC	CI	CI <sub>Au</sub>	NC
2004	181	6	155	72.79	201	337	49	288	141.36	377	347	50	297	145.19	391
2005	226	9	197	87.45	222	427	57	370	185.37	459	441	59	382	191.34	480
2006	301	33	268	115.68	274	508	47	461	227.83	567	522	49	473	234.26	590
2007	351	4	307	127.81	250	704	74	630	337.30	694	716	78	638	338.90	703
2008	406	5	351	181.41	324	820	101	719	419.30	831	836	102	734	427.95	851
2009	548	2	496	258.71	429	1115	83	1032	625.15	1131	1122	83	1039	627.51	1143
2010	718	4	634	306.53	518	1389	130	1259	738.40	1371	1398	131	1267	741.52	1379
2011	841	9	762	390.10	644	1600	147	1453	839.84	1510	1610	149	1461	843.85	1520
2012	1134	0	1034	508.68	836	1933	160	1773	992.72	1747	1963	166	1797	1005.94	1789
2013	1280	8	1212	643.95	983	2201	153	2048	1205.25	2051	2234	152	2082	1215.81	2073
2014	1338	10	1228	636.06	939	1843	152	1691	990.01	1622	1928	159	1769	1018.00	1666
<b>Total</b>	<b>7324</b>	<b>80</b>	<b>6644</b>	<b>3329.18</b>	<b>5620</b>	<b>12877</b>	<b>1153</b>	<b>11724</b>	<b>6702.52</b>	<b>12352</b>	<b>13117</b>	<b>1178</b>	<b>11939</b>	<b>6790.28</b>	<b>12573</b>

TC - Total Citations; AC - Auto Citations; CI - Pure Citations; CI<sub>Au</sub> - Pure Citations per Author; NC - Normalized Citations

### **In 2014, the Faculty of Computer and Information Science was active in the following projects:**

- 4 EU funded FP7 projects
- 7 other projects funded by structural funds
- 1 European Science Foundation (ESF) funded project
- 6 other international projects
- 6 national research programmes funded by the Slovenian Research Agency
- 14 national research projects funded by the Slovenian Research Agency
- 6 bilateral projects in cooperation with the Republic of Croatia, Bosnia and Herzegovina, Montenegro and the USA
- 41 industry funded applied research projects

### **Professors and researches of the Faculty of Computer and Information Science won several awards and recognitions:**

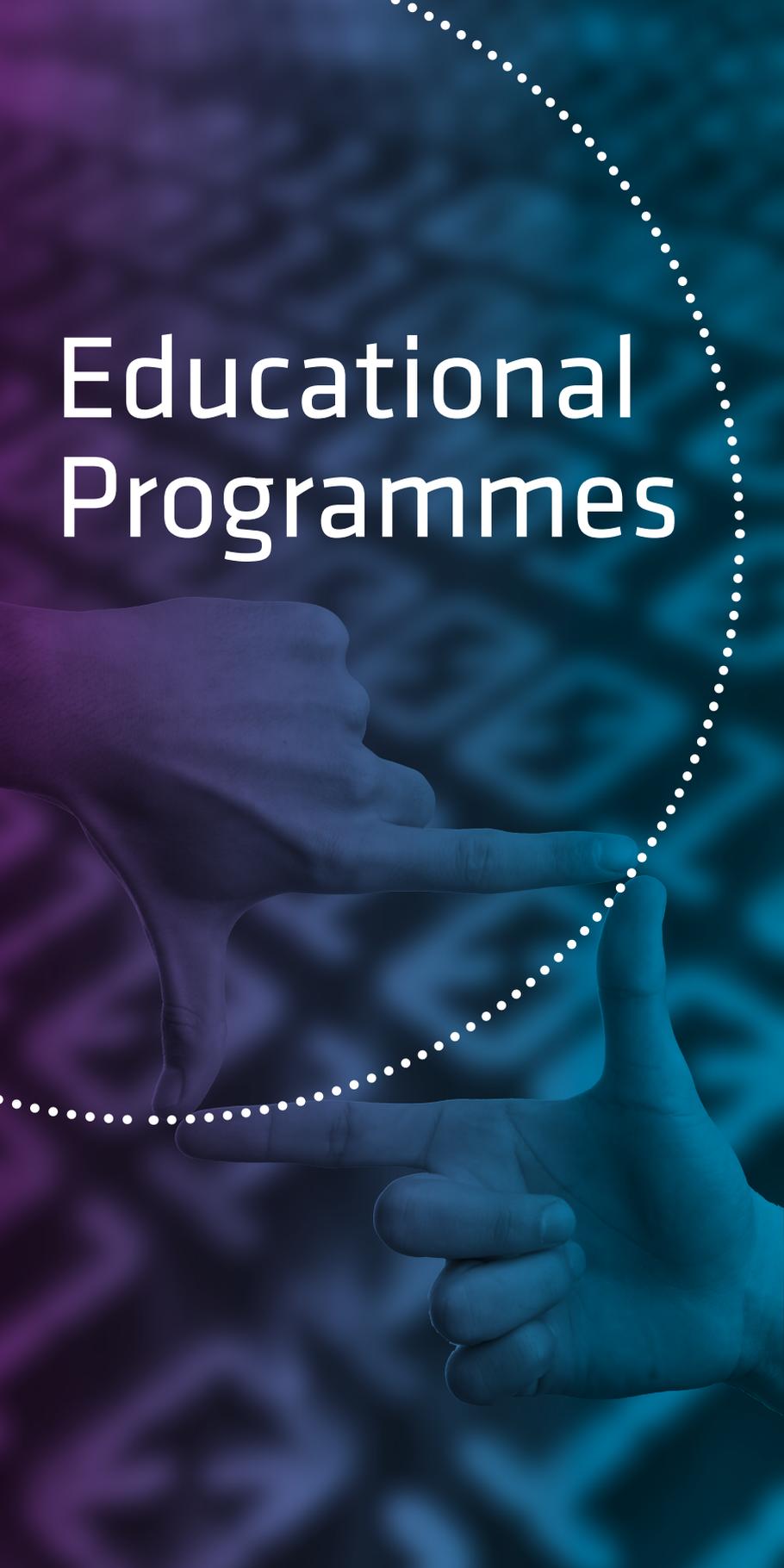
- Assoc. Prof. Janez Demšar, PhD received the Republic of Slovenia Award for his outstanding achievements in education. He also received the award for current achievements at the Information Society 2014 multi-conference.
- Assist. Prof. Jure Leskovec, PhD received the Zois Award for the Ambassador of Science of the Republic of Slovenia.
- At the University of Ljubljana week's formal sitting of the University Senate, Prof. Marko Bajec, PhD, received the gold medal for outstanding achievements in scientific developments and enhancing the university's reputation. He was also the recipient of the Mentor of the Year Award 2014.
- Prof. Saša Divjak, PhD received the honorary title of Professor Emeritus 2014 for his important contributions to the university's development and increasing reputation.

### **The most notable awards and recognitions won by our exceptional students and their supervisors are the following:**

- The University Prešeren Award was received by Žiga Lesar for his undergraduate thesis paper titled 'Visualisation of medical volumetric data in real time' (mentor: Assist. Prof. Matija Marolt, PhD).
- Maja Žbogar received the honourable certificate of the University of Ljubljana for her outstanding academic success.
- The Faculty Prešeren Award was received by Blaž Sovdat for his thesis paper 'Algorithms for incremental learning of decision trees on variable data flows (mentor: Assoc. Prof. Zoran Bosnić, PhD), Marko Lalović for 'Partial drawings of full graphs' (mentor: Assoc. Prof. Gašper Fijavž, PhD) and Blaž Repas for his thesis paper 'Checking the correctness of programmes with subsidiary types in Idris' (mentor: Assist. Prof. Jurij Mihelič, PhD).

- Students Anton Zvonko Gazvoda, Aleks Huč and Benjamin Kastelic won first place with their project titled 'Software tool for the Kanban project management method' in the framework of the Slovenian Days of Information Science.
- Student Urška Pangerc and prof. Franc Jager, PhD competed at the Robust Detection of Heart Beats in Multimodal Data: the PhysioNet/Computing in Cardiology Challenge 2014 at the Computing in Cardiology 2014 international Conference. They won second, third and sixth place in the three separate challenge phases.

# Educational Programmes



The academic year at the University of Ljubljana consists of the autumn and spring semesters. Courses in the autumn semester begin on 1 October and last for 15 full weeks. According to the University of Ljubljana's current academic calendar, the spring semester courses start each year in the second half of February and end in the beginning of June. There are three examination periods: winter (from the end of the autumn semester until the beginning of the spring semester), spring (a full month after the end of the spring semester) and autumn (from mid-August until mid-September). At the Faculty of Computer and Information Science the courses consist of lectures, problem sessions (tutorials), laboratory work and independent work assigned to the students. All courses last one semester and the student course load per semester, according to the European Credit Transfer System (ECTS), is 30 ECTS. In most study programmes, the work load is uniformly distributed among the courses, the majority of which have 6 ECTS at all levels.

The Faculty of Computer and Information Science participates in several international educational programmes, such as the European Union SOCRATES/ERASMUS programme and the CEEPUS programme, which encourages student and teacher mobility between European universities, the Erasmus Mundus BASILEUS programme for exchange between European and western Balkan universities, the Erasmus Mundus LOTUS programme for exchange with SE Asia, the Erasmus Mundus EMINTE programme for exchange with India and, as part of the Utrecht group of universities, in the EUROSA programme for exchange between European and South African universities. The study programmes of the Faculty of Computer and Information Science are registered with the Slovenian Quality Assurance Agency for Higher Education and the European Federation of National Engineering Associations (FEANI), and they meet the criteria for the title EUR ING.

## UNDERGRADUATE PROGRAMMES

The Faculty of Computer and Information Science offers the following first cycle programmes:

- University study programme **Computer and Information Science**,
- Professional study programme **Computer and Information Science**,
- Interdisciplinary university study programme **Computer Science and Mathematics**, offered jointly with the Faculty of Mathematics and Physics of the University of Ljubljana
- Interdisciplinary university study programme **Administrative Information Systems**, offered jointly with the Faculty of Administration of the University of Ljubljana
- Interdisciplinary university study programme **Multimedia**, offered jointly with the Faculty of Electrical Engineering of the University of Ljubljana

All first cycle programmes last three years. They comprise six semesters of course work and have a total work load of 180 ECTS.

## MASTER PROGRAMMES

At the second cycle level, the following programmes are offered:

- Master's study programme **Computer and Information Science**
  - **Double Degree Study Programme in Computer and Information Science**  
The students of the master programme Computer and Information Science may, in the second year enrol in the double degree study programme conducted jointly with the Graz University of Technology (Technische Universität Graz). The master programme at Graz University enables students to deepen their knowledge in algorithms, software technology, intelligent systems, information security, image processing, computer graphics visualisation, media and computer science in multimedia systems. The programme is delivered in the English language.
- Interdisciplinary master's study programme **Computer Science and Mathematics**, offered jointly with the Faculty of Mathematics and Physics of the University of Ljubljana
- Interdisciplinary master's study programme **Computer Science Education**, offered jointly with the Faculty of Education of the University of Ljubljana
- Interdisciplinary master's study programme **Cognitive Sciences**, offered jointly with the Faculty of Education, Faculty of Medicine and the Faculty of Arts of the University of Ljubljana, and several other European universities (University of Vienna, Technical University of Budapest, University of Zagreb and Comenius University in Bratislava)

The second cycle master study programmes last two years. They comprise four semesters of course work with a total work load of 120 ECTS.

## DOCTORAL PROGRAMMES

At the third cycle level, the following programmes are offered:

- Doctoral study programme **Computer and Information Science**
- Interdisciplinary doctoral study programme **Biosciences**, offered jointly with the Biotechnical Faculty, Faculty of Electrical Engineering and Faculty of Engineering of the University of Ljubljana

The third cycle doctoral study programmes last three years. They comprise six semesters of course work with a total workload of 180 ECTS.

## Undergraduate Programmes

## University Study Programme Computer and Information Science

The programme leads to the degree “diplomirani inženir računalništva in informatike (UN)”, abbr. “dipl. inž. rač. in inf. (UN)”.

The first two years contain the core-curriculum courses including mathematics and the theoretical foundations of computer science, one professional elective course and one general elective course in the spring semester of the second year. In the third year, elective modules consisting of three courses each are offered. The student is required to choose two modules. In addition, there is one compulsory course in each semester and one general elective course in the spring semester. The general electives are chosen from appropriate courses offered at the faculty or within other study programmes at the University of Ljubljana. The study programme concludes with a diploma thesis with a work load of 6 ECTS in the last semester.

### FIRST YEAR COURSES:

Semester	Title	ECTS
Autumn	Programming 1	6
	Calculus	6
	Discrete Structures	6
	Introduction to Digital Circuits	6
	Physics	6
Spring	Programming 2	6
	Linear Algebra	6
	Fundamentals of Databases	6
	Computer Communications	6
	Human-Computer Interaction	6

## SECOND YEAR COURSES:

Semester	Title	ECTS
Autumn	Algorithms and Data Structures 1	6
	Computer Systems Architecture	6
	Probability and Statistics	6
	Operating Systems	6
	Introduction to Information Systems	6
Spring	Algorithms and Data Structures 2	6
	Theory of Information and Systems	6
	Computer Systems Organisation	6
	General elective	6
	Professional elective	6

## SECOND YEAR PROFESSIONAL ELECTIVE COURSES:

Title	ECTS
Mathematical Modelling	6
Principles of Programming Languages	6
Computer Technologies	6

## THIRD YEAR COURSES:

Semester	Title	ECTS
Autumn	Introduction to Artificial Intelligence	6
	Module 1, Course 1	6
	Module 1, Course 2	6
	Module 2, Course 1	6
	Module 2, Course 2	6
Spring	Economics and Entrepreneurship	6
	Module 1, Course 3	6
	Module 2, Course 3	6
	General elective	6
	Diploma thesis	6

## ELECTIVE MODULES:

### Information Systems

- Course 1: Electronic Business
- Course 2: Organisation and Management
- Course 3: Business Intelligence

### Management of Information Systems

- Course 1: Information Systems Development
- Course 2: Data Management Technologies
- Course 3: Informatics Planning and Management

### Software Engineering

- Course 1: Software Development Processes
- Course 2: Web Programming
- Course 3: Software Engineering

### Computer Networks

- Course 1: Computer Network Modelling
- Course 2: Communication Protocols
- Course 3: Mobile and Wireless Networks

### Computer Systems

- Course 1: Digital Design
- Course 2: Systems Reliability and Performance
- Course 3: Distributed Systems

### Algorithms and System Utilities

- Course 1: Computational Complexity and Heuristic Programming
- Course 2: System Software
- Course 3: Compilers

### Artificial Intelligence

- Course 1: Intelligent Systems
- Course 2: Machine Perception
- Course 3: Development of Intelligent Systems

### Multimedia

- Course 1: Computer Graphics and Game Technology
- Course 2: Multimedia Systems
- Course 3: Introduction to Design

## Undergraduate Programmes

# Professional Study Programme Computer and Information Science

This application oriented study programme leads to the degree “diplomirani inženir računalništva in informatike (VS)”, abbr. “dipl. inž. rač. in inf. (VS)”.

The first year consists of core-curriculum courses. In the remaining two years, the students choose from a structured list of professional elective courses according to their individual interests and preferences, respecting the required criteria for each course. In addition to the elective courses with a workload of 6 ECTS each, the students can choose two out of a block of “technical” courses with a workload of 3 ECTS each and with topics changing from year to year and ranging from specific programming languages to platforms or tools of current interest. The last semester consists of 6 ECTS of general electives, 18 ECTS of practical work within the industry and 6 ECTS for the diploma thesis. The total workload of 180 ECTS is divided into 66 ECTS of mandatory courses, 78 ECTS of professional electives, 12 ECTS of general electives, 18 ECTS for practical work and 6 ECTS for the diploma thesis.

The general electives are chosen from appropriate courses offered at the faculty or within other study programmes at the University of Ljubljana.

### FIRST YEAR COURSES:

Semester	Title	ECTS
<b>Autumn</b>	Introduction to Computer Science	6
	Programming I	6
	Computer Architecture	6
	Mathematics	6
	Discrete Structures	6
<b>Spring</b>	Programming II	6
	Databases	6
	Computer Communications	6
	Operating Systems	6
	Introduction to Probability and Statistics	6

### SECOND YEAR COURSES:

Semester	Title	ECTS
<b>Autumn</b>	Professional elective course	30
<b>Spring</b>	Professional elective course	24
	General elective or professional elective course	6

### SECOND YEAR ELECTIVE COURSES:

Semester	Title	Prerequisites	ECTS
<b>Autumn</b>	Algorithms and Data Structures I		6
	Electronic and Mobile Business		6
	Databases II		6
	Information Systems		6
	Graphic Design		6
	Communications Protocols and Network Security		6
	Computer Organization		6
	Digital Circuits		6
	Computer Graphics		6
	Artificial Intelligence		6
<b>Spring</b>	User Interfaces		6
	Compilers and Virtual Machines	Algorithms and Data Structures I	6
	Algorithms and Data Structures II	Algorithms and Data Structures I	6
	Testing and Quality	Algorithms and Data Structures I	6
	Information Systems Development	Information Systems	6
	Multimedia Content Production	Graphic Design	6
	Digital Signal Processing		6
	Web Technologies	Algorithms and Data Structures I, Communications Protocols and Network Security	6
	Input-Output Systems	Algorithms and Data Structures I	6
	Digital Logic Design	Computer Organization, Digital Circuits and Algorithms and Data Structures I	6
<b>Technical courses</b>	Implementation of algorithms		3
	Computer tools, languages and platforms		3

### THIRD YEAR MANDATORY COURSES:

Semester	Title	ECTS
<b>Autumn</b>	Project Practicum	6
	Professional elective course	18
<b>Spring</b>	Industrial Practice	18
	General elective or professional elective course	6
	Diploma Thesis	6

### THIRD YEAR PROFESSIONAL ELECTIVE COURSES:

Semester	Title	Prerequisites	ECTS
Autumn	Software Engineering	Algorithms and Data Structures I, Algorithms and Data Structures II	6
	Information Systems Strategic Planning	Algorithms and Data Structures II Information Systems Development	6
	Multimedia Technologies	Digital Signal Processing, Algorithms and Data Structures I, Algorithms and Data Structures II, Multimedia Content Production	6
	Parallel and Distributed Systems and Algorithms	Algorithms and Data Structures I, Algorithms and Data Structures II	6
	System Software	Algorithms and Data Structures I, Algorithms and Data Structures II	6
	Process Automation	Input-Output Systems	6
	Embedded Systems	Input-Output Systems, Algorithms and Data Structures II	6
	Robotics and Machine Perception	Computer Graphics, Artificial Intelligence, Algorithms and Data Structures II	6
	Game Technology and Virtual Reality	Algorithms and Data Structures I, Algorithms and Data Structures II, Computer Graphics, Artificial Intelligence	6
	Decision Systems	Data Mining, Algorithms and Data Structures II	6
	Numerical Methods		6

### Undergraduate Programmes

## Interdisciplinary University Study Programme Computer Science and Mathematics

This programme is offered jointly with the Faculty of Mathematics and Physics and is oriented towards theoretical computer science and topics in modern discrete and computational mathematics which are closely connected thereto. The programme leads to the degree “diplomirani inženir računalništva in matematike (UN)”, abbr. “dipl. inž. rač. in mat. (UN)”.

The first two years contain mandatory core-curriculum courses. The third year contains three mandatory courses, one elective module from the university study programme, Computer and Information Science, a professional elective with a work load of 5 ECTS chosen from among the courses offered at the Faculty of Mathematics and Physics, and general electives with a total load of 10 ECTS. The study programme concludes with a diploma thesis with a work load of 4 ECTS in the last semester.

### FIRST YEAR COURSES:

Title	ECTS
Programming 1	6
Analysis 1	7
Discrete Structures 1	6
Introduction to Digital Circuits	6
Linear algebra	10
Programming 2	6
Fundamentals of Databases	6
Analysis 2	7
Discrete Structures 2	6

## SECOND YEAR COURSES:

Title	ECTS
Algorithms and Data Structures 1	6
Computer Systems Architecture	6
Analysis 3	5
Operating Systems	6
Combinatorics	7
Optimisation Methods	7
Algorithms and Data Structures 2	6
Principles of Programming Languages	6
Computer Communications	6
Topics in Mathematics	5

## THIRD YEAR COURSES:

Title	ECTS
Numerical methods	7
Introduction to Artificial Intelligence	6
Probability and Statistics	10
Elective module, Course 1	6
Elective module, Course 2	6
Elective module, Course 3	6
Professional elective	5
General electives	10
Undergraduate thesis	4

The professional elective course is chosen from the following list of courses offered at the Faculty of Mathematics and Physics:

Title	ECTS
General Topology	5
Algebraic Curves	5
Introduction to Geometric Topology	5
Affine and Projective Geometry	5
Coding Theory and Cryptography	5
Financial Mathematics 1	5
Game Theory	5
Mathematical Modelling	5
Numerical Methods II	5

## Interdisciplinary University Study Programme Administrative Information Systems

### Undergraduate Programmes

The study programme is offered jointly with the Faculty of Administration and leads to the title "diplomirani inženir upravne informatike (UN)", abbr. "dipl. inž. upr. inf. (UN)".

The joint study programme is designed to provide students with knowledge of computer, internet and new information technologies as well as the administration-legislation, economics and management knowledge required for understanding public and business administration.

The first year consists of general courses in both fields with 6 ECTS of elective courses, while the second and third year courses provide the students with a combined understanding of both study fields. The programme concludes with a diploma thesis with a work load of 16 ECTS in the last semester.

## FIRST YEAR COURSES:

Title	ECTS
Introduction to Programming	6
Theory of Public Administration	8
Basic Economics	7
Theory of Organisation	7
Fundamentals of Probability and Statistics	6
Informatics	8
Programming and Algorithms	6
Database Basics	6
General electives	6

## SECOND YEAR COURSES:

Title	ECTS
Methods and Techniques for Decision-Making Process Support in Public Administration	4
Computer Communication	6
Introduction to Artificial Intelligence	6
Legislative Regulation of Public Administration	6
Human Resource Management in Public Administration	7
Business Process Informatisation in Public Administration	7
Data management technologies	6
Web Programming	6
Elective courses	12

## THIRD YEAR COURSES:

Title	ECTS
Communication and Project Management	6
Planning and Governance	6
Information Systems Development	6
Administrative Procedure and Judicial Review of Administrative Acts	8
Information Systems in Public Administration	6
Management in the Public Sector	6
E-business	6
Diploma Thesis	16

Students will obtain ECTS` by choosing courses that are from compatible accredited study programmes on other faculties or by choosing courses from partner institutions from this study programme.

## Interdisciplinary University Study Programme Multimedia

### Undergraduate Programmes

The study programme is offered jointly with the Faculty of Electrical Engineering and leads to the title "diplomirani inženir multimedije (UN)", abbr. "dipl. inž. mm. (UN)".

The joint study programme combines knowledge of electrical engineering, computer science, design and business. The study programme teaches skills in multimedia while familiarising students with the latest technology and equipment that form the basis of new industry.

The first year consists of general courses in both fields, while the second and third year courses provide the students with a combined understanding of both study fields. The programme concludes with a diploma thesis with a work load of 6 ECTS in the last semester.

## FIRST YEAR COURSES:

Semester	Title	ECTS
<b>Autumn</b>	Introduction to Multimedia Systems	6
	Programming 1	6
	Career Communication	5
	Communication Systems	7
	Calculus	6
<b>Spring</b>	Linear Algebra	6
	Multimedia Technology Base	7
	Programming 2	6
	Human-Computer Interaction	6
	Information Systems	5

## SECOND YEAR COURSES:

Semester	Title	ECTS
Autumn	Internet Systems	6
	Acoustics in Communication	6
	Digital Broadcasting Systems	6
	Computer Graphics and Game Technology	6
	Information and Communication Technology and Society	6
	Introduction to Graphic Design	6
Spring	Project Management, Innovation and Teamwork	5
	Digital Signal Processing	7
	Mobile and Telematic Systems	6
	General Elective Course	6
	Information Systems	5

## THIRD YEAR COURSES:

Semester	Title	ECTS
Autumn	Studio and Multimedia Production Technology	6
	Multimedia Content	6
	Web Programming	6
	Communications Security and Content Protection	6
	General Elective Course	6
Spring	Business Intelligence	6
	Editing and Postproduction of Content	6
	Terminals and User Interfaces	6
	General Elective Course	6
	Diploma Thesis	6

The general elective course is chosen from the following list of courses offered at the Faculty of Computer and Information Science and Faculty of Electrical Engineering:

Semester	Title	ECTS
Autumn	Electronic Business	6
	Organization and Management	6
	Electronic Components and Sensors	6
Spring	Computer Systems Reliability and Performance	6
	Computer Simulation	6
	Speech and Image Technologies	6
	Telecommunication Protocols	6

## Master Programmes

## Master Study Programme Computer and Information Science

The programme leads to the degree “magister inženir računalništva in informatike”, abbr. “mag. inž. rač. in inf.”.

The first year consists of 4 mandatory courses including mathematics and core-curriculum topics in computer and information science, 4 professional elective courses and 12 ECTS of general elective courses. In the second year, students choose 6 additional professional elective courses, while a work load of 24 ECTS is devoted to the preparation of the master's thesis. All mandatory and professional elective courses have a workload 6 ECTS. The general elective courses can be chosen from suitable courses offered by the Faculty or within other second cycle programmes at the University of Ljubljana.

## FIRST YEAR COURSES

Title	ECTS
Mathematics II	6
Programming	6
Professional elective	24
General elective	12
Algorithms	6
Computer Systems	6

## SECOND YEAR COURSES

Title	ECTS
Professional elective	36
Master's Thesis	24

## PROFESSIONAL ELECTIVE COURSES:

Title	ECTS
Artificial Intelligence	6
Wireless Sensors Networks	6
Unconventional Computing	6
Perception in Cognitive Systems	6
Biomedical Signal and Image Processing	6
Modern Software Development Methods	6
Digital Signal Processing	6
Computability and Computational Complexity	6
E Learning	6
Machine Learning	6
Introduction to Bioinformatics	6
Information Security and Privacy	6
Numerical Mathematics	6
Computer Based Sound Production	6
Soft Computing and Natural Algorithms	6
Data Mining	6
IT Governance	6
Interaction and Information Design	6
Cryptography and Computer Security	6
Exploiting Processors' Performance	6
Digital Forensics	6
Contemporary Approaches and Architectures in Information Systems Development	6
Discrete Mathematics	6
Operations Management	6
Cloud Computing	6
Computational Topology	6
Teaching Algorithmic Thinking	6
Computer-based Process Control	6
Topical research themes I	6
Topical research themes II	6

## Master Programmes

### Interdisciplinary Master Study Programme Computer Science and Mathematics

The study programme is offered jointly with the Faculty of Mathematics and Physics and leads to the degree “magister inženir računalništva in matematike”, abbr. “mag. inž. rač. mat.”

The first year consists of 2 mandatory and 2 elective courses in computer science, 5 elective courses in mathematics, and a total of 11 ECTS for the general elective course. The second year consists of only elective courses: 4 in mathematics, 3 in computer science and 1 in either mathematics or computer science. In addition, a work load of 17 ECTS is given to the preparation of the master's thesis, which is distributed throughout the spring semester of the second year. Among the mathematics elective courses, the students are required to choose 4 out of group A and 5 out of group B in the list of courses.

#### FIRST YEAR COURSES

Title	ECTS
Professional elective courses in Mathematics or in Computer Science	42
General elective	6
Algorithms	6
Programming	6

#### SECOND YEAR COURSES

Title	ECTS
Professional elective courses in Mathematics or in Computer science	36
Seminar	3
General elective	6
Master's Thesis	15

## PROFESSIONAL ELECTIVE COURSES IN MATHEMATICS (GROUP A):

Title	ECTS
Logic in Computer Science	5
Computer aided Geometric Design	5
Computational Geometry	6
Coding theory and cryptography	6
Probability Methods in Computer Science	6

## PROFESSIONAL ELECTIVE COURSES IN MATHEMATICS (GROUP B):

Title	ECTS
Data Analysis and Visualization	6
Topics in Computer Mathematics	6
Topics in Numerical Mathematics	6
Topics in Game Theory	6
Mathematics with Computers	6
Symbolic Computation	6
Graph Theory	6
Selected Topics in Discrete Mathematics	6
Combinatorics 2	6
Optimization Methods 2	6
Cryptography and Computer Security	6
Computational Topology	6
Coding Theory and Cryptography 2	6

## PROFESSIONAL ELECTIVE COURSES IN COMPUTER SCIENCE:

Title	ECTS
Artificial Intelligence	6
Digital Signal Processing	6
Computability and Computational Complexity	6
Introduction to Bioinformatics	6
Modern Software development Methods	6
Machine Learning	6
Perception in Cognitive Systems	6
Soft Computing and Natural Algorithms	6
Theory of Programming Languages	6
Information an Interaction Design	6
Contemporary Approaches and Architectures in IS Development	6
Data Mining	6
Information Security and Privacy	6

Topical research themes I	6
Topical research themes II	6
Topics in Computer and Information Science	6
Unconventional Computing	6
Biomedical Signal and Image Processing	5
Teaching Algorithmic Thinking	6
Digital Forensic	6
Computer Based Sound Production	6
Cloud Computing	6
Computer Systems	6

## Master Programmes

# Interdisciplinary Master Study Programme Computer Science Education

The study programme is offered jointly with the Faculty of Education and leads to the degree “magister profesor računalništva in informatike”, abbr. “mag. prof. rač. inf.”.

Modern trends in the teaching of computer science reject teaching of technology and the use of office applications and emphasize the understanding of computer concepts and the training of algorithmic thinking. This type of approach requires a suitable teacher profile. The goal of this study programme is to educate the teachers of tomorrow in a way that will enable them to well understand the computer perspective and at the same time have the required knowledge and skills from the fields of pedagogy, didactics and most importantly computer didactics.

In the first year students gain knowledge in the field of didactics. The second year is more oriented towards computer science and includes some advanced general courses and as well as elective courses from different fields of computer science.

### FIRST YEAR COURSES:

Title	ECTS
Didactics of Computer Science and the Teaching	7
Scientific Research Methodology	3
Theory of Education	6
Didactics and Teaching Practice	8
General elective course	6
Practical Pedagogical Training	7
Inclusive Education Work	3
Philosophical and Sociological Aspects of Education	6
Psychology for Teachers and Pedagogical Practice	8
Elective course	6

### SECOND YEAR COURSES:

Title	ECTS
Mathematics II	6
Programming	6
Algorithms	6
Teaching Algorithmic Thinking	6
E-Teaching and E-Learning	6
Computer Systems	6
Elective course	6
Master's Thesis	18

### ELECTIVE COURSES:

Title	ECTS
Perception in Cognitive Systems	6
Introduction to Bioinformatics	6
Computability and Computational Complexity	6
Information Security and Privacy	6
Text and Web Mining in Education	6
Data Mining	6
Interaction and Information Design	6
Artificial Intelligence	6
Modern Software Development Methods	6
IT Governance	6
Numerical Mathematics	6
Computer Based Sound Production	6
Learning with Multimedia	6
Computer Supported Collaborative Work and Learning	6
Intelligent Systems in Education	6
Computer Games and Simulations for Education and Exploration	6

## Master Programmes

# Interdisciplinary Master Study Programme Cognitive Science

The study programme is offered jointly by the Faculty of Computer and Information Science, Faculty of Arts, Faculty of Medicine, Faculty of Education and several central European universities (University of Vienna, Technical University in Budapest, University of Zagreb and Comenius University in Bratislava) and leads to the degree “magister kognitivne znanosti”, abbr. “mag. kog. zn.”.

The programme is organised as a two-year 120 ECTS study programme, 60 ECTS each year. Lectures in first, second and fourth semester are held in Slovene language, while lectures in the third semester are held in English. Based on their research topic chosen individually, students select one of the universities participating in the network in line with the areas of expertise of the respective partner universities. Mobility is planned for the third semester with the possibility of extending it to the fourth semester.

### FIRST YEAR COURSES:

Title	ECTS
Introduction to Cognitive Science 1	5
Introduction into Research 1	5
Basic Elective Course	15
Tools	5
Introduction to Cognitive Science 2	10
Introduction into Research 2	10
Basic or Advanced Elective Course	5
Tools	5

### GENERAL AND ADVANCED ELECTIVE COURSES FOR FIRST YEAR:

Title	ECTS
Introduction to Artificial Intelligence	5
Introduction to Linguistics	5
Introduction to Neuroscience	5
Introduction to Philosophy	5
Cognitive Psychology	5
Advanced Artificial Intelligence	5
Advanced Linguistics	5
Advanced Neuroscience	5
Advanced Philosophy	5
Advanced Cognitive Psychology	5

### FIRST YEAR TOOLS:

Title	ECTS
Basic Maths and Programming	5
Statistics	5
First person research	5
Statistical analysis in Cognitive Science (advanced tools)	5

### SECOND YEAR COURSES:

Title	ECTS
New trends in Cognitive Science	10
Interdisciplinary approach to a cognitive phenomenon 1 or “Vzajemno učenje in raziskovanje”	10
Interdisciplinary approach to a cognitive phenomenon 2	10
Master's Thesis Seminar	5
Master's Thesis	25

## Doctoral Programmes

# Doctoral Study Programme in Computer and Information Science

The doctoral programme Computer and Information Science is designed to deepen the candidate's knowledge of computer science and information technology, while also providing training in soft skills for research and development. We recommend it for students who intend to pursue a career in academia and for students who intend to carry out demanding and innovative development in the computing industry. Beginning with the year 2014/15 some changes to the programmes are being put in place that are adapted to students' needs, with the aim of delivering even more efficient studies.

The entire courseware, lectures and exams are in English. The span of the doctoral programme is three years and the total workload is 180 ECTS.

The doctoral study of Computer and Information Science consists of organised forms of study, research, and the doctoral dissertation:

- Organised forms of study, a total of 60 ECTS:
  - two mandatory courses with 5 ECTS each
  - two elective courses from computer and information science with 5 ECTS each
  - elective courses from computer and information science or other courses offered at the University of Ljubljana or other universities amounting to 10 ECTS
  - five seminars with a total of 30 ECTS
- Other forms of study, a total of 120 ECTS:
  - Research with a total of 75 ECTS
  - Doctoral dissertation with 45 ECTS

The schema of the programme is presented in Table 1.

**Table 1: Schema of the study programme**

Year 1	Computer science course (elective)	Research 1				Scientific skills 1	Seminar 1
	General elective course					Seminar 2	
Year 2	Computer science course (elective)	Research 2				Seminar 3	
	General elective course					Seminar 4	
Year 3	Doctoral dissertation					Scientific skills 2	
						Seminar 5	
	5 ECTS	5 ECTS	5 ECTS	5 ECTS	5 ECTS	5 ECTS	

### First year

The first study year is composed of two elective courses, the course Scientific skills 1, and Seminars 1 and 2. The candidate sets up the research directions with the guidance of the mentor and starts conducting the research.

### Second year

In the second year, the candidate takes part in in two elective courses, and in Seminars 3 and 4, but primarily focuses on research which is guided by the candidate's mentor and on which the candidate closely collaborates with the chosen laboratory. To advance to the third year the candidate must have an approved thesis topic which includes giving a written description and a defence.

### Third year

The third year is reserved for research and preparation of the doctoral thesis, which the candidate presents within Seminar 5. In addition, the candidate writes a project proposal within the course Scientific skills 2.

### MANDATORY COURSES

The two mandatory courses are Scientific Skills 1 and Scientific Skills 2, with topics included such as paper writing, preparing a good oral and poster presentation, copyright and patent laws, ethics in science, writing project proposals and the like.

### ELECTIVE COURSES

The candidate chooses two from the twelve available elective courses in the following topics:

- Selected Topics in Software Development 1 and 2



# Research

Research activities (as well as most undergraduate, master's, and doctoral theses research) at the Faculty of Computer and Information Science are performed in 20 research laboratories. The main sources of research funding are the Slovenian Research Agency, the Ministry of Education, Science and Sport, the Ministry of Defence, European Union programmes (COST, 7th Framework Programme, Horizon 2020 Programme), EU structural funds, industry partners, and various bilateral programmes including those in the USA, France, Austria, Norway, Portugal, Greece, the UK, Czech Republic, Poland, Bosnia and Herzegovina, Serbia, Croatia and Montenegro. The Ministry of Education, Science and Sport, together with the Slovenian Research Agency also supports some of postgraduate students by means of individual scholarships.

Many application projects are financed by Slovenian and European companies. In 2014, the faculty had project collaborations in place with the following companies: 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.

Besides being at the cutting edge of basic computer science, software engineering, information systems and information technology, our researchers are active in a number of fields of potential interest to partners from industry and government, such as

- Microcomputer systems,
- GRID technologies and parallel processing,
- Cloud and HPC computing,
- Fuzzy and neuro-fuzzy controllers,
- 3D design, visualization and animation, video editing,
- Process informatics and programmable technologies,
- Short SIMD processing,
- Intelligent RFID systems,
- Cryptography, security, privacy, digital identity management, intrusion detection,
- Digital libraries and multimedia information retrieval,
- E-learning environments,
- Numerical simulations of physical phenomena,
- Prototyping of transaction-intensive systems,
- Design of people-focused software development methodologies based on best practices,
- Service oriented architecture-based system integration,
- Fraud detection from transaction data,
- Data mining, machine learning, data visualization,
- Data analytics and Big Data,
- Mobile robotics, applications of artificial intelligence in robotics,
- Computer vision, visual cognitive systems,
- Biometry, human face detection and recognition,
- Object recognition and tracking in video streams, visual surveillance and forensic,
- Medical diagnosis and prognosis,
- Biomedical informatics, and
- Biomedical computer systems and imaging.

More information on individual laboratories and current projects may be found at the faculty's web pages at <https://www.fri.uni-lj.si/en>.

# Laboratory for Computer Graphics and Multimedia

## Head:

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## RESEARCH ACTIVITIES

Digital media in their various forms are ubiquitous in today's world. The Laboratory for Computer Graphics and Multimedia is involved in research and development activities in the fields of multimedia technologies, human-computer interaction and computer graphics.

The main ongoing activities in the laboratory are dedicated to researches in the following areas:

- audio processing and music information retrieval (semantic audio description, indexing and organization of music archives),
- interactive 3D visualization and games (medical imaging, gamification),
- e-learning (personalization, learning for impaired),
- human computer interaction (innovative user interfaces).

We also have extensive experience in developing software solutions for desktop, mobile and cloud platforms. Additionally, we are active in the development of visualizations, interactive learning systems, and didactic simulations. We collaborate with partners in a number of national, EU and industrial projects.

In the past, members of the laboratory cooperated with other research groups in the development of military training systems, medical imaging applications, simulation tools for computer supported industrial automation, including robotized environments, and computer supported quality control and management systems. The laboratory was also a member of the international consortium CoLoS, which was active in the area of computer supported conceptual learning of natural sciences.

## EQUIPMENT

The laboratory is well equipped with professional software tools for 3D design, visualization, animation, and video editing. Some presentation and videoconferencing equipment is also available. The laboratory has also built a multi-touch table, which is used for developing and testing alternative ways of human computer interaction. To support the alternative and natural user interface research, the laboratory has Oculus Rift DK2, some high-performance GPU-s (sponsored by Nvidia), some Kinect and LeapMotion depth sensors, as well as 3D mouse and multi-monitor system.

## PROJECTS

Publication Browsing System. Industry-Funded Project, Consortium of vocational high schools (2014-2015).

Clicker Classroom Response System. Industry-Funded Project, Arnes (2014).

## RESEARCH VISITS

Ciril Bohak: Norwegian University of Science and Technology, Trondheim, Norway, 8. 6. - 15. 6. 2014. The purpose of the visit was to exchange the experiences on mutual research topics on high-performance computation, interactive 3D data visualization and simulation.

## INVITED TALKS AND LECTURES

Alenka Kavčič: Creative use of games in the classroom, 2. 10. 2014, an invited talk at the eTwinning contact seminar: Game based learning in the future classroom, Ljubljana, Slovenia.

Ciril Bohak: Introduction to music information retrieval, 12. 6. 2014, an invited talk at Norwegian University of Science and Technology, Department of Computer and Information Science, Trondheim, Norway.

Matevž Pesek, Aleš Leonardis, Matija Marolt: Compositional hierarchical model for pattern discovery in music, 17. - 20. 9. 2014, an invited talk at EuroMAC 2014, Eighth European Music Analysis Conference, Leuven, Belgium.

## SELECTED PUBLICATIONS

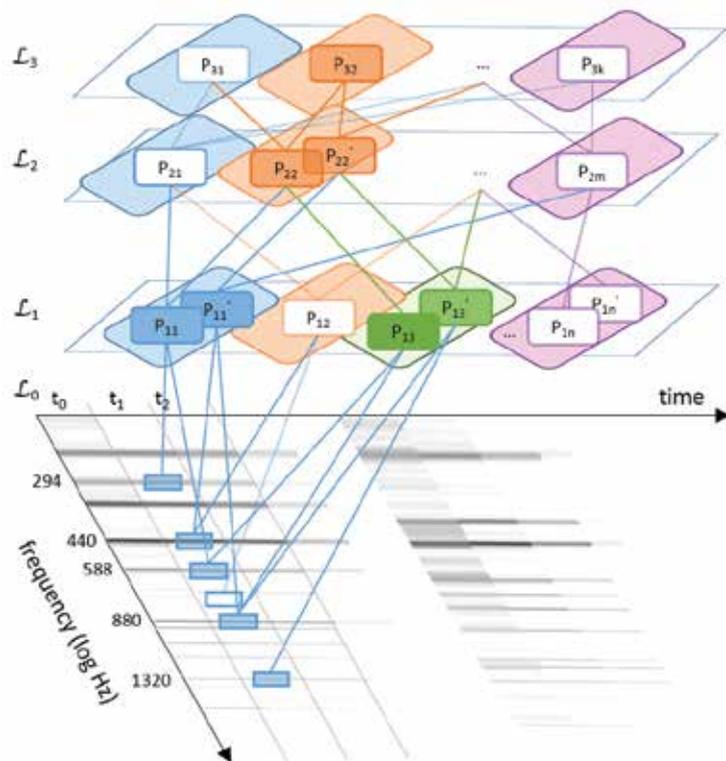
M. Pesek, A. Leonardis, M. Marolt. A compositional hierarchical model for music information retrieval. Proceedings of the 15th Conference of the International Society for Music Information Retrieval, ISMIR 2014, 27. – 31. 10. 2014, Taipei, Taiwan.

M. Pesek, P. Godec, M. Poredoš, G. Strle, J. Guna, J. Guna, E. Stojmenova, M. Pogacnik, M. Marolt. Introducing a dataset of emotional and colour responses to music. Proceedings of the 15th Conference of the International Society for Music Information Retrieval, ISMIR 2014, 27. – 31. 10. 2014, Taipei, Taiwan.

A. Černivec, C. Bohak. Using Kinect for touchless interaction with existing applications. Human-computer interaction in information society: proceedings of the 17th International Multiconference Information Society - IS 2014, 8. 10. 2014, Ljubljana, Slovenia.

M. Pesek, A. Leonardis, M. Marolt. Compositional hierarchical model for pattern discovery in music. EuroMAC 2014 (Eight European Music Analysis Conference), 17. – 20. 9. 2014, Leuven, Belgium.

M. Pesek, P. Godec, M. Poredoš, G. Strle, J. Guna, J. Guna, E. Stojmenova, M. Pogacnik, M. Marolt. Capturing the mood: evaluation of the moodstripe and moodgraph interfaces. IEEE ICME 2014 (IEEE International Conference on Multimedia and Expo), 14. – 18. 7. 2014, Chengdu, China.



Compositional hierarchical model for music understanding



Medical diagnostic using virtual reality

M. Pesek, P. Godec, M. Poredoš, G. Strle, J. Guna, J. Guna, E. Stojmenova, M. Pogacnik, M. Marolt. Gathering a dataset of multi-modal mood-dependent perceptual responses to music. UMAP 2014 (Conference on User Modeling, Adaptation, and Personalization), 7. 7. – 11. 7. 2014, Aalborg, Denmark.

G. Strle, M. Marolt. Uncovering semantic structures within folk song lyrics. Proceedings of the Fourth International Workshop on Folk Music Analysis, 12. and 13. 6. 2014, Istanbul, Turkey.

C. Bohak, A. Sodja, M. Marolt, U. Mitrović, F. Pernuš. Fast segmentation, conversion and rendering of volumetric data using GPU. IWSSIP 2014: proceedings, (International Conference on Systems, Signals, and Image Processing), 12. – 15. 5. 2014, Dubrovnik, Croatia.

M. Pesek, A. Leonardis, M. Marolt. Boosting audio chord estimation using multiple classifiers. IWSSIP 2014 (International Conference on Systems, Signals, and Image Processing), 12. – 15. 5. 2014, Dubrovnik, Croatia.

A. Kavčič, C. Bohak, M. Pesek, M. Marolt. Edo: involving teachers in the development of e-learning material. Open education for a multicultural world: OCWC Global Conference, 23. – 25. 4. 2014, Ljubljana, Slovenia.

# Laboratory of Biomedical Computer Systems and Imaging

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## RESEARCH ACTIVITIES

The laboratory is involved in basic research connected to biomedical signal and imaging data. The main research goals are summarized as following:

- understanding and describing physiological phenomena, using computers in modelling and understanding of physiologic relationships, locally and remotely monitoring physiologic events, graphically displaying anatomic details and physiologic functions, visualizing and representing biomedical signal and imaging data, developing standardized databases to study physiologic mechanisms and to evaluate the performance and robustness of recognition techniques, characterizing data, establishing detection criteria and recognition techniques to automatize the analysis of bioelectric patterns to as high a degree as possible, examinations, procedures, and medical practice, in order to improve the quality and reliability of examinations, and to interpret data and results qualitatively and quantitatively,
- developing performance measures and protocols to evaluate detection techniques, developing biomedical information technologies and software.

The principal research topic currently underway is the development and evaluation of recognition algorithms for accurately detecting transient ischaemic events and classifying true ischaemic events from non-ischaemic events in biomedical signal data using the LTST DB (Long-Term ST Database) of human-expert annotated ambulatory electrocardiogram (ECG) records. The second research topic is maintaining, updating and distributing the standardized international reference-annotated ECG database LTST DB. The database is result of a multinational research effort and contains 86 24-hour ambulatory recordings with a number of human-expert annotated transient ischaemic and non-ischaemic ST events. The database is intended to serve as a reference set in evaluating the performance of ST analysers, and as a reference set to study physiologic mechanisms responsible for ischaemia. See:

- <http://www.physionet.org/physiobank/database/ltstdb/> and
- <http://www.physionet.org/challenge/2003/>.

From 2007 the database is publicly available. See also:

- <http://lbcsi.fri.uni-lj.si/ltstdb/>.

The next research topic is the development of interactive graphic user interface editing tools (SEMIA - semi-automatic) to visualize, display and annotate long-term electrocardiograms. SEMIA, version 3.0.1, to view diagnostic and morphology feature-vector time series, and to examine the human annotations to the LTST DB is under GNU General Public License and is available at <http://www.physionet.org/physiobank/database/ltstdb/semia/>.

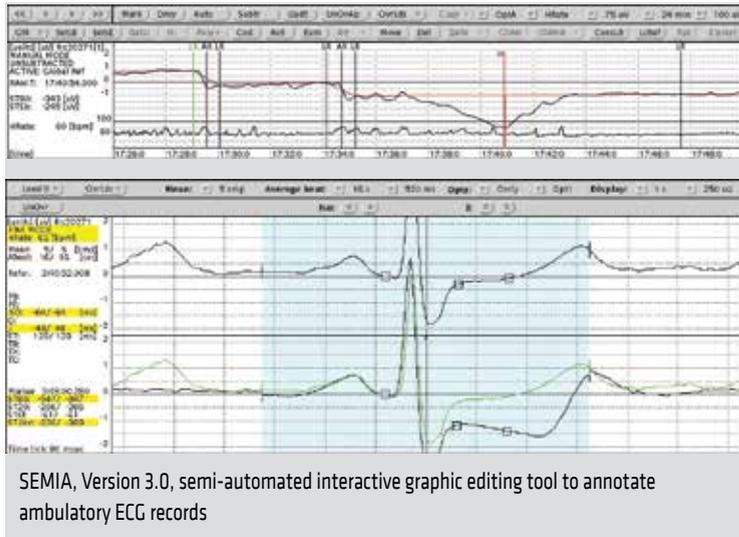
Another research topic is the characterization of the temporal patterns of transient ischaemic events and time-frequency representations of diagnostic parameters in ambulatory ECG signals. The goals are to differentiate physiologic mechanisms generating ischaemia and predicting impending ischaemia.

Another important contribution of the laboratory to the world community is the interactive graphic tool EVAL\_ST, used to evaluate the performance and robustness of ischaemia analysers. The tool is under GNU General Public License and is available at [http://www.physionet.org/physiotools/eval\\_st/](http://www.physionet.org/physiotools/eval_st/).

Another research topic concerns the comparison of various linear and non-linear signal processing techniques to separate uterine electromyogram (EMG) records of term and pre-term delivery groups with the final goal to predict pre-term delivery.

Another research topic is automated detection of macula in retinal images and quantitative assessment of auto fluorescence in retinal images.

The Laboratory supports a Web mirror site (<http://physionet.fri.uni-lj.si>) for a part of Europe to the PhysioNet Web site (<http://www.physionet.org>) which is located at the Massachusetts Institute of Technology in Cambridge, USA. Maintenance of the PhysioNet Web site is supported by the U.S. National Institutes of Health. PhysioNet offers free access via the Web to large collections of recorded physiologic signals and related open-source software.



## EQUIPMENT

The laboratory owns two high-speed electroencephalographic recording devices to record and monitor electroencephalogram (EEG) signals and one EEG Holter recorder.

## RESEARCH PROJECTS

Metabolic and inborn factors of reproductive health, birth II (P3-0124). Research Programme, Slovenian Research Agency (2009-2019).

## SCIENTIFIC CHALLENGES

MSc student U. Pangerc and F. Jager participated at the scientific challenge Robust Detection of Heart Beats in Multimodal Data: the PhysioNet/Computing in Cardiology Challenge 2014. The challenge was organized in the scope of international conference Computing in Cardiology 2014, Boston, Sept. 2014. In the three phases of the competition U. Pangerc and F. Jager took the second, third, and the sixth place among over sixty competing teams. Their average range among the three phases was the second place.

## SELECTED PUBLICATIONS

U. Pangerc, F. Jager. Robust Detection of Heart Beats in Multimodal Data Using Integer Multiplier Digital Filters and Morphological Algorithms. *Computing in Cardiology*; 41:285-288, 2014.

A. Smrdel and F. Jager. Automatic classification of long-term ambulatory ECG records according to type of ischemic heart disease. *BioMedical Engineering OnLine*, 10: 107, 2011.

A. Minchola, F. Jager and P. Laguna. Discrimination between ischemic and artifactual ST segment events in Holter recordings. *Biomedical signal processing control*, 5: 21-31, 2010.

J. Faganeli and F. Jager. Automatic classification of transient ischaemic and transient non-ischaemic heart-rate related ST segment deviation episodes in ambulatory ECG records. *Physiological Measurement*, 31: 323-337, 2010.

G. Fele-Žorž, G. Kavšek, Ž. Novak-Antolič and F. Jager. A comparison of various linear and non-linear signal processing techniques to separate uterine EMG records of term and pre-term delivery groups. *Medical & Biological Engineering & Computing*, 46(9):911-922, 2008.

A. Smrdel, F. Jager. Diurnal Changes of the Heart Rate and Sympathovagal Activity for Temporal Patterns of Transient Ischemic Episodes in 24-hour Electrocardiograms. *EURASIP J, Adv. Signal. Process.* 2007, Article ID 32386, 10 pages, 2007.

F. Jager, G.B. Moody, R.G. Mark. Protocol to assess robustness of ST analysers: A case study. *Physiological Measurement*, 25:629-643, 2004.

A. Smrdel, F. Jager. Automated detection of transient ST-segment episodes in 24h electrocardiograms. *Medical & Biological Engineering & Computing*, 42:303-311, 2004.

F. Jager, A. Tadei, G.B. Moody, M. Emdin, G. Antolič, R. Dorn, A. Smrdel, C. Marchesi, R.G. Mark. Long-Term ST Database: A Reference for the Development and Evaluation of Automated Ischaemia Detectors and for the Study of the Dynamics of Myocardial Ischaemia. *Medical & Biological Engineering & Computing*, 41:172-182, 2003.

F. Jager, G.B. Moody, R.G. Mark. Detection of Transient ST-Segment Episodes During Ambulatory ECG-Monitoring. *Computers and Biomedical Research*, 31:305-322, 1998.

# Laboratory of Adaptive Systems and Parallel Processing

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## RESEARCH ACTIVITIES

The main research topics include development of adaptive algorithms in areas of soft computing, clustering, data mining, and design of computer systems, ranging from high performance computing to on-chip designs. Within these areas we are mainly focused on problems where the lack of theoretical knowledge prevents exact solutions and where the size of the problems demands special software and hardware for efficient processing.

In the first research topic we have broad experience in methods based on natural computing algorithms, which comprise artificial neural networks, evolutionary algorithms, fuzzy logic and other biologically inspired algorithms. Currently we are working on the modelling of sub-cell structures with Boolean networks, and on new efficient methods for data clustering. We are also researching information-theoretic methods for feature selection and Monte Carlo Tree Search extensions to direct

the exploration of sub-optimal solutions in large state spaces. Besides, we are investigating applications of temporal difference reinforcement learning methods inside the Monte Carlo Tree Search framework.

In the second research topic the activities include the development of approximate arithmetic circuits for signal processing and for adaptive systems where efficient implementations in terms of shorter time delays, resource utilization, and energy efficiency prevail over accuracy. We have wide experience also in the field of heterogeneous parallel computing where on one hand we work on parallelization of complex algorithms from various research fields including bioinformatics and image analysis, and on the other hand develop self-adaptive strategies for on-line modification of execution environment to reach processing time or power consumption constraints of variable complexity algorithms.

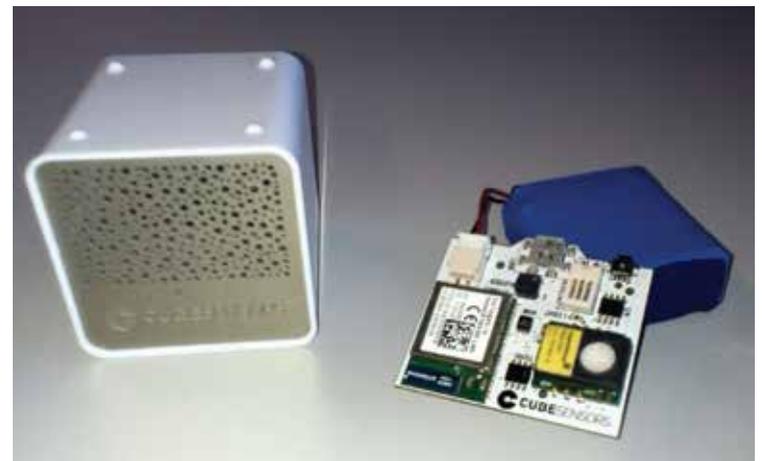
We are also cooperating with industry in the development of embedded systems and in software development and optimization of fully automated warehouses. The results of our work can be seen in numerous products worldwide.

## EQUIPMENT

nVidia Tesla K20 GPU Computing Processor, Intel Xeon Phi 5110P, FPGA design boards.

## RESEARCH PROJECTS

Synergy of the technological systems and processes (P2-0241). Basic Research Programme (together with the Faculty of Mechanical Engineering, University of Ljubljana), Slovenian Research Agency (2009-2017).



We have developed a firmware for the Cubesensors devices that monitor the living conditions in a home or an office. It features monitoring of air quality, temperature, humidity, pressure, noise, illumination, and shaking.

Pervasive computing (P2-0359). Research Programme, Slovenian Research Agency (2009-2017).

Development of firmware for the Cubesensors devices. Industry-Funded Project, CubeSensors (2013-2014).

Control and optimization of elevated transport vehicles at New Dubai airport, UAE. Industry-Funded Project, Iskra impuls, 2014.

## RESEARCH VISITS

Tom Vodopivec: School of Computer Science and Electronic Engineering, University of Essex, Colchester, UK, 27. 10. – 28. 11. 2014. Collaboration with Prof. Simon Lucas and his research group in improving algorithms for artificial intelligence in games.

## INVITED TALKS AND LECTURES

Patricio Bulić: Fixed-point multiplication and division in the logarithmic number system: a way to low-power design, 25. 9. – 27. 9. 2013, an invited talk at Workshop on Digital Electronic Systems, Kranjska Gora, Slovenia.



We have written a software for control and optimization of three single-rail autonomous transport vehicles at Al Maktoum International Airport in Dubai. These transport vehicles are used to transport air cargo of length up to 20 feet and weight up to 14 tons from truck docks to the storage locations and vice-versa.

## SELECTED PUBLICATIONS

A. Avramović, Z. Babić, D. Raič, D. Strle, P. Bulić. An approximate logarithmic squaring circuit with error compensation for DSP applications. *Microelectronics journal*, 45: 263-271, 2014.

R. Gaber, T. Lebar, A. Majerle, B. Šter, A. Dobnikar, M. Benčina, R. Jerala. Designable DNA-binding domains enable construction of logic circuits in mammalian cells. *Nature chemical biology*, 10: 203-208, 2014.

D. Olszewski, B. Šter. Asymmetric clustering using the alpha-beta divergence. *Pattern recognition*, 47: 2031-2041, 2014.

K. Tušek-Bunc, M. Petek Šter, B. Šter, D. Petek, J. Kersnik. Validation of the Slovenian version of Patient Assessment of Chronic Illness Care (PACIC) in patients with coronary heart disease. *Collegium antropologicum*, 38: 437-444, 2014.

M. Petek Šter, I. Švab, B. Šter. Final year medical students' understanding of family medicine. *Acta Medica Academica*, 43: 40-49, 2014.

D. Sluga, T. Curk, B. Zupan, U. Lotrič. Heterogeneous computing architecture for fast detection of SNP-SNP interactions. *BMC bioinformatics*, 15: 216, 2014.

M. Cankar, M. Artač, M. Šterk, U. Lotrič, B. Slivnik. Co-allocation with collective requests in grid systems. *Journal for universal computer science*, 19, 282-300, 2013.

P. Bulić, V. Guštin, D. Šonc, A. Štrancar. An FPGA-based integrated environment for computer architecture. *Computer applications in engineering education*, 21: 26-35, 2013.

R. Češnovar, V. Risojević, Z. Babić, T. Dobravec, P. Bulić. A GPU implementation of a structural-similarity-based aerial-image classification. *The journal of supercomputing*, 65: 978-996, 2013.

N. Kunstelj, D. Žnidarčič, B. Šter. Using association rules mining for sweet potato (*Ipomoea batatas* L.) in Slovenia: a case study. *International journal of food, agriculture & environment - JFAE*, 11: 253-258, 2013.

N. Kunstelj, D. Žnidarčič, B. Šter. Employing artificial neural networks and regression in analysis on knowledge about sweet potato (*Ipomoea batatas* L.) in Slovenia. *Italian journal of food science*, 25: 263-274, 2013.

B. Šter. Selective recurrent neural network. *Neural processing letters*, 38: 1-15, 2013.

N. Ilc, A. Dobnikar. Generation of a clustering ensemble based on a gravitational self-organizing map. *Neurocomputing* 96: 45-56, 2012.

# Computer Communications Laboratory

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## RESEARCH ACTIVITIES

The main research interests of our laboratory members are diverse: communication networks and protocols, computer networks design, cloud architectures and services, cloud security, network security and security policies, sustainability in all ICT areas, computer supported learning systems and practical use of agile methodologies for the development of software and information systems.

In 2014, we have researched most actively the following areas:

- In the area of cloud architectures, we have researched complex virtual environments building automatization (orchestration). Such environments could be used for e-learning (virtual laboratories), software and distributed systems testing, network components etc.
- In the area of networking, we have researched SDN and their usage within cloud environments.
- In the area of e-learning, we have expanded our virtual laboratory in a cloud, which is used for teaching computer communications and other courses. The infrastructure is used by more than 400 students each year. We are continuously improving the virtual lab and evaluating



Cloud computing - physical infrastructure: servers, storage, Infinband switch

the students' feedback. At the same time we are researching the pedagogical aspects of introducing e-learning in a cloud into the teaching process: how could we enable our students to perform complex exercises that include multiple servers, diverse network topologies and other resources 24/7, regardless of their location.

- Our research also included hybrid public-private clouds, sky computing (cloud bursting) and integration of several e-learning related systems into a cloud. Further, we studied possibilities for e-learning environment for learning about cloud administration. It would be highly inconvenient if we would need to provide each student with several physical servers so that he could practice how to deploy a cloud. We made a proof of concept that it is possible to build a virtual cloud in cloud environment and that it is possible to use it for learning cloud-related themes.
- We have also researched requirements for carrier-grade cloud architecture and its usage in large telecommunication company. Further, we have tested identity management, authentication, authorization and remote administration protocols integration with large production environments and in cloud systems.

## EQUIPMENT

Besides the typical office equipment, the Computer Communications Laboratory is equipped with a few pieces of advanced networking/cloud computing hardware and software equipment. Hardware: one 20 Gb/s Infinband DDR network switch, two 24-port and two 48-port Dell Gigabit Switches, one 24-port Arista 10Gb/s SFP Data Center Switch for testing purposes, Dell Power Vault NAS 745 (2 TB), an IBM dual processor eServer

xSeries 336 storage server with 3 TB of locally attached SCSI storage in an HP MSA-20 enclosure, one SuperMicro storage server with 12 TB of locally attached SATA storage, a private cloud consisting of 11 Dell PowerEdge QuadCore R200 servers each with four Gigabit Ethernet ports and an Infiniband SDR 10 Gb/s connection, 4 Dell PowerEdge DualCore Servers, 2 HP Proliant Servers with 32GB of ram for testing purposes, 6 802.11b/g/n wireless Access Points, various mobile devices...

Software: network management tools and utilities, OpenStack private cloud, VMware virtualization tools, Nexenta and Openfiler storage appliance software, databases and development tools, Redmine project management software, Gitlab software to collaborate on code, Moinmoin Wiki, Microsoft development tools and utilities; several open-source Java development tools and utilities including Mobile Phone development utilities, ...

## RESEARCH PROJECTS

HESUDI - Healthcare Support Using Domotics and IT. Erasmus Intensive Programme Project, European Commission (2013-2014).

Platform for Test Environments Orchestration in the Cloud. Industry-Funded Project (2013-2014).

Unified Highly Available and Robust Application Platform for Telecommunication Services. Industry-Funded project (2013-2015).

HOME - Higher Education Online: MOOCs the European Way. Lifelong Learning Programme, European Commission (2013-2016).

STACKLABS - Cloud Education Platform. Industry-funded project (2014-2015).

STORK 2.0 (Secure idenTity acrOss boRders linKed 2.0) Higher Education Pilot. Jožef Stefan Institute and European Commission (2014-2015).

Initiatives Affecting "Green Data Center" Area and Market Shape. Industry-funded project, 2014.

Municipal WiFi Network. Industry-funded project, 2014.

## LABORATORY GUESTS

Vanya Lazarova, Paisii Hilendarski Plovdiv University, Faculty of Mathematics and Informatics, Bulgaria. 1. 3. - 30. 3. 2014. Web-based educational systems research.

Andrej Krevl, Stanford University, USA. 20. 12. 2013 - 6. 1. 2014 and 21. 12. 2014 - 5. 1. 2015. Software defined networking research.

James Snow, Google. 30. 6. - 2. 7. 2014. Cloud and Security Summer School.

Matthias Luft, ERNW GmbH. 1. 7. - 3. 7. 2014. Cloud and Security Summer School.

Kai Roer, CSA Norway. 29. 6. - 3. 7. 2014. Cloud and Security Summer School.

Michele Bezzi, SAP Labs France. 30. 6. - 3. 7. 2014. Cloud and Security Summer School.



A teacher's front end for building complex virtual environment, which will be used later by students in virtual laboratory

Fabrizio Volpe, Iccrea Banking Group. 30. 6. - 2. 7. 2014. Cloud and Security Summer School.

Olivier Caleff, CSA France. 1. 7. - 4. 7. 2014. Cloud and Security Summer School.

## RESEARCH VISITS

Miha Grohar: Metropolia University, Helsinki, Finland, 13. 4. - 18. 4. 2014. Research of IT healthcare support.

Miha Grohar: IP Solutions, Stockholm, Sweden, 18. 6. - 19. 6. 2014. Research of cloud teaching methodologies.

Miha Grohar: Ericsson Software Campus, Athlone, Ireland, 23. 6. - 25. 6. 2014. Research of cloud teaching methodologies.

Miha Grohar: ERICSSON TELECOMUNICACOES S.A., Sao Paulo, Brazil, 17. 11. - 19. 11. 2014. Research of cloud teaching methodologies.

## INVITED TALKS AND LECTURES

Matjaž Pančur, Miha Grohar: Openstack CEE Day, 26. 5. 2014, OpenStack Bootcamp Lead, Budapest, Hungary.

Matjaž Pančur, Miha Grohar: Openstack CEE Day, 26. 5. 2014, The OpenStack Community Training Manuals project, Budapest, Hungary.

## SELECTED PUBLICATIONS

N. Škoberne, O. Maennel, I. Phillips, R. Bush, J. Žorž, M. Cigliarič. IPv4 address sharing mechanism classification and tradeoff analysis. IEEE/ACM transactions on networking, ISSN 1063-6692, vol. 22, no. 2, doi: 10.1109/TNET.2013.2256147, 2014.

J. Porenta, M. Ciglarič. Comparing commercial IP reputation databases to open-source IP reputation algorithms. *Computer systems science and engineering*, ISSN 0267-6192, vol. 28, no. 1, str. 1-14, 2013.

M. Matičič, T. Selič Kurinčič, A. Kastelic, M. Poljak, G. Lesničar, J. Meglič-Volkar, M. Rajter, J. Prah, Z. Balkan, M. Ciglarič, M. Pančur. A national multidisciplinary healthcare Network for Treatment of Hepatitis C in People who Inject Drugs in Slovenia: High Enrollment, Adherence and Sustained Virological Response. In: M. Soyka, M. Backmund, *Suchtmedizin in Forschung und Praxis*, Proc. 3rd International Symposium on Hepatitis Care in Substance Users, *Suchtmed* 15(4), pp.245, 2013.

M. Pančur, M. Ciglarič. Impact of test-driven development on productivity, code and tests: A controlled experiment, *Information and Software Technology* 53, pp. 557-573 DOI information: 10.1016/j.insof.2011.02.002, 2011.

J. Rugelj, M. Ciglarič, A. Krevl, M. Pančur, A. Brodnik. Constructivist learning environment in a cloud. In: UDEN, Lorna (ur.). *Workshop on learning technology for education in cloud (LTCE'12)*, (Advances in intelligent systems and computing, Vol. 173), pp. 193-204, New York: Springer, 2012.

N. Škoberne, M. Ciglarič. Practical Evaluation of Stateful NAT64/DNS64 Translation, *Adv. electr. comput. eng*, vol. 11, no. 3, pp. 49-54. <http://www.aece.ro/abstractplus.php?year=2011&number=3&article=8>, 2011.

M. Ciglarič, T. Lesjak, A. Krevl, A. Brodnik. Getting more from virtual laboratory: a case study. In: AUER, Michael E. (ur.), SCHREURS, Jeanne (ur.). *Academic and corporate e-learning in a global context*. Wien: International Association of Online Engineering; Kassel: University Press, str. 1170-1178, 2010.

M. Ciglarič, A. Krevl, M. Jeličič, A. Brodnik. Laboratory as a service: architecture, implementation and experiences. *Asia-Pac. collab. educ. journal*, vol. 6, no. 2, str. 69-86, 2010.

M. Ciglarič, S. Mavsar. Raziskovanje omrežnih napadov: muholovec Simx. *Elektrotehniški vestnik*, letn. 77, št. 4, str. 173-178, 2010.

M. Pančur, M. Ciglarič, M. Trampuš, T. Vidmar. Towards empirical evaluation of test-driven development in a university environment. V: ZAJC, Baldomir (ur.), TKALČIČ, Marko (ur.). *The IEEE Region 8 EUROCON 2003: computer as a tool: 22-24 September 2003*, Faculty of Electrical Engineering, University of Ljubljana, Slovenia: proceedings. Piscataway: IEEE, vol. 2, pp. 83-86, 2003.

## Computer Structures and Systems Laboratory

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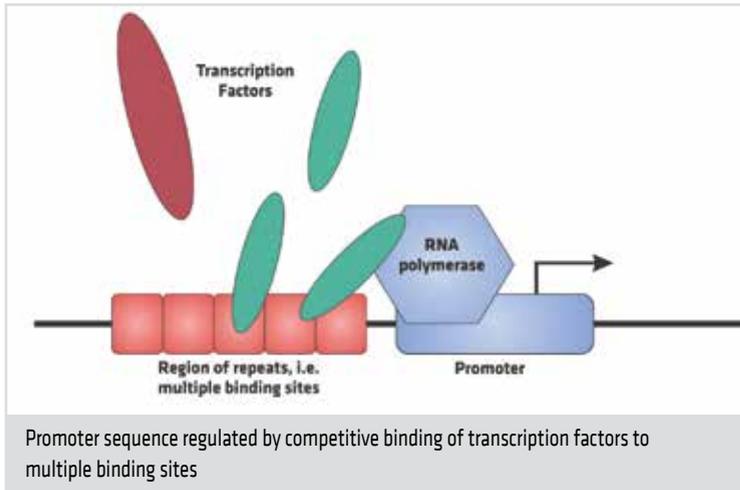
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### RESEARCH ACTIVITIES

The laboratory is focused on the computational methods for modelling, simulation and analysis of three fundamentally different system families, i.e. biological systems with information processing capabilities, biological systems that reflect coordinated behaviour and quantum-dot cellular automata. Respectively, the laboratory consists of three groups, the Computational Biology Group, the Collective Behaviour Group and the Quantum-dot Cellular Automata group. Our results have been published in *Nanotechnology* and *Animal Behaviour*, the most respectable journals in their respective fields.

The Computational Biology group is focused on the computational analysis and design of synthetic biology structures with information processing capabilities. Research is oriented towards the establishment



of new modelling approaches, parameter estimation techniques, sensitivity and robustness analyses and performance evaluation. The goal is to fully automatize the design of synthetic biological systems with predefined functionalities. We attended the iGEM competitions as mentors to the modelling part of team Slovenia in the past, where we received the leading positions among almost 200 teams. We are currently focused on the computational methods for analysis and design of gene regulatory networks with multiple transcription factor binding sites.

The Collective Behaviour group uses soft computing methods to model coordinated behaviour in biological systems. Animal groups such as fish schools, insect swarms and bird flocks are frequently admired in awe as they exhibit complex coordinated behaviour. May these behaviours result from social interactions among individuals or be fruit of our pattern seeking mind we are researching soft computing algorithms that allow controlled entities to display behaviours similar to those observed in nature. Our aim is to support Biologists in forming or proving their hypotheses about why and how animal groups behave as they do. Our group developed a fuzzy logic based computer model of bird flocking which uses fuzzy logic to describe an individual's drives. Simulations performed using the model present behaviour remarkably similar to behaviours of natural flocks. Our research activities are concentrated on the extension of the model to support studies of various collective behaviours, such as: bird flocks landing and take-off, sensory system studies, predator/prey relations, and flocking behaviour under predation.

The Quantum-dot Cellular Automata group is involved with studies of nano-scale devices capable of performing computation at very high switching speeds and consuming extremely small amounts of electrical power. The devices have been proposed in 1993 by Craig Lent, et al. as a physical implementation of an automaton using quantum-dot cells and combine the discrete nature of both cellular automata and quantum mechanics. Lent's automaton is intended as a binary processing platform that will eventually replace the current transistor switching circuits. The

proposal quickly gained popularity and it was first fabricated in 1997. Our group with the premise that future processing platforms should not disregard the advantages of multi-valued processing extended Lent's automaton so that it supports ternary processing. Our research activities are concentrated on the general problem of planning and routing in quantum-dot cellular automata, the analysis of the ternary quantum-dot cell parameter space, but mostly with processing structures implemented using ternary quantum-dot cells.

## RESEARCH PROJECTS

Pervasive computing (P2-0359). Research Programme, Slovenian Research Agency (2013-2016).

Designed cellular logic (J1-6740). Basic Research and Application Project, Slovenian Research Agency (2014-2017).

Agile Database for Tensiomyographic Measurements: Case study and Implementation, Industry-Funded Project, TMC-BMC Ltd., 2013.

## SELECTED PUBLICATIONS

J. Demšar, I. Lebar Bajec. Simulated predator attacks on flocks: a comparison of tactics. *Artificial life*, vol. 20, no. 3, pp. 343-359, 2014.

M. Petroni, N. Zimic, M. Mraz, M. Moškon. Stochastic simulation algorithm for gene regulatory networks with multiple binding sites. *Journal of computational biology*, 2014 (accepted for publication).

M. Moškon, M. Mraz. Systematic approach to computational design of gene regulatory networks with information processing capabilities. *IEEE/ACM transactions on computational biology and bioinformatics*, vol. 11, no. 2, pp. 431-440, 2014.

M. Stražar, M. Mraz, N. Zimic, M. Moškon. An adaptive genetic algorithm for parameter estimation of biological oscillator models to achieve target quantitative system response. *Natural computing*, vol. 13, no. 1, pp. 119-127, 2014.

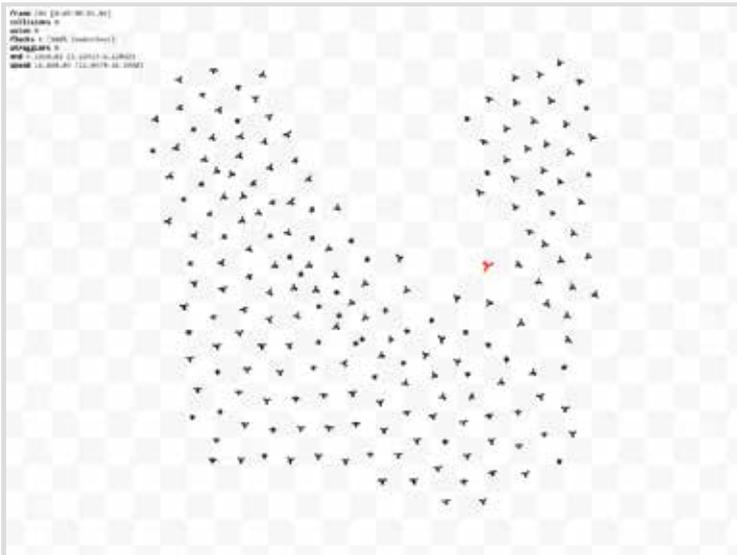
M. Moškon, Š. Novak, M. Medeot, I. Lebar Bajec, N. Zimic, M. Mraz. Solving the logistic problems with optimal resource assignment using fuzzy logic methods. *Journal of Advanced Transportation*, vol.47, no.4, p.447-460, 2013.

I. Lebar Bajec, P. Pečar. Two-layer synchronized ternary quantum-dot cellular automata wire crossings. *Nanoscale research letters*, vol. 7, p. 1-12, 2012.

M. Moškon, M. Mraz. Modelling and analysing the information processing capabilities of simple biological systems. *Math. model. anal.*, vol. 17, no. 4, p. 467-484, 2012.

M. Janež, P. Pečar, M. Mraz. Layout design of manufacturable quantum-dot cellular automata. *Microelectron. j.*, vol. 43, no. 7, p. 501-513, 2012.

I. Lebar Bajec, F.H. Heppner. Organized flight in birds. *Animal behaviour*, 78(4): 777-789, 2009.



A frame from synflocks, our fuzzy logic based bird behaviour simulator, using which we are currently investigating predator/prey relations, more precisely the interplay of flocking behaviour and various predation strategies

P. Pečar, A. Ramšak, N. Zimic, M. Mraz, I. Lebar Bajec. Adiabatic pipelining: a key to ternary computing with quantum dots. *Nanotechnology*, 19(49): 1-12, 2008.

P. Pečar, M. Mraz, N. Zimic, M. Janež, I. Lebar Bajec. Solving the ternary quantum-dot cellular automata logic gate problem by means of adiabatic switching. *Jpn. j. appl. phys.*, 47(6): 5000-5006, 2008.

I. Lebar Bajec and M. Mraz. Multi-valued logic based on quantum-dot cellular automata. *International Journal of Unconventional Computing*, 3(4):311-322, 2007.

A. Jazbec, M. Mraz, I. Lebar Bajec, N. Zimic. Towards automated cooking process. *Food Research International*, 40(6):733-741, 2007.

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### RESEARCH ACTIVITIES

The Information Systems Laboratory is involved in basic and applied research in the field of Information Systems. The following primary areas of research are currently being pursued:

*Software Development Methodologies (SDM)*. Based on the collaborative practice research we strive to define the methodology and supporting tools for designing new or adapting existing SDMs. Specifically, we focus on the methodologically socio-technical suitability to both organization and project-specific requirements. From this topic two PhD theses have been developed. An approach for reengineering methodologies (Agile methodology framework) and supporting tools (Agile Methodology Toolset - AMT, see figure below) present the most important results of this research. We applied the approach in several Slovenian software

companies. We also developed a model of resistance to change that evaluates the economic risks of using specific parts of information systems. The model was applied in NLB and is currently being applied in Pediatric clinic of University Medical Centre Ljubljana.

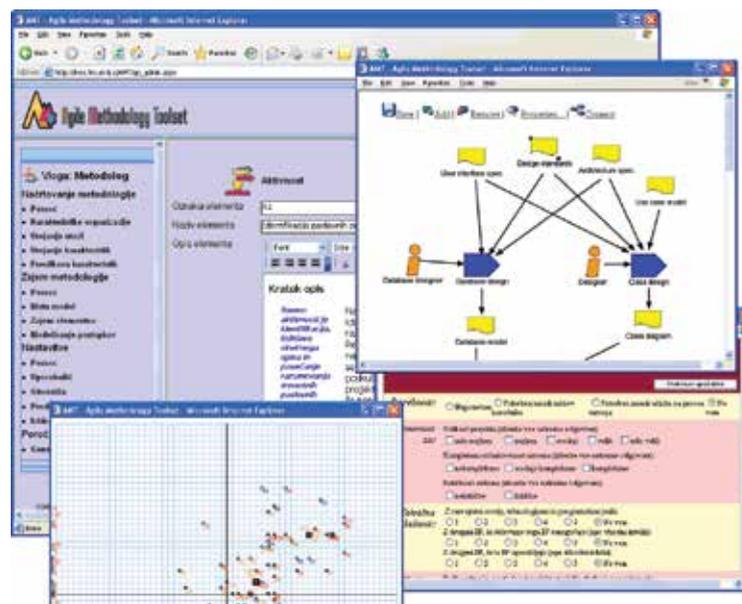
*IT/IS Strategy Planning and Enterprise Architecture.* Strategy planning is one of the research areas that have been traditionally present in the Information systems laboratory since its existence. We developed strategic plans for the various companies and organizations.

*Contemporary approaches to software development.* In collaboration with software companies we do research on the maturity level of the new approaches to software development. Recently we have been focusing on: "Model-driven development", "Business-rule approach", and "Method engineering".

*Mobile business and mobile applications.* We explore different mobile applications models focusing on the research of the context-awareness and context-aware mobile application model. The results have been presented as the Methodology for developing mobile applications. Furthermore, we developed a context-server that is able to connect with Process Control Systems. On the basis of contextual data (NFC, location, the role of employee, business rules, characteristics of the production process, the current state of equipment, logistics characteristics, etc.) the context server prepares the relevant data for the given situation and delivers to the mobile device employed in the proper context.

We are currently involved in a European project AgrolIT that deals with increasing the efficiency of farming through on open standards platform. The overall objective of the project is to set-up and pilot AgrolIT platform to be tested in different parts of Europe (Denmark, Poland, FYR of Macedonia and Romania). AgrolIT platform will integrate key applications and services that will address the challenges presented above. More specifically the project will select mobile applications for inclusion in ArgolIT user interface for simple and efficient input of data during farmers' daily activities (into database of ERP system of farms). Integrate services and applications for wireless data collection from sensors, monitoring systems and other devices into the platform. Provide advanced decision support for farming through implementation of decision support system and cloud based. Integrate all of the above into a working AgrolIT platform, based on open standards (enabling the inclusion of additional applications and services after the end of the project thus achieving sustainability of the platform) and pilot test it. AgrolIT project brings together partner experts from farming consultancy, software industry, agriculture and HEI. Additionally, this problematic is also being pursued in the context of project MAK - Mobilne aplikacije v kmetijstvu (Mobile applications to increase efficiency in farming). Rok Rupnik, head of laboratory, was project manager of project MAK and is project manager of project AgrolIT.

*Data Mining applications and Decision Support Systems.* Our areas of interest are innovative approaches for decision support. We combine research in this area with research in the area of mobile applications and as result we do research on mobile decision support.



Screenshot of the AMT system

*IT governance.* We actively analyse IT processes in different organizations. IT process analyses are performed with regard to COBIT model and ITIL standards. We also analyse the efficiency of the informatics in the organizations and their business information architectures.

## RESEARCH PROJECTS

MAK - Mobile applications to increase efficiency in farming. Structural Funds Project, Ministry of education, science and sport (2012-2014).

e-DKES - Expert dynamic human resource decision support system. Structural Funds Project, Ministry of education, science and sport (2012-2014).

AgrolIT - Increasing the efficiency of farming through on open standards based AgrolIT platform (621031), European Project (Framework Programs, CIP project) (2014-2016); Rok Rupnik (Head of research group) is project coordinator (project manager).

Pervasive computing (P2-0359). Research Programme, Slovenian Research Agency (2013-2016).

## LABORATORY GUESTS

Dr. Olegas Vasliecas, Vilnius Gediminas Technical University, 8. 12. 2014 - 13. 12. 2014. Lecture: Ontologies and business rules in information systems software engineering.

## SELECTED PUBLICATIONS

V. Mahnič, T. Hovelja. Teaching user stories within the scope of a software engineering capstone course: analysis of students' opinions. International

journal of engineering education, ISSN 0949-149X, vol. 30, no. 4, str. 901-915, 2014.

M. Ravljen, M. Bilban, L. Kajfež-Bogataj, T. Hovelja, D. Vavpotič. Influence of daily individual meteorological parameters on the incidence of acute coronary syndrome. *International journal of environmental research and public health*, ISSN 1661-7827, vol. 11, no. 11, str. 11616-11626, 2014.

S. Vrhovec, M. Trkman, A. Kumer, M. Krisper, D. Vavpotič. Outsourcing as an economic development tool in transition economies: scattered global software development. *Information technology for development*, ISSN 0268-1102, 2014.

M. Trkman, P. Trkman. Actors misaligned interests to explain the low impact of an information system: a case study. *International journal of information management*, ISSN 0268-4012, 2014.

D. Vavpotič, B. Žvanut, I. Trobec. A comparative evaluation of E-learning and traditional pedagogical process elements. *Educational technology & society*, ISSN 1436-4522, vol. 16, no. 3, str. 76-87, 2013.

A. Pivk, O. Vasilecas, D. Kalibatiene, R. Rupnik. On approach for the implementation of data mining to business process optimization in commercial companies. *Technological and economic development of economy*, ISSN 2029-4913., vol. 19, no. 2, str. 237-256, 2013.

T. Hovelja, O. Vasilecas, R. Rupnik. A model of Influences of Environmental Stakeholders on Strategic Information Systems Planning Success in an Enterprise. *Technological and Economic Development of Economy*, vol. 19, no. 3, str. 465-488, 2013.

A. Šaša, M. Krisper. Multi-criteria decision making in ontologies. *Information sciences*, ISSN 0020-0255, vol. 222, str. 593-610, 2013.

## Laboratory of e-media

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### RESEARCH ACTIVITIES

The Laboratory of e-media is actively involved in research areas of security, privacy and trust management with an emphasis on cryptographic protocols, formal methods, security infrastructure systems like PKI and AAA. In addition, the laboratory's research activities cover quantitative modelling of human factor, aimed at the development of solutions that support decision making for the management of information systems and critical infrastructures. The foundations for these activities are methodologies like system dynamics and quantitative assessment dynamics (QAD).

Results include patented cryptographic protocols that provide security in environments with limited system resources like smart cards and RFIDs. In addition, we are developing simulation models to support the management of information systems security and technological solutions for trust management in global networks. The results also include implementations of supply chains management in food sector based on RFID technologies. Furthermore, our research results have been published in renowned international journals (like those published by Elsevier and IEEE), and in monographs published by Springer, Francis & Taylor (chapter contribution) and IGI Global (chapter contribution).

Finally, laboratory members are (or have been) nominated to serve on board of important EU and international organizations (e.g., MB of

ENISA, ISC NATO Panel). They also serve as reviewers for renowned publishers (of scientific journals and monographs) they are examiners and jury members for PhDs at other EU universities, and lecturers at other universities and international events. Laboratory of e-media has an extensive international collaboration network; it participates in national, as well as European projects. Its references also include several examples of transfer of new knowledge to the market.

## EQUIPMENT

Advanced body area sensor network equipment.

## RESEARCH PROJECTS

Pervasive computing (P2-0359). Research Programme, Slovenian Research Agency (2009-2017).

SALUS - Security And Interoperability in Next Generation PPDR Communication InfrastructureS. European Project (Framework Programmes) (2013-2016).

COST IC1403 - Cryptanalysis of ubiquitous computing systems (CRYPTACUS). Other International Project (2014-2018).

COST IC1306 - Cryptography for secure digital interaction. Other International Project (2014-2018).

COST IC1303 - Algorithms, architectures and platforms for enhanced living environments (AAPELE). Other International Project (2013-2017).

## SELECTED PUBLICATIONS

D. Trček, B. Likar, Driving information systems security through innovations: first indications. *Cybernetics and systems*, ISSN 0196-9722, vol. 45, iss. 1, str. 56-68, 2014.

D. Trček. Computational trust management, QAD, and its applications. *Informatica*, ISSN 0868-4952, vol. 25, no. 1, str. 139-154, 2014.

D. Trček. Qualitative assessment dynamics: complementing trust methods for decision making. *International journal of information technology & decision making*. [Online ed.], vol. 12, no. 6, str. 1-19, 2014.

I. Cuiñas, R.M. Newman, M. Trebar, L. Catarinucci, A. Alvarez Melcon. RFID-based traceability along the food-production chain. *IEEE antennas & propagation magazine*, ISSN 1045-9243. [Print ed.], vol. 56, no. 2, pp. 196-207, 2014.

A. Parreno Marchante, A. Alvarez Melcon, M. Trebar, P. Filippin. Advanced traceability system in aquaculture supply chain. *Journal of food engineering*, ISSN 0260-8774. [Print ed.], vol. 122, pp. 99-109, 2014.

D. Trček. Lightweight protocols and privacy for all-in-silicon objects. *Ad hoc networks*, ISSN 1570-8705, vol. 11, no. 5, pp. 1619-1628, 2013.

D. Trček, A. Brodnik. Hard and soft security provisioning for computationally weak pervasive computing systems in e-health. *IEEE wireless communications*, ISSN 1536-1284. [Print ed.], vol. 20, no. 4, pp. 1-8, 2013.

D. Jelenc, D. Trček. Qualitative trust model with a configurable method to aggregate ordinal data. *Autonomous agents and multi-agent systems*, ISSN 1387-2532, pp. 1-31, 2013.

D. Jelenc, R. Hermoso, J. Sabater-Mir, D. Trček. Decision making matters: a better way to evaluate trust models. *Knowledge-based systems*, ISSN 0950-7051. [Print ed.], vol. 52, pp. 147-164, 2013.

D. Trček. An integrative architecture for a sensor-supported trust management system. *Sensors*, vol. 12, no. 8, pp. 1-14, 2012.

D. Trček. Security metrics foundations for computer security. *Comput. j.*, vol. 53, no. 5, pp. 1106-1112, doi: 10.1093/comjnl/bxp094, 2010.

D. Trček. A formal apparatus for modeling trust in computing environments. *Math. comput. model* pp. 1-8, doi: 10.1016/j.mcm.2008.05.005, 2008.

D. Trček, H. Abie, A. Skomedal, I. Starc. Advanced framework for digital forensic technologies and procedures. *J Forensic Sci*, 2010, pp. 1-10, doi: 10.1111/j.1556-4029.2010.01528.x.

D. Trček, P. Jäppinen. RFID security. V: ZHANG, Yan (ur.), YANG, Laurence Tianruo (ed.), CHEN, Jiming (ed.). *RFID and sensor networks: architectures, protocols, security, and integrations (Wireless networks and mobile communications)*. Boca Raton: Taylor & Francis, pp. 147-168, 2010.

J. Hernantes, J.M. Torres, A. Lauge, J.M. Sarriegi, I. Starc, E. Zupančič, D. Trček. Using GMB methodology on a large crisis model, FRENCH, Simon (ed.), TOMASZEWSKI, Brian (ed.), ZOBEL, Christopher (ed.). *Defining crisis management 3.0: proceedings*, pp. 1-5, 2010.

D. Trček. Managing communications in critical infrastructures protection. *Proc. of the ICCSA 2010*, 2010. Vol. 1. Los Alamitos (California): Washington: IEEE Computer Society, pp. 11-15, 2010.

# Laboratory for Data Technologies

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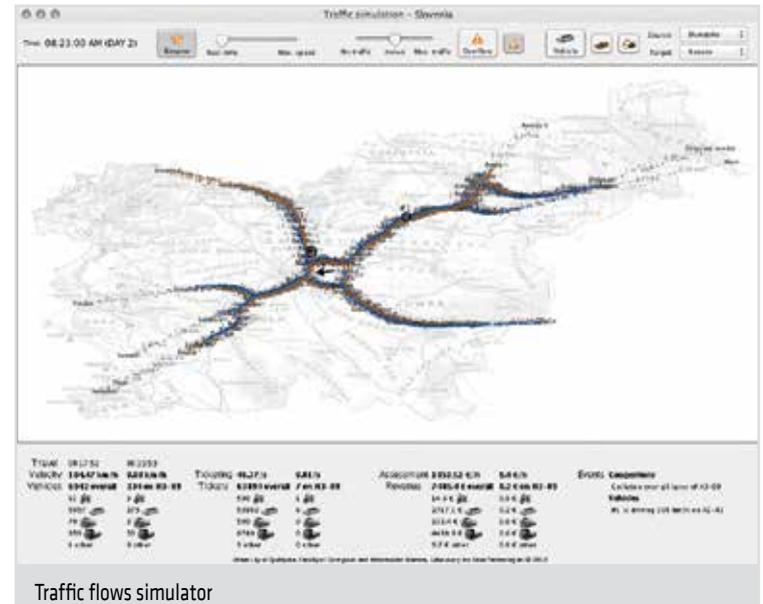
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## RESEARCH ACTIVITIES

The Laboratory for Data Technology was founded in 2009 and is one among the youngest laboratories at the Faculty for Computer and Information Science. Its members are involved in basic and applied research in the fields of data analysis, data representation, data visualization, semantic web and method engineering.

*Data analysis:* is a very broad research area. We focus on the segments of business rules management systems, business intelligence, fraud management and (social) networks. Research is divided between academic research and applicative research. Applicative research is closely connected to the fields of fraud management and transaction intensive information systems architectures.

*Data representation:* Data entities are typically represented in an ordinary flat form. However such representation is not adequate when we are interested in relations between entities or in patterns in these



relations. In that case one must employ some enhanced representation of data-like networks. Networks are the most natural representation of any relational domain (hyper pages, social networks etc.) allowing formulation of complex relations between entities. They allow the analysis of entities in the context of related entities and not in complete isolation. Networks are currently one of the hot topics in many research areas (network analysis, data mining, bioinformatics, etc.). Our research is mainly focused on analysis and mining of networks' data and using networks for fraud detection in different fields.

*Data visualization:* As the volume and complexity of data increases it becomes very difficult for users to effectively explore large-scale datasets. A possible solution for this problem is visualization (graphical representation of data). Visualizing large amounts of data allows us to see patterns that may otherwise remain hidden and it also allows us to quickly grasp and process large amounts of data that would otherwise require a lot of time to study. Visualizations are used in many fields (medicine, education, geo-visualizations, data-mining, financial data analysis etc.) and employ different visualization techniques (graphs, cluster diagrams, volume rendering etc.), but just any arbitrary visualization may not be inherently useful and may even lead to flawed conclusions. An important aspect of visualization is also dynamics of representation and interactivity (e.g. dynamical adjustment of mapping in real-time).

*Semantic web:* The current version of the World Wide Web consists of several mutually connected documents that are presented to human users by computers. These documents originated in interconnected systems where every user could contribute. This also results in the fact that information quality cannot always be guaranteed. The current World Wide Web consists of data, information and knowledge, but the role of

computers at this stage is only to deliver and represent the content of the documents that describe knowledge. To integrate different information resources users have to manually interpret these data. Semantic Web tends to improve current World Wide Web with computers processing, interpreting, integrating data on the web and with this approach aiding human users in discovering complex knowledge. Semantic Web is focused towards sharing and reusing of data and not documents. The research area emphasizes the establishment of a common framework to enable the sharing and reusing of data among applications and enterprises.

*Method Engineering (ME):* We are mainly focusing on situational method engineering (SME), which focuses on construction of methods by selecting appropriate method components from method-base which are later on tailored and integrated in a newly created development method for a specific situation. In the last two decades, a number of SME approaches have been proposed, but their application in practice is rare due to many reasons. With all that reasons in mind, we are now trying to develop innovative approaches that will simplify the use of SME principles by only marginal user involvement. On the other hand we are also interested in capturing new evidences, from real cases, about software development practice (e.g. what are organizations' base methods, what are developers and other project members doing on projects, what are reasons for declinations from base methods, how to keep base methods up-to date with knowledge gained from former projects, etc.).

## RESEARCH PROJECTS

Uniform highly available and robust application platform for telecommunications services. Industry-Funded Project, Iskratel d.d. (2013-2014).

Research on the development, usage and application of TellMeMore and WhoKnowsWho methods. Industry-Funded Project, Optilab d.o.o. (2013-2014).

Development of algorithms for network analysis in large company (430-168/2013/91). Structural Funds Project, Slovenian Ministry of Education, Science and Sport (2014-2015).

Anomally detection in operational data. Industry-Funded Project, Celtra (2014-2015).

## LABORATORY GUESTS

Prof. Dr. Dalibor Fiala, University of West Bohemia, Czech Republic, 21. 7. - 25. 7. 2014. Research collaboration on bibliometric network analysis.

## RESEARCH VISITS

Lovro Šubelj: University of West Bohemia, Czech Republic, 3. 2. - 7. 2. 2014. Research collaboration on bibliometric network analysis.

Marko Jankovič: Software Engineering Research Group at the University of Klagenfurt, 1. 3. - 1. 7. 2014. Research collaboration at prof. Dr. Martin Pinzger.

## INVITED TALKS AND LECTURES

Lovro Šubelj: Network and link analysis, February 2014, University of West Bohemia, Czech Republic.

Lovro Šubelj: Detecting groups of nodes in networks by label propagation, January 2014, Faculty of Information Studies in Novo mesto, Slovenia.

## SELECTED PUBLICATIONS

S. Žitnik, M. Žitnik, B. Zupan, M. Bajec. Sieve-Based Relation Extraction of Gene Regulatory Networks from Biological Literature in BMC Bioinformatics, pp. 1-23, 2014.

S. Žitnik, L. Šubelj, M. Bajec. SkipCor: Skip-Mention Coreference Resolution using Linear-Chain Conditional Random Fields in PLoS One, 9(6), pp. 1-14, 2014.

L. Šubelj, S. Žitnik, N. Blagus, M. Bajec. Node mixing and group structure of complex software networks in Advances in Complex Systems, 17, 1450022, pp. 1-26, 2014.

L. Šubelj, D. Fiala, M. Bajec. Network-based statistical comparison of citation topology of bibliographic databases. Scientific Reports, 4, 6496, 2014.

L. Šubelj, S. Žitnik, N. Blagus, M. Bajec. Node mixing and group structure of complex software networks. Advances in Complex Systems, 17, 1450022, 2014.

L. Šubelj, M. Bajec. Group detection in complex networks: An algorithm and comparison of the state of the art. Physica A: Statistical Mechanics and its Applications, 397, 144-156, 2014.

N. Blagus, L. Šubelj, M. Bajec. Assessing the effectiveness of real-world network simplification. Physica A: Statistical Mechanics and its Applications, 413, 134-146, 2014.

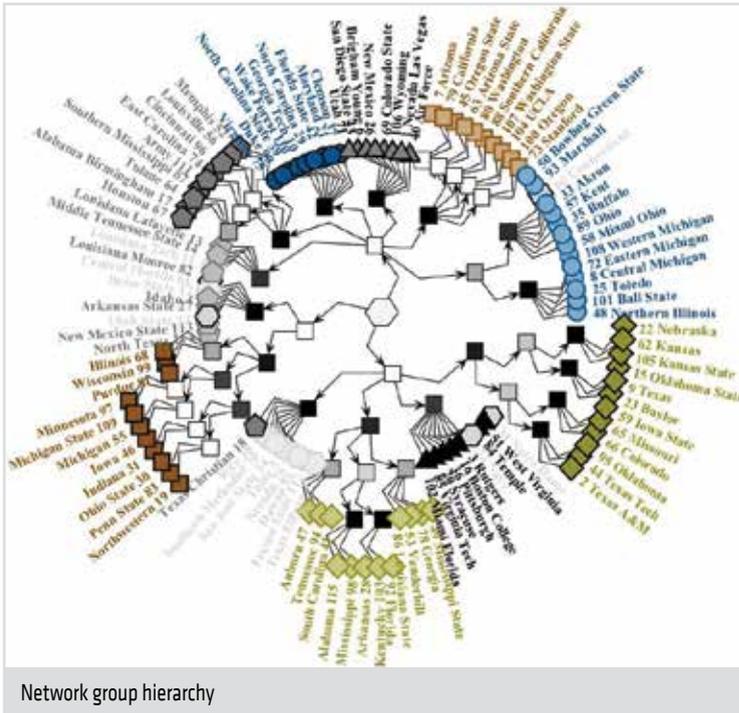
M. Jankovič, S. Žitnik, L. Šubelj, N. Blagus, A. Zrnec, M. Bajec. Improvement of software development method with minimal involvement of developers in Uporabna Informatika, 22(1), pp. 1-12, 2014.

N. Blagus, L. Šubelj, A. Zrnec, M. Jankovič, M. Bajec. Ohranjanje lastnosti pri zmanjševanju družbenih omrežij. Uporabna informatika, ISSN 1318-1882, letn. 22, št. 3, str. 127-136, 2014.

N. Blagus, M. Bajec. Omrežje sodelovanj med slovenskimi raziskovalci na področju informatike. V: RAJKOVIČ, Vladislav (ur.), et al. Informatika - neizkoriščeni dejavniki razvoja: zbornik. 1. izd. Ljubljana: Slovensko društvo Informatika, str. 1-10, 2014.

L. Šubelj, Z. Bosnić, M. Kukar, M. Bajec. Automatization of the stream mining process. In: Proceedings of the International Conference on Advanced Information Systems Engineering (CAISE '14), pp. 409-423, 2014.

L. Šubelj, M. Bajec. Network group discovery by hierarchical label propagation. In: Proceedings of the European Social Networks Conference (EUSN '14), pp. 284, 2014.



L. Šubelj, G. Weiss, N. Blagus, M. Bajec. What coins the bitcoin? Exploratory analysis of bitcoin market value by network group discovery. In: Proceedings of the International Conference on Network Science (NetSci '14), pp. 1, 2014.

L. Šubelj, S. Žitnik, M. Bajec. Who reads and who cites? Unveiling author citation dynamics by modeling citation networks. In: Proceedings of the International Conference on Network Science (NetSci '14), pp. 1, 2014.

N. Blagus, L. Šubelj, G. Weiss, M. Bajec. Large networks grow smaller: How to choose the right simplification method. In: Proceedings of the International Conference on Network Science (NetSci '14), pp. 1, 2014.

## AWARDS AND RECOGNITIONS

In 2014, Marko Bajec received a Gold Plaque from the University of Ljubljana for his achievements in pedagogical and research work.

In 2014, Marko Bajec received the Mentor of the Year Award 2014 from Slovenian association of young researchers.

# Laboratory for Integration of Information Systems

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## RESEARCH ACTIVITIES

The Laboratory for Integration of Information Systems has been focusing on the research and development in the field of integration and interoperability of applications, devices, information systems, architectures and platforms. Integration and interoperability is an important topic and covers all aspects of software and information systems development. Laboratory for Integration of Information Systems focuses specifically on software platforms, particularly Java Enterprise Edition, HTML5, Service Oriented Architectures (SOA) and Cloud Computing (with focus on IaaS/PaaS/SaaS).

We research technologies, which enable execution, configuration and adaptation of business processes in wider and comprehensive scenarios. Cloud



Computing represents technologies that provide computation, software, data access, and storage services via the internet. It enables to address new areas and to develop innovative software solutions, IT services, and efficient cost-effective usage of information resources. This technology provides significant progress in the economy, government and academic circles, particularly in the field of competitiveness, business optimization and innovation. Our laboratory conducts research, development and mentoring for the development of complex Java EE and BPM/SOA solutions, e-services and e-content, and Cloud Computing solutions. This allows to address new areas and to find innovative solutions.

In collaboration with important partners such as Oracle, IBM, and Microsoft we are working on many projects that incorporate following research fields and technologies:

- Integration and interoperability methods of information systems
- Cloud computing (IaaS, PaaS, SaaS):
  - Infrastructure as a Service
  - Platform as a Service
  - Software as a Service
- Business Process Management (BPM):
  - Modelling business processes
  - Executing business processes
  - Integrated BPM/SOA life cycle
  - Service design based on the concept of service science
- Internet of Things
- Client side web development
- Modern multitier architectures
- Java Enterprise Edition, Java EE and .NET platforms
- Architectural and technological aspects of integration and interoperability
- Middleware
- Integration platform technologies
- Service platforms and Web services
- Application and Process Servers

## RESEARCH PROJECTS

Model for domain-specific forecasting trends based on semantic enrichment of unstructured samples (J5-5552). Research project, Slovenian Research Agency (2013-2016).

Ubiquitous Computing (P2-0359). Programme group, Slovenian Research Agency (2009-2017). FLEXICIENCY - services demonstration on demand response, FLEXibility and energy efficiency based on metering data. Horizon 2020 LCE 7 European project, European Commission (2015-2019).

AGROIT - Increasing the efficiency of farming through on open standards based AgrolT platform. FP European project, European Commission (2014-2016).

R&D and Knowledge Transfer Collaboration. Industry Funded Project, Akrapovic d.d., 2014.

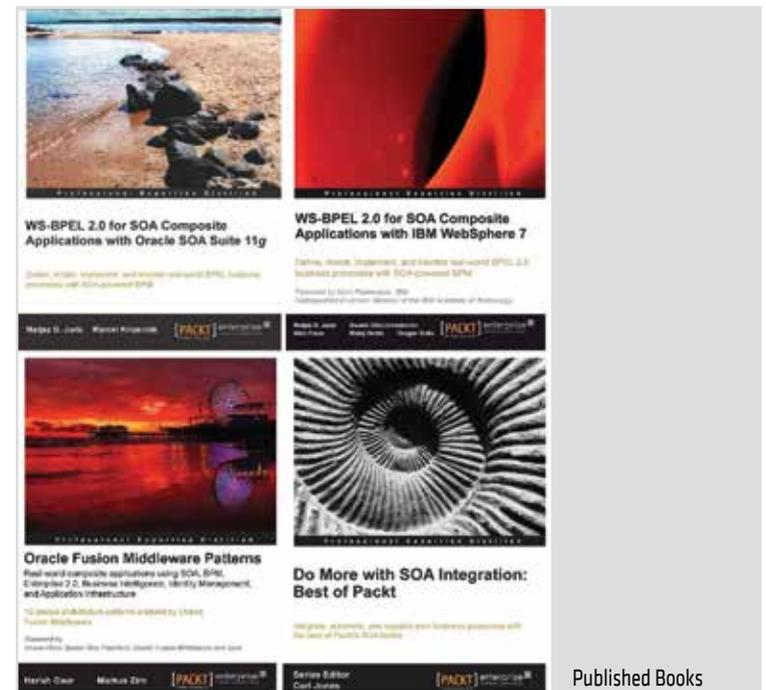
Process-aware Information Systems Research and Development. Industry Funded Project, Informatika d.d. (2010-2014).

SOA-RIJS (SOA and the concept of cloud services in the case of RIJS system). Industry-Funded Project, Ministry of Public Administration, 2014.

Information System Architecture and Java, BPM/SOA and Integration R&D. Industry Funded Project, Poštna banka Slovenije, d.d., 2014.

R&D Collaboration and Knowledge Transfer. Industry Funded Project, SRC d.o.o., 2014.

Slovenian Innovation Forum, SPIRIT. Public Agency of the Republic of Slovenia for the Promotion of Entrepreneurship, Innovation, Development, Investment and Tourism, Industry-Funded Project, 2014.



BlueMix Cloud Platform. Industry-Funded Project, IBM Slovenia, 2014.  
OpenStack Research. Industry-Funded Project, XLAB, 2014.

## INVITED TALKS AND LECTURES

Miha Nagelj: Best practices for using HTML5 and AngularJS with Java EE. 20. 10. 2014, the 19. Expert Meeting SIOUG and JavaSi, Ljubljana, Slovenia.

Matjaž B. Jurič: What's new in SOA and BPM Suite 12c, and how to deal with business processes in the cloud with Oracle Process Cloud Service, 13. 10. 2014, the 19. Expert Meeting SIOUG and JavaSi, Ljubljana, Slovenia.

## SELECTED PUBLICATIONS

M. Potočnik, M.B. Jurič. Towards complex event aware services as part of SOA. IEEE transactions on services computing, ISSN 1939-1374, vol. 7, no. 3, pp. 486-500, illustr. <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6461877>, doi: 10.1109/TSC.2013.7, 2014.

M. Hertiš, M.B. Jurič. An empirical analysis of business process execution language usage. IEEE transactions on software engineering, ISSN 0098-5589, vol. 40, no. 8, pp. 738-757, graph. repr. <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6812231>, 2014.

A. Kocbek, M.B. Jurič. Towards a reusable fault handling in WS-BPEL. International journal of software engineering and knowledge engineering, ISSN 0218-1940, vol. 24, no. 2, pp. 243-267, illustr., doi: 10.1142/S0218194014500107, 2014.

M. Pušnik, K. Harej, M. Heričko, M.B. Jurič, B. Šumak. Investigation of developer's perceptions in XML schema development using textual and visual tool types. International journal of software engineering and knowledge engineering, ISSN 0218-1940, vol. 24, no. 3, pp. 445-463, doi: 10.1142/S021819401450017X, 2014.

R. Povše, M.B. Jurič. Model for integration, migration and backup of SaaS applications via a common data model. Elektrotehniški vestnik, ISSN 0013-5852, vol. 81, no. 3, pp. 81-85, illustr. <http://ev.fe.uni-lj.si/3-2014/Povse.pdf>, 2014.

M.B. Jurič, D. Weerasiri. WS-BPEL 2.0: beginner's guide: design and develop WS-BPEL executable business processes using Oracle SOA Suite 12c, (Learn by doing). Birmingham (UK): Packt Publishing, cop. 2014. VII, 365 pp., illustr. ISBN 978-1-84968-896-3, 2014.

A. Frece, M.B. Jurič. Complete and reusable description of message structural constraints in web service interfaces. Computer Standards and Interfaces, 35(2): 218-230, 2013.

J. Laznik, M.B. Jurič. Context aware exception handling in business process execution language. Information and Software Technology, 55(10): 1751-1766, 2013.

G. Srdić, M.B. Jurič. Model for integrated monitoring of BPEL business processes. International Journal of Cooperative Information Systems, 22(2): 1-29, 2013.

R. Dukarič, M.B. Jurič. A taxonomy and survey of infrastructure-as-a-service systems. Lecture notes on information theory. 1(1): 29-33, 2013.

## PATENTS

Anton Zvonko Gazvoda, Matjaž B. Jurič. Generic method for automatic data integration based on event-driven architecture. Ljubljana: The Slovenian Intellectual Property Office (SIPO), 2014.

Robert Dukarič, Matjaž B. Jurič. Compensation Management in Cloud Computing Orchestration Devices, Ljubljana: The Slovenian Intellectual Property Office (SIPO), 2013.

## AWARDS AND RECOGNITIONS

Jure Tuta, Characterisation and automatic quality detection of pumps in washing machines / Jure Tuta. - Ljubljana: [J. Tuta], 2014. - 71 str : ilustr.; 30 cm (Faculty Prešeren Award).

*Certificates:* Java Champion, IBM Champion, Oracle ACE Director, Certified IBM SOA Solution Designer, Certified SOA Associate, Oracle Service Oriented Architecture Infrastructure Implementation Certified Expert, Certified IBM SOA Associate, Certified IBM Solution Advisor for Cloud Computing, Certified IBM SOA Associate, IBM Certified Solution Architect - Cloud Computing Infrastructure, Certified Cloud Computing Engineer (C3E), IBM Certified SOA Solution Designer, IBM Certified Developer - WebSphere Application Server Developer Tools V8.5 with Liberty Profile, IBM Certified BPM Application Developer - Business Process Manager Express or Standard Edition V8.0, Certification for IBM PureFlex Systems.

# Laboratory for Algorithms and Data Structures

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## RESEARCH ACTIVITIES

Staff members perform research in the areas of approximation and randomized algorithms, algorithms for problems in combinatorial optimization (routing, covering, and location problems, flexibility in optimization problems), parallel computation (mapping and scheduling, algorithms in parallel systems), grid computing (data replication on Data Grids, P2P-based distributed search), compiler design (parsing methods and attribute grammars), linear algebra (matrix multiplication), and operating systems design. As of 2006, the Laboratory is a member of the PlanetLab, an open platform for developing, deploying, and accessing planetary-scale services.

## RESEARCH PROJECTS

Parallel and Distributed Systems (P2-0095). Research Programme, jointly with Jožef Stefan Institute and the Faculty of Electrical Engineering, University of Ljubljana, Slovenian Research Agency (2009-2016).

## SELECTED PUBLICATIONS

U. Čibej, B. Robič, J. Mihelič. Empirical estimation of the halting probabilities. *Computability in Europe (CiE)*, Budapest, 23. 6. – 27. 6. 2014.

M. Bezenšek, B. Robič. A survey of parallel and distributed algorithms for the Steiner tree. *International Journal of Parallel Programming*, 42 (2):239-264, 2013.

M. Cankar, M. Artač, M. Šterk, U. Lotrič, B. Slivnik. Co-allocation with collective requests in grid systems. *Journal for Universal Computer Science*. 19(3):282-300, 2013.

R. Češnovar, V. Risojevič, Z. Babič, T. Dobravec, P. Bulič. A GPU implementation of a structural-similarity-based aerial-image classification. *The Journal of Supercomputing*, 65(2):978-996, 2013.

U. Čibej, J. Mihelič. Search strategies for subgraph isomorphism algorithms. V: *First International Conference on Applied Algorithms*, Kolkata, India, 13. 1. – 14. 1. 2014, (Lecture Notes in Computer Science).

J. Mihelič, T. Dobravec. SicSim: a simulator of the educational SIC/XE computer for a system-software course. *Computer Applications in Engineering Education*, doi: 10.1002/cae.21585, 2013.

I. Rožanc, B. Slivnik. Using reverse engineering to construct the platform independent model of a web application for student information systems. *Computer Science and Information Systems*, 10(4):1557-1583, 2013.

W. Stallings, J. Mihelič, B. Klemenc, P. Peer. *Koncepti operacijskih sistemov z Linuxovo lupino in programiranjem v Bashu*. Pearson, 2013.

B. Slivnik. LLLR parsing. *Proc. of the 28th annual ACM Symposium on Applied Computing SAC-2013*, pp. 1698-1699, Coimbra, Portugal, 2013.

# Laboratory for Architecture and Signal Processing

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## RESEARCH ACTIVITIES

The Laboratory for Architecture and Signal Processing is dedicated to research, undergraduate and postgraduate education in computer architecture and digital signal processing. The laboratory is engaged in national and international research projects that include development projects for the industry. The following areas of research are currently being pursued:

- In Computer Architecture:* Design and development of special-purpose computers, both hardware and software. Comparative studies of superscalar and VLIW processors. DSP processor design and architecture. Cache replacement and coherence preservation strategies. Input/output architectures. Integrated entertainment and automation systems for "smart home" houses.
- In Digital Signal Processing:* Design and development of algorithms, hardware and software. Complexity of integer minimax approximation

problem. Theoretical aspects and performance bounds for finite word-length digital filters. In particular, bounds for minimax integer polynomial approximation over collections of non-overlapping intervals are investigated. A general purpose finite wordlength FIR design programme was developed during the course of this work. Various applications of DSP processors are studied and implemented. Among them is a low-cost DSP processor based spectrum and vibration analyser that is now in production.

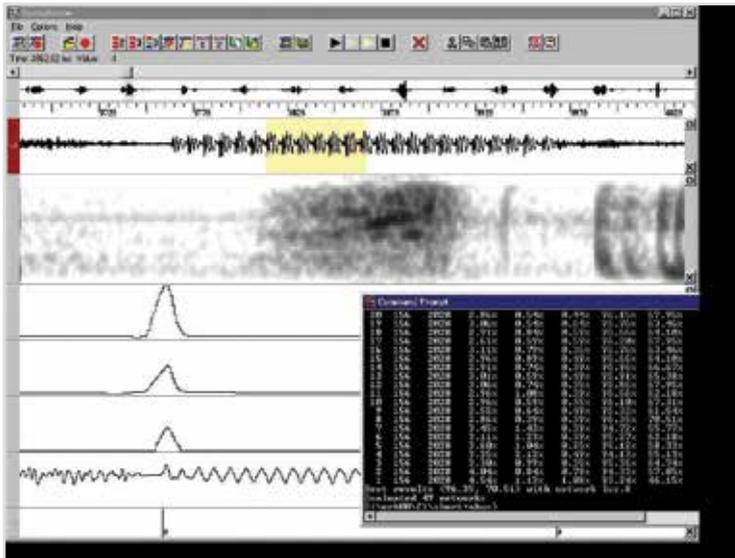
3. *In Speech Processing:* Speech recognition over telephone lines. Trainable high quality speech synthesis. Considerable experience from collaboration in the COST-232 European project has been acquired. The laboratory contributed to the collection of the European multi-English database. In the framework of a project with the Slovenian Telekom one of the first real-time systems for speaker-independent recognition of Slovenian digits and control words over the telephone has been developed. A national database of 780 speakers from all across Slovenia has been collected. A new technique that uses asymmetrical window functions for feature extraction and dynamically adjusted window length was tested and implemented.

## RESEARCH PROJECTS

Parallel and Distributed Systems (P2-0095). Research Programme, jointly with Jožef Stefan Institute and Faculty of Electrical Engineering, University of Ljubljana, Slovenian Research Agency (2009-2016).

## SELECTED PUBLICATIONS

- D.M. Kodek. Length limit of optimal finite wordlength FIR filters. Digital signal processing, vol. 23, no. 5, pp. 1798-1805, 2013.
- P. Bulič, V. Guštin, D. Šonc, A. Štrancar. An FPGA-based integrated environment for computer architecture. Computer applications in engineering education, vol. 21, no. 1, str. 26-35, 2013.
- R. Rozman. Simplified design of the speech recognition system. Electrotechnical review, vol. 80, no. 4, pp. 171-176, 2013.
- D. M. Kodek. LLL algorithm and the optimal finite wordlength FIR design. IEEE Transactions on Signal Processing, vol. 60, no. 3, pp. 1493-1498, 2012.
- A. Božiček. Finite wordlength linear-phase FIR filter design using Babai's algorithm. Signal processing, vol. 6, no. 5, str. 146-152, 2012.
- D. Stanjko, P. Beer, M. Lešnik, V. Jejčič, M. Lakota, A. Štrancar, M. Hočevar, J. Rakun. Programmable ultrasonic sensing system for targeted spraying in orchards. Sensors, vol. 12, no. 11, pp. 15500-15519, 2012.
- V. Jejčič, T. Godeša, M. Hočevar, B. Širok, A. Malneršič, A. Štrancar, M. Lešnik, D. Stanjko. Design and testing of an ultrasound system for targeted spraying in orchards. Strojniški vestnik, vol. 57, no. 7/8, str. 587-598, 2011.
- R. Rozman, D. M. Kodek. Using asymmetric windows in automatic speech recognition. Speech Communication, vol. 49, no. 4, pp. 268-276, 2007.
- D. M. Kodek, M. Krisper. Telescopic rounding for suboptimal finite



Speech recognition system that students use during the Digital Signal Processing course

wordlength FIR digital filter design. *Digital Signal Processing*, vol. 15, no. 6, pp. 522-535, 2005.

D. M. Kodek, M. Krisper. Optimal algorithm for minimizing production cycle time of a printed circuit board assembly line. *International Journal of Production Research*, vol. 42, no. 23, pp. 5031-5048, 2004.

## Software Engineering Laboratory

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### RESEARCH ACTIVITIES

The Software Engineering Laboratory is involved in teaching and researching in the areas of Software Engineering and Information Systems with an emphasis on Agile Software Development Methods, Graph Grammars and Graph Algorithms, Model Driven Development, and Web Data Mining. The following areas of research are currently being pursued:

- In Agile Software Development Methods:* Factors affecting successful adoption. Agile project management. Performance evaluation. Balancing agility and discipline. Introduction of lean concepts.
- In Graph Grammars and Graph Algorithms:* Graph grammars as a generalization of string grammars. Parsing graph grammars and translating graph-based languages. Graph grammar induction. Graph grammars in software engineering. Graph data mining and general graph algorithms.
- In Model Driven Development:* Reverse Engineering of Web Applications to produce Platform Independent Model.

4. In *Web Data Mining and User Behaviour Analysis*: Clickstream data mining. Using stochastic models for user behaviour analysis. Separating interleaved web sessions using heuristic methods and graph search algorithms.

## RESEARCH PROJECTS

Introducing Scrum in the development process of a small software development company. Industry-Funded Project, Pronet, d.o.o. (2014- ).

## SELECTED PUBLICATIONS

J. Mihelič, L. Fürst, U. Čibej. Exploratory equivalence in graphs: definition and algorithms. Proceedings of the 2014 Federated Conference on Computer Science and Information Systems, Warsaw, Poland, pp. 447-456, 2014.

V. Mahnič, T. Hovelja. Teaching user stories within the scope of a software engineering capstone course: analysis of students' opinions. *International journal of engineering education*, 30(4): 901-915, 2014.

I. Rožanc, M. Požanel. Reconstruction of the web application hypertext model using web logs. Proceedings of the IASTED International Conference on Informatics, Innsbruck, Austria, pp. 148-155, 2014.

I. Rožanc, B. Slivnik. On the appropriateness of domain-specific languages derived from different metamodels. QUATIC 2014 proceedings. Piscataway: IEEE, pp. 190-195, 2014.

L. Fürst, M. Mernik, V. Mahnič. Converting metamodels to graph grammars: doing without advanced graph grammar features. To appear in *Software and Systems Modeling*, <http://link.springer.com/article/10.1007/978-3-319-270-013-0380-2#page-1>, 2013.

L. Fürst, V. Mahnič. Introductory programming course: motivating students with prior knowledge. *World Transactions on Engineering and Technology Education*, 11(4): 400-405, 2013.

I. Rožanc, B. Slivnik. Using reverse engineering to construct the platform independent model of a web application for student information systems. *Computer Science and Information Systems*, 10(4): 1557-1583, 2013.

M. Požanel. Assessing teamwork in a software engineering capstone course. *World transactions on engineering and technology education*, 11(1): 6-12, 2013.

V. Mahnič, T. Hovelja. On using planning poker for estimating user stories. *Journal of Systems and Software*, 85(9): 2086-2095, 2012.

V. Mahnič. A capstone course on agile software development using Scrum. *IEEE Transactions on education*, 55(1): 99-106, 2012.

L. Fürst, M. Mernik, V. Mahnič. Graph grammar induction as a parser-controlled heuristic search process. *Lecture notes in computer science* 7233, 121-136, 2012.

V. Mahnič, N. Žabkar. Measuring progress of Scrum-based software projects. *Electronics and Electrical Engineering*, 18(8): 73-76, 2012.

I. Rožanc, B. Slivnik. Producing the platform independent model of an existing web application. Proceedings of the Federated Conference on Computer Science and Information Systems, Wrocław, Poland, pp. 1341-1348, 2012.

L. Fürst, M. Mernik, V. Mahnič. Improving the graph grammar parser of Rekers and Schürr. *IET Software*, 5(2): 246-261, 2011.

V. Mahnič. A case study on agile estimating and planning using Scrum. *Electronics and Electrical Engineering*, 2011. No. 5: 123-128, 2011.

M. Požanel, V. Mahnič, M. Kukar. Separation of interleaved Web sessions with heuristic search. 10th IEEE International Conference on Data Mining, Sydney, Australia, pp. 411-420, 2010.

# Computer Vision Laboratory

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## RESEARCH ACTIVITIES

The laboratory is dedicated to research in computer vision and multimedia.

Topics that are of interest are capture, processing and interpretation of 3D visual data, understanding and interpretation of the human form in images (face detection, face recognition, gait recognition, fingerprint recognition), machine learning in computer vision, and the use of images in computer-human interaction.

Application areas that we work in are interpretation of medical images, interactive visual signage systems, 3D documentation in archaeology and cultural heritage, multimedia applications for learning sign language, recognition of text in natural and urban scenes, computer games, forensic analysis of images and video, analysis of images in sports, information design, and interactive new media art installations.

An ongoing collaboration with the New media department of the Academy of Fine Arts at the University of Ljubljana supports the creation of interactive art installations using the latest information technology.

Art projects serve as an excellent framework for testing research ideas in practical applications.

## RESEARCH PROJECTS

Computer vision (P2-0214). Basic Research Programme, Slovenian Research Agency (2009-2014).

Consulting with 3D scanning and modeling in archaeology. Industry-Funded Project, Magelan skupina, raziskave, proizvodnja, trgovina in storitve, d.o.o., Kranj (2011-).

Gait recognition. Industry-Funded Project, Mega M d.o.o. (2011-2014).

Fingerprints recognition system. Industry-Funded Project, Mega M d.o.o., MIEL d.o.o. (2011-2014).

Innovative services for persons with complex communication needs. Bilateral Project (Faculty of Graphic Arts, University of Zagreb, Croatia), 2014.

## RESEARCH VISITS

P. Peer, Faculty of Graphic Arts, University of Zagreb, Croatia, 16. 6. – 19. 6. 2014. Project meeting and dissemination event.

P. Peer, Department of Computer Science, Columbia University, NY, USA, 28. 10. 2014. Research meeting.

## INVITED TALKS AND LECTURES

N. Bovcon, A. Vaupotič: Digital humanities, new media art and information visualization, 5. 10. – 10. 10. 2014. In: Design Biotop, Poligon, Poligon Creative centre, Ljubljana, Slovenia.

F. Solina: The role of information technology in modern art (Vloga informacijske tehnologije v novomedijski umetnosti), 15. 4. 2014, Days of Slovenian Informatics conference (Dnevi slovenske informatike), Portorož, Slovenia.

## SELECTED PUBLICATIONS

M. Erič, A. Gaspari, K. Čufar, F. Solina, T. Verbič. Early Roman barge from the Ljubljanica River at Sinja Gorica (Zgodnjerimska ladja iz Ljubljane pri Sinji Gorici), *Arheol. vestn.* 65: 187-254, 2014.

N. Bovcon. Literary aspects in new media art works, *CLCWeb* (Edmont.) 15(7): 1-13, 2014.

F. Solina, G. Majcen, N. Bovcon, B. Batagelj. Preservation of a computer-based art installation. In: *Digital heritage: progress in cultural heritage: documentation, preservation, and protection: 5th International Conference, EuroMed 2014, Limassol, Cyprus: proceedings*, (LNCS 8740), Marinos Ioannides, Ed., et al, Heidelberg [etc.], Springer, 2014, pp. 643-650, 2014.

R. Ravnik, B. Batagelj, B. Kverh, F. Solina. Dynamic anamorphosis as a special, computer-generated user interface. *Interact. comput.* 2(1): 46-62, 2014.

P.I. Nam, R. S. Jin, P. Peer. Robust eye localization by combining classification and regression methods. *ISRN appl. math.* 2014: 1-7, 2014.

J. Bule, P. Peer. Technical, legal, economic and social aspects of biometrics for cloud computing. *J. inf. organ. sci.* 38(2): 83-95, 2014.

N. Bovcon. Jezik gibljivih slik v računalniških vizualizacijah literarnozgodovinske podatkovne zbirke, In: *Literatura in gibljive slike: tematski sklop: thematic section*, *Primerjalna književnost* 37(2): 119-133, 235-242, 2014.

R. Kreslin, P.M. Calvo, L.G. Corzo, P. Peer. Linear chromatic adaptation transform based on Delaunay triangulation. *Math. probl. eng. (Print)* 2014: 1-9, 2014.

P. Peer, Ž. Emeršič, J. Bule, J. Žganec Gros, V. Štruc. Strategies for exploiting independent cloud implementations of biometric experts in multibiometric scenarios. *Math. probl. eng. (Print)* 2014: 1-15, 2014.

J. Kovač, P. Peer. Human skeleton model based dynamic features for walking speed invariant gait recognition. *Math. probl. eng. (Print)* 2014: 1-15, 2014.

R. Ravnik, F. Solina, V. Žabkar. Modelling in-store consumer behaviour using machine learning and digital signage audience measurement data, In: *Video analytics for audience measurement: First International Workshop, VAAM 2014, Stockholm, Sweden: revised selected papers*, (LNCS 8811), Springer, 2014, pp. 123-133, 2014.

A. Vaupotič, N. Bovcon. Integracija pesniške zbirke balada za Metko Krašovec Tomaža Šalamuna v medij videa. In: *Obzorja jezika - obnebja jezika: poezija Tomaža Šalamuna*, Zagreb, FF Press, pp. 173-183, 2014.

F. Solina, S. Dragan. Novomedijski umetniški projekti kot most med realnim in virtualnim svetom. In: *Robotika in umetna inteligenca*, T. Bajd, I. Bratko, Eds., Ljubljana, Slovenska matica., pp. 187-230, 2014.

P. Peer, A. Jaklič, L. Šajn. A computer vision based system for a rehabilitation of a human hand. *Periodicum biologorum*, ISSN 0031-5362, vol. 115, no. 4, str. 535-544, 2013.

## AWARDS

Narvika Bovcon, Aleš Vaupotič. The May Salon Award (Priznanje Majskega salona), 2014.

## EXHIBITIONS

B. Bensa, N. Bovcon, A. Vaupotič, et al. *Voyage II: The May Salon Water* (Potovanje II: majskega salona Voda), June 2014, Korotan, Vienna, Austria, 2014.

V. Mervič, N. Bovcon, A. Vaupotič. Opening of the Microscopy and Spectroscopy Centre of the UNG in Ajdovščina; "SEM" art exhibition (SEM: Center za mikroskopijo in spektroskopijo v Raziskovalnem središču Univerze v Novi Gorici v Ajdovščini), 27. 3 - 30. 9. 2014, Ajdovščina, 2014.

A. Gruden Dannenberg, M. Batinič, N. Bovcon, A. Vaupotič, M. Igor Bravničar, R. Černelč, S. Dragan, J. Fingušt Prebil, V. Gačina, K. Gorup, A. Grobler, B. Kavčič, E. L. Kozak, A. Šakti Kralj, D. Križan, G. Krnc, B. Lapajne, D. Mahnič, V. Mervič, K. Kesherović, N. Oblak, P. Novak, A. Schaub, S.



Photogrammetrically obtained 3D point cloud of Roman sarcophagi cargo on a Roman shipwreck near Sutivan, Island Brač, modeled with superimposed superquadric models.

Sedlaček, K. Skušek, N. Skušek, F. Solina, Z. Srdić Janežič, E. Stermitz, K. Tomšič, J. Zajac Slapničar, T. Žbona, B. Batagelj, P. Peer, S. Juvan, G. Majcen. *Video, et gaudeo: Celebrating 15 years of ArtNetLab* (Video, et gaudeo: 15 let Društva za povezovanje umetnosti in znanosti ArtNetLab), 1. 12. - 16. 12. 2014, Galerija ZDSLU, Ljubljana, 2014.

M. Bahovec, N. Bovcon, A. Vaupotič, et al. *Water: The May Salon* (Voda: majskega salona), 26. 6. - 31. 8. 2014, Lokarjeva galerija Ajdovščina, Slovenia, 2014.

N. Bovcon, M. Duh, A. Krašna, P. Marolt, A. Vaupotič, et al. *Exhibition: "Water: The May Salon"* (Voda : Majskega salona), Association of Slovenian Artists (Zveza društev slovenskih likovnih umetnikov), Gospodarsko razstavišče Ljubljana, Slovenia, 15. 5. - 16. 6. 2014.

## EXPERTISE

B. Batagelj, Computer Science Expertise in a criminal case, no. II K 7583/2010 (Izvedensko mnenje računalniške stroke v kazenski zadevi opr. št. II K 7583/2010), District court Novo mesto, Slovenia, 2014.

# Visual Cognitive Systems Laboratory

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\* With the University of Birmingham, School of Computer Science, Centre for Computational Neuroscience and Cognitive Robotics, and 10 % with FRI.

\*\* Also with the Machine Vision Laboratory at the Faculty of Electrical Engineering.

## RESEARCH ACTIVITIES

Visually enabled cognitive systems are intelligent artificial systems that use vision among other sensors in order to act and interact in everyday situations. Examples include mobile robots, intelligent environments, smart mobile devices, intelligent transportation systems, cognitive assistants, etc. The Visual Cognitive Systems Laboratory is involved in basic and applied research of such systems, with emphasis on visual learning, recognition, categorization, and tracking.

Research in the area of visually enabled cognitive systems focuses on various theories regarding requirements, architectures, forms of representation, kinds of ontologies and knowledge, and varieties of mechanisms relevant to integration and control of vision systems. In this context, cognitive vision implies functionalities for knowledge representation, learning, reasoning about events and structures,



Visual tracking using a smart mobile device

recognition and categorization, and goal specification, all of which are concerned with the semantics of the relationship between the visually enabled agent and its environment. This requires a vast effort in a multidisciplinary understanding of cognitive processes, involving studies in cognitive psychology, neuroscience, and linguistics.

In the past, our research in the area of visual learning and recognition has primarily focused on subspace methods, which enable direct view-based building of visual representations and subsequent visual recognition of objects, scenes, and activities. Our main research achievement in the framework of subspace methods is development of robust approaches to both learning and recognition. We have also developed methods for incremental subspace learning that enable updating of representations and therefore facilitate continuous life-long visual learning.

Recently, continuous learning has become a major topic of our research; we have been developing both, low-level incremental learning methods (based on mixture models), as well as a high-level general framework for continuous learning of categorical knowledge. This learning is performed in an interactive manner in a dialogue with a human; we have been exploring different learning strategies ranging from fully autonomous to completely tutor guided learning, in simulation as well as on real robots. Our research has also shifted towards learning scalable representations suitable for recognition and detection of a large number of object categories. Within this framework, we developed an approach, which learns a hierarchy of spatially flexible compositions in an unsupervised, statistics-driven manner. Visual tracking has also been very important research topic recently. We developed a novel class of coupled-layer visual model trackers that combines the target's global and local appearance, leading to a more robust tracking through significant appearance

changes. Members of the lab also play a major role in organization of the Visual object tracking challenges, which are annually held at major computer vision conferences. Applications include recognition of objects, scenes, and activities in visual cognitive tasks, such as surveillance and cognitive assistants. In mobile computing, we are developing methods that use visual context and geo-referenced intelligent maps for smart vision-based positioning, and for direct camera based interaction with objects in urban environments, as well as other computer vision approaches applicable on smart mobile devices.

## EQUIPMENT

Our theoretical findings on visual tracking, learning and recognition are often integrated and implemented on mobile robots. Specifically, we use two in-door and one out-door mobile platforms equipped with monocular, omnidirectional, stereo, and RGBD camera setups. We are also implementing direct interaction and object manipulation with a Katana HD6M light weighted robot arm. The laboratory is also equipped with several low cost robotic mobile platforms such as TurteBots and AR.Drone quadcopters. On the other hand, the research in mobile computing is being integrated and tested on the state of the art mobile phones and tablets, which come equipped with numerous sensors and enough computing power and connectivity to support the development of ubiquitous visually aware cognitive agents. Both robots and gadgets shall ultimately be able to perceive and understand their environment through interaction, to categorize and recognize objects and subjects around them as well as actions they are performing, and will be able to communicate with humans and other agents on a semantic level.

## RESEARCH PROJECTS

Computer vision (P2-0214). Basic Research Programme, Slovenian Research Agency (2009-2014).

Learning, analysis, and detection of motion in the framework of a hierarchical compositional visual architecture (J2-4284). Basic Research Project, Slovenian Research Agency (2011-2014).

Development of a system for measuring feet with smart mobile devices. Industry-Funded Project, UCS d.o.o. (2013-2014).

Autonomous tracking and control for next-generation videoconferencing devices. Industry-Funded Project, Mottr (2013-2014).

Maintenance of large databases using visual information and incremental learning (L2-6765). Applied Research Project, Slovenian Research Agency (2014-2017).

## RESEARCH VISITS

Domen Tabernik: University of Birmingham, School of Computer Science, Birmingham, UK, 11. 3. - 20. 3. 2014. Research on hierarchical compositional models.

## INVITED TALKS AND LECTURES

Aleš Leonardis: Robots learning from experiences, 16. 2. - 22. 2. 2014, Dagstuhl Seminar, Dagstuhl, Germany.

Matej Kristan: Online Kernel Density Estimation for learning and classification, 8. 4. 2014, an invited talk at the Graz University of Technology, Austria.

Danijel Skočaj: Knowledge gap detection for interactive continuous learning of categorical knowledge, 25. 9. 2014, an invited talk at IDIAP, Martigny, Switzerland.

Aleš Leonardis: Hierarchical Compositional Representations of Object Structure, 6. 11. 2014, a keynote talk at the Eighth ACM/IEEE International Conference on Distributed Smart Cameras ICDS-C 2014, Venice, Italy.

Matej Kristan: The Visual Object Tracking VOT2014 challenge results, 2. 12. 2014, an invited talk at the IEEE workshop on visual object detection challenge VOT2014, Zurich, Switzerland.

Danijel Skočaj: Subspace methods (for visual learning and recognition), 5. 12. 2014 and 12. 12. 2014, an invited seminar at University of Udine, Udine, Italy.

## SELECTED PUBLICATIONS

M. Kristan, A. Leonardis. Online Discriminative Kernel Density Estimator with Gaussian Kernels. *IEEE transactions on cybernetics*, vol. 44, no. 3, pp. 355-365, 2014.

N. Krüger, P. Janssen, S. Kalkan, M. Lappe, A. Leonardis, J. H. Piater, A. J. Rodríguez-Sánchez, L. Wiskott. Deep Hierarchies in the Primate Visual Cortex: What Can We Learn for Computer Vision? *IEEE Trans. Pattern Anal. Mach. Intell.* 35(8): 1847-1871, 2013.

P. Uršič, D. Tabernik, M. Boben, D. Skočaj, A. Leonardis, M. Kristan. Room categorization based on a hierarchical representation of space. *International journal of advanced robotic systems*, vol. 10, pp. 1-13, 2013.

L. Čehovin, M. Kristan, A. Leonardis. Robust Visual Tracking using an Adaptive Coupled-layer Visual Model. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. Pre-published, 2012.

A. Vrečko, A. Leonardis, D. Skočaj. Modeling binding and cross-modal learning in Markov Logic Networks. *Neurocomputing*, vol. 96, pp. 29-36, 2012.

M. Kristan, A. Leonardis, D. Skočaj. Multivariate online kernel density estimation with Gaussian kernels, *Pattern recogn.*, pp. 2630-2642, 2011.

J. L. Wyatt, A. Aydemir, M. Brenner, M. Hanheide, N. Hawes, P. Jensfelt, M. Kristan, G. J. Kruijff, P. Lison, A. Pronobis, K. Sjöo, A. Vrečko, H. Zender, M. Zillich, D. Skočaj. Self-Understanding and Self-Extension: A Systems and Representational Approach. *IEEE Transactions on Autonomous Mental Development*, Vol. 2, no. 4, pp. 282 - 303, 2010.

M. Kristan, S. Kovačič, A. Leonardis, J. Perš. A two-stage dynamic model for visual tracking. *IEEE transactions on systems, man, and cybernetics. Part B, Cybernetics*, Vol. 40, no. 6, pp. 1505 - 1520, 2010.



Integrated system for interactive learning in dialogue with a human

M. Kristan, D. Skočaj and A. Leonardis. Online Kernel Density Estimation for Interactive Learning. *Image and Vision Computing*, 2009.

M. Kristan, J. Perš, M. Perše, S. Kovačič. Closed-world tracking of multiple interacting targets for indoor-sports applications. *Computer vision and image understanding*, 2009.

B. Leibe, A. Leonardis, B. Schiele. Robust Object Detection with Interleaved Categorization and Segmentation. *International Journal of Computer Vision, Special Issue on Learning for Recognition and Recognition for Learning*, Vol. 77, no. 1-3, pp. 259-289, 2008.

D. Skočaj, A. Leonardis. Incremental and robust learning of subspace representations. *Image and Vision Computing*, vol. 26, no. 1, pp. 27-38, 2008.

D. Skočaj, A. Leonardis, H. Bischof. Weighted and robust learning of subspace representations. *Pattern Recognition*, vol. 40, no. 5, pp. 1556-1569, 2007.

S. Fidler, D. Skočaj, A. Leonardis. "Combining reconstructive and discriminative subspace methods for robust classification and regression by subsampling". *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 28, no. 3, pp. 337-350, 2006.

A. Leonardis, H. Bischof, J. Maver. "Multiple Eigenspaces". *Pattern Recognition*, 35, no. 11, pp. 2613-2627. Twenty-Ninth Annual Pattern Recognition Society Award. Selected as the most original manuscript from all 2002 *Pattern Recognition* issues, 2002.

## ORGANISATION OF CONFERENCES AND WORKSHOPS

ICRA 2014 Workshop on Active Visual Learning and Hierarchical Visual Representations for General-Purpose Robot Vision, 31. 5. 2014, Hong Kong, China (A. Leonardis co-organizer).

IEEE Workshop on Visual Object Tracking VOT 2014 in conjunction with ECCV 2014 (M. Kristan, A. Leonardis members of organizing committee, L. Čehovin member of technical committee).

Pattern Recognition Section in 23rd International Electrotechnical and Computer Science Conference ERK 2014 (L. Čehovin organizer).

The 11th IEEE International Conference on Automatic Face and gesture Recognition, FG 2015 (A. Leonardis general co-chair, M. Kristan evaluation co-chair, D. Skočaj publication co-chair, L. Čehovin web chair).

# Artificial Intelligence Laboratory

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\* from 1 December 2013

## RESEARCH ACTIVITIES

The laboratory carries out research in machine learning, data mining, inductive logic programming, qualitative reasoning, and AI approaches to robotics, systems control, bioinformatics, and intelligent tutoring systems. A notable aspect of much of this research is its application to problems in medicine, robotics, intelligent tutoring systems, systems control, game playing and analysis, ecological modelling, and reconstruction of human control skill.

The highlights of research in 2014 include:

- Idea of using our ABML machine learning approach in a “tutoring mode” whereby a student learns through ABML refinement loop. This is the reversal of the usual use of ABML, which is knowledge acquisition for a computer from an expert.

- Automatic on-line generation of hints to a novice programmer while the tutoring system is observing the programmer while writing program code. This requires the tutoring system’s understanding of the student’s intentions.
- Efficient qualitative simulation of a robot with Answer Set Programming, and use of a qualitative model with numerical constraints for robot planning.
- Opening a new research question of automatic assessment by computer of the difficulty of a mental task for humans; with experiments in chess tactical problems.
- Publications based on the ParkinsonCheck mobile application for early screening for Parkinson’s disease, developed in 2013 in collaboration with the Ljubljana Neurological Clinic.

Past achievements of this laboratory include: a demonstration of autonomous robot learning by experimentation (<http://www.ailab.si/xpero/>, part of the XPERO project) won the first prize at the European Exhibition in Future Emergent Technologies, Prague, 200; research programme “Artificial Intelligence and Intelligent Systems”, carried out in part by this laboratory, was in 2006 listed among the best research programmes funded by the Slovenian research agency ARRS; two former members of this laboratory Aleks Jakulin and Dorian Šuc received the prestigious best European AI dissertation awards, sponsored by ECCAI (European Coord. Committee in AI). In 2007; Ivan Bratko received the highest national Zois award for outstanding scientific achievements; Aleksander Sadikov was elected by students as best lecturer in the faculty’s study programmes in Computer Sc. and Mathematics in 2008, 2010 and 2011.

## EQUIPMENT

The laboratory owns a NAO humanoid robot by Aldebaran Robotics, a Universal Robots robot arm, and a motion capture sensor suit Animazoo IGS-190.

## RESEARCH PROJECTS

Artificial Intelligence and Intelligent Systems (P2-0209). Research Programme, Slovenian Research Agency (2009-2014).

Machine Learning in Building Intelligent Tutoring Systems (J2-4222). Basic Research Project, Slovenian Research Agency (2011-2014).

Molecular and other prognosticators of lung cancer and mesothelioma (J3-4076). Basic Research Project, Slovenian Research Agency (2011-2014).

Code Q: Teaching computer programming with automatically generated hints. Applied research project, European Structural Funds and Slovenian Ministry of education, science and sports (2014-2015).

Development and MAINTENANCE of recommendation systems for Guru Cue services for personalised SiOL TV. Industry-Funded Project, Gure Cue (2014-2015).



The AI Lab's Nao robot at the Future Emergent Technologies Exhibition, Prague, April 2009. The scientific message of the demonstration "A day in the life of the Nao robot" was to show how a robot could autonomously learn by performing experiments in its environment. The demonstration won the first prize at the exhibition.

Machine learning for building intelligent tutoring systems: conceptualization of problem-solving domains (BI-US/13-14-031). Bilateral Collaboration Project Slovenia - USA, Slovenian Research Agency (2013-2014).

## LABORATORY GUESTS

Dayana Hristova, University of Vienna, Cognitive Science Master Student. 1. 1. – 31. 12. 2014. Research in estimating problem difficulty for people, and human motion capture with Animazoo sensory suit.

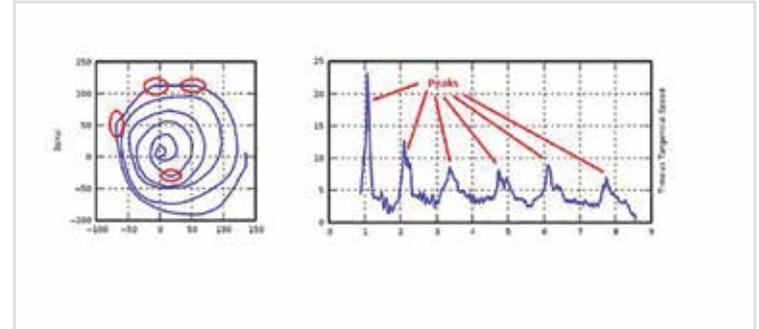
Timothy Wiley, University of New South Wales, Australia. 12. 8. – 15. 8. 2014. Research in qualitative model learning of a track wheeled mobile robot.

Peter Backus, University of Manchester, UK, 16. 9. – 19. 9. 2014. Research on stereotype threats.

## RESEARCH VISITS

Ivan Bratko: visit at University of New South Wales, School of Computer Sc. and Eng., Sydney, Australia, 30. 10. – 10. 12. 2014. Research collaboration in learning qualitative models for robot planning.

Matej Guid: visit to Human Computer Interaction Institute, Carnegie Mellon University, ZDA, 24. 1. – 10. 2. 2014. Machine learning for building



Analysis of handwritten spirals for diagnosing Parkinsonian tremor

intelligent tutoring systems: conceptualization of problem-solving domains (research project).

## INVITED TALKS AND LECTURES

Ivan Bratko: Selected Topics in Artificial Intelligence, June 2014, a course at Alpe Adria University, Klagenfurt.

## SELECTED PUBLICATIONS

B. Šeruga, A. Sadikov, A. Cazap, et al. Barriers and challenges to global clinical cancer research. *The oncologist*, vol. 14 (2014), pp. 61-67, 2014.

D. Hristova, M. Guid, I. Bratko. Assessing the Difficulty of Chess Tactical Problems. *Int. J. on Advances in Intelligent Systems*, vol 7 (2014) pp. 728-738, 2014.

M. Zapušek, M. Možina, I. Bratko, J. Rugelj, M. Guid. Designing an interactive teaching tool with ABML knowledge refinement loop. *Proc. Intelligent tutoring systems: ITS 2014, Lecture notes in computer science Vol. 8474*, p.p. 575-582. Springer, 2014.

T. Lazar, I. Bratko. Data-driven program synthesis for hint generation in programming tutors. *Proc. Intelligent tutoring systems: ITS 2014, Lecture notes in computer science Vol. 8474*, pp. 306-311. Springer, 2014.

T. Wiley, C. Sammut, I. Bratko. Qualitative Planning with Quantitative Constraints for Online Learning of Robotic Behaviours. *Artificial Intelligence (AAAI), Proc. 28th AAAI Conference on Artificial Intelligence, Quebec City, Canada*. pp. 2578-2584, 2014.

T. Wiley, C. Sammut, I. Bratko. Qualitative Simulation with Answer Set Programming. *Proc. ECAI 2014 (21st European Conference on Artificial Intelligence, Prague)*, pp. 915-920, 2014.

D. Hristova, M. Guid, I. Bratko. Toward modeling task difficulty: the case of chess. *Proc. COGNITIVE 2014, Venice, Italy, 2014. IARIA, cop. 2014*, pp. 211-214, Best paper award.

A. Sadikov, V. Groznik, J. Žabkar, M. Možina, D. Georgijev, Z. Pirtošek, I. Bratko. ParkinsonCheck smart phone app. *ECAI 2014: proceedings*,

(Frontiers in artificial intelligence and applications, vol. 263). Amsterdam: IOS Press, cop. 2014, pp. 1213-1214, 2014.

V. Groznik, A. Sadikov, J. Žabkar, M. Možina, J. Žabkar, D. Georgijev, I. Bratko. Attribute visualisation for computer-aided diagnosis: a case study. 2014 IEEE International Conference on Healthcare Informatics, Verona, Italy, 2014, ICHI 2014: proceedings. Los Alamitos (California); Washington; Tokyo: IEEE Computer Society, Conference Publishing Services, pp. 294-299, 2014.

V. Groznik, M. Guid, A. Sadikov, M. Možina, D. Georgijev, V. Kragelj, S. Ribarič, Z. Pirtošek, I. Bratko. Elicitation of neurological knowledge with argument-based machine learning. Artificial intelligence in medicine, vol. 57, pp. 133-144, 2013.

T. Janež, J. Žabkar, M. Možina, I. Bratko. Learning faster by discovering and exploiting object similarities. International journal of advanced robotic systems, vol. 10, str. 1-18, 2013.

M. Guid, I. Bratko. Search-based estimation of problem difficulty for humans. Proc. Artificial intelligence in education: AIED 2013, Memphis, TN, USA, 2013 (Lecture notes in computer science, SL 7, Lecture notes in artificial intelligence, 7926), Springer, pp. 860-863, 2013.

I. Bratko. Prolog Programming for Artificial Intelligence. 4th ed. Harlow (England): Addison-Wesley / Pearson, cop. 2012. XXI + 673 pp.; previous editions also translated into German, Italian, French, Slovene, Japanese, and Russian, 2012.

A. Košmerlj, I. Bratko, J. Žabkar. Embodied concept discovery through qualitative action models. Int. J. Uncertainty, Fuzziness and Knowledge-based systems, vol. 19, pp. 453-475, 2011.

J. Žabkar, M. Možina, I. Bratko, J. Demšar. Learning qualitative models from numerical data. Artificial Intelligence, Vol. 175, pp. 1604-1619, 2011.

D.S. Nau, M. Luštrek, A. Parker, I. Bratko, M. Gams. When is it better not to look ahead? Artificial Intelligence, Vol. 174, pp. 1323-1338, 2010.

M. Možina, J. Žabkar, I. Bratko. Argument based machine learning. Artificial Intelligence, Vol. 171, pp. 922-937, 2007.

M. Luštrek, M. Gams, I. Bratko. Is real-valued minimax pathological? Artificial Intelligence Vol. 170, pp. 620-642, 2006.

M. Guid, I. Bratko. Computer analysis of world chess champions. ICGA Journal, Vol. 29: 65-73, 2006.

A. Sadikov, I. Bratko. Learning long-term chess strategies from databases. Machine Learning, Vol. 63: 329-340, 2006.

## Laboratory for Cognitive Modelling

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### RESEARCH ACTIVITIES

The Laboratory for Cognitive Modelling (LKM) was officially founded in 2001. LKM carries out research in cognitive modelling, machine learning, neural networks, statistics, picture and data mining. Research results concern the modelling of noisy data related to cognitive, medical, biological and other processes. We are developing, testing and applying new approaches and algorithms for modelling from numeric, symbolic and pictorial data, and new approaches to building, evaluation and explanation of models, derived from data. Recent research is related to evaluating the utility of ordinal attributes, generation of semi-artificial data, analysis of big data with map-reduce approach, analysis of graphs, evaluating the reliability of single models' predictions in classification and regression,

evaluating the reliability of clustering, explaining single predictions by arbitrary classification and regression model, text summarization using archetypal analysis, analysing and modelling of sport data, user profiling by mining the web-logs, recommendation systems, learning of imbalanced classification problems, applying evolutionary computation to data mining focused on using ant colony optimization, prediction intervals which represent the distribution of individual future points in a more informative manner, spatial data mining with multi-level directed graphs, employing background knowledge analysis for search space reduction in inductive logic programming, detection of (non)-ischemic episodes in ECG signals, heuristic search methods in clickstream mining and mining of data streams. A notable aspect of much of this research is its application to problems in image analysis, medical diagnosis, ecological modelling, marketing and financial modelling.

## RESEARCH PROJECTS

Artificial Intelligence and Intelligent Systems (P2-0209). Research Programme, Slovenian Research Agency (2009-2014).

AGROIT - Increasing the efficiency of farming through on open standards based AgrolT platform. European Project (Framework Programmes) (2014-2016).

Development of new e-learning models for game-based learning using mobile technologies (BI-ME/14-15-009). Bilateral Collaboration Project, Slovenian Research Agency (2014-2015).

A component for intelligent analysis of data streams. Industry-Funded Project, Optilab (2012-2014).

Supervised and unsupervised learning from imbalanced datasets for assistance in movement of persons with low vision (BI-HR/14-15-024). Bilateral Collaboration Project, Slovenian Research Agency (2014-2015).

Computer based modelling in bioinformatics for gene based cancer classification focused on reliability and machine learning (BI-BA/14-15-008). Bilateral Collaboration Project, Slovenian Research Agency (2014-2015).

## LABORATORY GUESTS

Dr. Josip Musić, University of Split. 9. 12. – 13. 12. 2014. Research collaboration on Supervised and unsupervised learning from imbalanced datasets for assistance in movement of persons with low vision.

Ante Panjkota, MSc, University of Split. 9. 12. – 13. 12. 2014. Research collaboration on Supervised and unsupervised learning from imbalanced datasets for assistance in movement of persons with low vision.

Dr. Ivo Stančić, University of Split. 9. 12. – 13. 12. 2014. Research collaboration on Supervised and unsupervised learning from imbalanced datasets for assistance in movement of persons with low vision.

Tripo Matijević, Univerzitet »Mediteran«, Fakultet za informacione tehnologije. 15. 12. – 18. 12. 2014. Research collaboration on bilateral project BI-ME/14-15-009.

Tijana Vujičić, Univerzitet »Mediteran«, Fakultet za informacione tehnologije. 15. 12. – 18. 12. 2014. Research collaboration on bilateral project BI-ME/14-15-009.

Nađa Žarić, Univerzitet »Mediteran«, Fakultet za informacione tehnologije. 15. 12. – 18. 12. 2014. Research collaboration on bilateral project BI-ME/14-15-009.

## RESEARCH VISITS

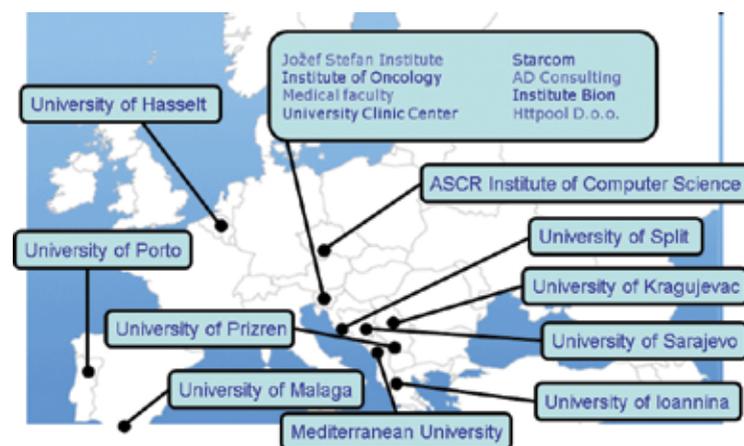
Zoran Bosnić. Awarded by CEEPUS and OeAD (Austrian Agency for International Cooperation in Education and Research) to visit Johannes Kepler University, Institute for System Software, Linz, Austria, 9. 11. – 15. 11. 2014.

Zoran Bosnić. Awarded CEEPUS Scholarship for Staff mobility to visit Reykjavik University, School of Computer Science, Iceland, 25. 8. – 30. 8. 2014.

Igor Kononenko, Matjaž Kukar, Petar Vračar, Darko Pevec: Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia, 26. 8. – 29. 8. 2014. Collaboration on research project »Supervised and unsupervised learning from imbalanced datasets for assistance in movement of persons with low vision«.

Matjaž Kukar, Domen Košir, Kaja Zupanc: Faculty of Information Technologies, Mediterranean University, Podgorica, Montenegro, 17. 11. – 19. 11. 2014. Collaboration on research project »Development of new e-learning models for game-based learning using mobile technologies«.

Igor Kononenko, Zoran Bosnić, Marko Robnik Šikonja, Miha Drole: University of Sarajevo, BiH, 3. 7. – 5. 7. 2014. Collaboration on research project: »Computer based modeling in bioinformatics for gene based cancer classification focused on reliability and machine learning«.



We collaborate with several Universities and Institutes from Belgium, BiH, Croatia, Czech Republic, Greece, Kosovo, Portugal, Serbia, Monte negro, and Spain



# Bioinformatics Laboratory

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Full Professor  
Blaž Zupan, PhD

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## RESEARCH ACTIVITIES

Bioinformatics Laboratory performs research in data mining, analysis of big data and networks, data fusion and techniques for data visualization. We apply our methods and algorithms to problems from molecular and system biology, functional genomics, chemogenomics and medicine. The lab maintains an open-source data mining package Orange (<http://orange.biolab.si>) with an attractive and easy-to-use visual programming

interface, and data analytics libraries like Nimfa (<http://nimfa.biolab.si>), a Python module for non-negative matrix factorization. Orange gained its popularity as the principal Python-based data mining tool and has a substantial community of users. We also maintain a set of interactive web-applications. These include dictyExpress (<http://dictyexpress.biolab.si>), a popular interactive exploratory data analytics tool that provides access to over 1,000 gene expression experiments on social amoeba *Dictyostelium discoideum*, SNPsyn (<http://snpsyn.biolab.si>) for exploratory gene interaction analytics, and GenePath (<http://www.genepath.org>) for interactive epistasis analysis and gene network reconstruction from mutant-based phenotypes. GenePath is over 10 years old but still in frequent use in scholar institutions. In collaboration with UCL Institute of Neurology in London we are also developing a computational pipeline for comprehensive analysis of next-generation high-throughput sequencing data (RNA-Seq and iCLIP) with the aim of modelling and understanding the molecular mechanisms associated with neurodegenerative diseases.

## RESEARCH PROJECTS

AXLE: Analytics for Xtremely Large European Data (FP7-318633). European Project (FP7), European Commission (2012-2015).

CARE-MI: Cardio Repair European Multidisciplinary Initiative (FP7-242038). EU FP7-HEALTH Programme project, European Commission (2010-2015).

Artificial intelligence and intelligent systems (P2-0209). Research Programme, Slovenian Research Agency (2009-2014).

Growth and defense trade-offs in multitrophic interaction between potato and its two major pests (J4-4165). Basic Research Project, Slovenian Research Agency (2011-2014).

Evaluation of neuro-muscular trunk stabilization functions and development of exercise programmes for lower back pain prevention (L5-4293). Research Application Project, Slovenian Research Agency (2011-2014).

Combination of next generation sequencing and metagenomic analysis in the diagnostics of severe hop stunting (J4-4153). Basic Research Project (2011-2014).

Functional genomics of cholesterol homeostasis: the role of lanosterol 14alpha-demethylase in development of metabolic disorders (J7-4053). Basic Research Project, Slovenian Research Agency (2011-2014).

Computational approaches for identification of bacterial resistance pathways in *Dictyostelium* (BI-US/13-14-016). Bilateral Collaboration Project, Slovenian Research Agency (2013-2014).

Functional genomics of potato-PVY interactions (J1-4268). Basic Research Project, Slovenian Research Agency (2011-2014).

Epidemiology and Biodiversity Studies of Plant Pathogens (L4-5525). Research Application Project (2013-2016).

Conquering the Curse of Dimensionality by Using Background Knowledge (J2-5480). Basic Research Project (2013-2016).

Post-transcriptional regulatory networks in neurodegenerative diseases (J7-5460). Basic Research Project (2013-2016).

## RESEARCH VISITS

Miha Štajdohar: Baylor College of Medicine, Computational and Integrative Biomedical Research Center, Houston, USA, from 1. 10. 2014. Development of analytics pipeline for next-generation sequencing data.

Marinka Žitnik, Niko Colnerič: Stanford University, Computer Science Department, 3. 8. - 12. 10. 2014. Research Scholarship under the supervision of Jure Leskovec.

Blaž Zupan: Baylor College of Medicine, Department of Molecular and Human Genetics, Houston, USA, 1. 8. 2013 - 31. 7. 2014. Research in computational approaches for biomedical data analysis.

Janez Demšar: Baylor College of Medicine, Department of Molecular and Human Genetics, Houston, USA, 19. 5. - 31. 5. 2014. Research in computational approaches for biomedical data analysis.

Marinka Žitnik: Baylor College of Medicine, Department of Molecular and Human Genetics, Houston, USA, 4. 12. 2013 - 4. 8. 2014. Research in data fusion and its applications in biomedicine.

Jure Žbontar: New York University, Courant Institute of Mathematical Sciences, New York, USA, 23. 1. - 14. 9. 2014. Research on stereo vision using convolutional neural networks, under the supervision of Yann LeCun.

## INVITED TALKS AND LECTURES

Janez Demšar: Orange: A visual programming platform, 13. 2. 2014, an invited talk at the European Synchrotron Radiation Facility, Grenoble, France.

Blaž Zupan: Biomedical data fusion, 7. 5. 2014, an invited talk at a CIBR Seminar, Baylor College of Medicine, Houston.

Janez Demšar: Data analysis with Orange, 7. 5. 2014, an invited talk at the Faculty of Mathematics and Physics, UL.

Martin Stražar: Orthogonal nonnegative matrix factorization for modelling protein-RNA, Interactions, 9. 9. 2014, an invited talk at the University College London, London.

Martin Stražar: Orthogonal nonnegative matrix factorization for modelling protein-RNA, Interactions, 13. 11. 2014, an invited talk at the Helmholtz Zentrum, Munchen.

Blaž Zupan:  $d(PI, Data) = 2$  PhD Students, 4. 12. 2014, an invited talk at BioBash, Ljubljana.

Blaž Zupan: Most of all, I like programming (not), 17. 12. 2014, an invited talk at a Seminar at cloudyDays, Hekovnik.

## SELECTED PUBLICATIONS

M. Žitnik, B. Zupan. Data fusion by matrix factorization. IEEE TPAMI, 37,



Attendees of Functional Genomics Workshop (Ljubljana, October 2014) during a hands-on tutorial on data mining, all enjoying the simplicity and power of Orange data mining suite and its visual programming environment.

1:41-53, 2015.

M. Toplak, R. Močnik, M. Polajnar, Z. Bosnić, L. Carlsson, C. Hasselgren, J. Demšar, S. Boyer, B. Zupan, J. Stålring. Assessment of machine learning reliability methods for quantifying the applicability domain of QSAR regression models. *J Chem Inf Model* 54(2):431-441, 2014.

M. Žitnik, B. Zupan. Gene network inference by probabilistic scoring of relationships from a factorized model of interactions. *Bioinformatics*, 30, 12:i246-i254, 2014.

M. Žitnik, B. Zupan. Matrix factorization-based data fusion for drug-induced liver injury prediction. *Systems Biomedicine*, 2, e28527, 2014.

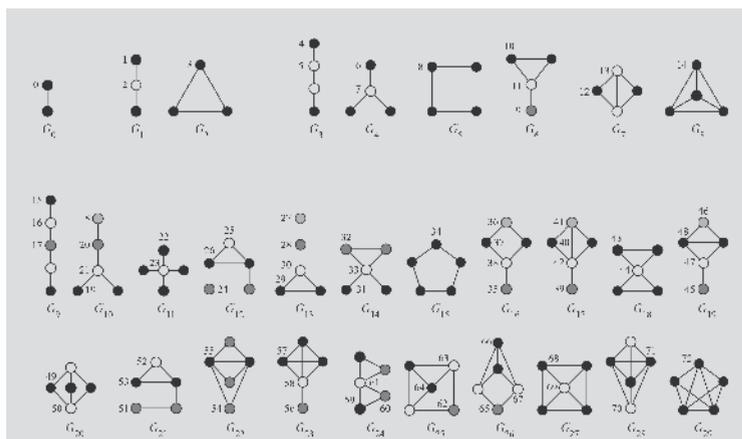
O. Rossbach, L. H. Hung, E. Khrameeva, S. Schreiner, J. König, T. Curk, B. Zupan, J. Ule, M.S. Gelfand, A. Bindereif. Crosslinking-immunoprecipitation (iCLIP) analysis reveals global regulatory roles of hnRNP L. *RNA Biol.* 11 (2):146-55, 2014.

M. Žitnik, B. Zupan. Survival Regression by Data Fusion. In *CAMDA/ISMB*, Boston, MA, USA, 2014.

M. Žitnik, B. Zupan. Imputation of quantitative genetic interactions in epistatic MAPs by interaction propagation matrix completion. In: *RECOMB*, Pittsburgh, 2014.

J. Demšar, T. Curk, A. Erjavec, Č. Gorup, T. Hočevar, M. Milutinović, M. Martin, M. Polajnar, M. Toplak, A. Starič, M. Štajdohar, L. Umek, L. Žagar, J. Žbontar, M. Žitnik, B. Zupan. Orange: data mining toolbox in Python. *Journal of Machine Learning Research*, 14: 2349-2353, 2013.

T. Hočevar, J. Demšar. A combinatorial approach to graphlet counting. *Bioinformatics*, 2013.



Graphlets with 2-5 nodes and their automorphism orbits. Nodes of the same color belong to the same orbit within that graphlet, e.g. both black nodes in  $G_{14}$  belong to orbit 31. Our ORbit Counting Algorithm (ORCA, Hočevar & Demšar 2013) computes graphlet orbit counts in a human protein-protein interaction network 1800-times faster than other graphlet counting tools.

M. Žitnik, V. Janjić, C. Larminie, B. Zupan, N. Pržulj. Discovering disease-disease associations by fusing systems-level molecular data, *Scientific Reports*, 13:3202, 2013.

M. Štajdohar, J. Demšar. Interactive network exploration with Orange. *Journal of statistical software*, 53(6): 1-24, 2013.

R. Kršmanc, A. Šajn - Slak, J. Demšar. Statistical approach for forecasting road surface temperature. *Meteorological Applications*, 20(4): 439-446, 2013.

D. Sluga and T. Curk and B. Zupan and U. Lotric. Heterogeneous computing architecture for fast detection of SNP-SNP interactions. *BMC Bioinformatics* 15:216, 2013.

W. Nasser, B. Santhanam, E.R. Miranda, A. Parikh, K. Juneja, G. Rot, C. Dinh, R. Chen, B. Zupan, G. Shaulsky, A. Kuspa. Bacterial discrimination by dictyostelid amoebae reveals the complexity of ancient interspecies interactions. *Current Biology*, 23(10):862-872, 2013.

J. Žbontar, M. Žitnik, M. Zidar, G. Majcen, M. Potočnik, B. Zupan. Team ULjubljana's Solution to the JRS 2012 Data Mining Competition. In *Rough Sets and Current Trends in Computing*, Chengdu, China, 2012.

M. Žitnik, B. Zupan. NIMFA: A Python library for nonnegative matrix factorization. *Journal of Machine Learning Research*, 13:849-853, 2012.

M.L. Änkö, M. Müller-McNicoll, H. Brandl, T. Curk, G. Črtomir, I. Henry, J. Ule, K.M. Neugebauer. The RNA-binding landscapes of two SR proteins reveal unique functions and binding to diverse RNA classes. *Genome Biology*, 13(3): R17, 2012.

Y. Sugimoto, J. König, S. Hussain, B. Zupan, T. Curk, M. Frye, J. Ule.

Analysis of CLIP and iCLIP methods for nucleotide-resolution studies of protein-RNA interactions. *Genome Biology*, 13(8): R67, 2012.

J. Žabkar, M. Možina, I. Bratko, J. Demšar. Learning qualitative models from numerical data. *Artificial Intelligence*, 175(9/10): 1604-1619, 2011.

J.R. Tollervey, T. Curk, B. Rogelj, M. Brieše, M. Cereda, M. Kayikci, J. König, T. Hortobágyi, A. L. Nishimura, V. Župunski, R. Patani, S. Chandran, G. Rot, B. Zupan, C.E. Shaw, J. Ule. Characterizing the RNA targets and position-dependent splicing regulation by TDP-43. *Nature Neuroscience*, 14(4): 452-459, 2011.

J. König, K. Zarnack, G. Rot, T. Curk, M. Kayikci, B. Zupan, D.J. Turner, N.M. Luscombe, J. Ule. iCLIP reveals the function of hnRNP particles in splicing at individual nucleotide resolution. *Nature Structural and Molecular Biology*, 17(7): 909-916, 2010.

## AWARDS AND RECOGNITIONS

Tomaž Curk: Best teacher award by students of UL FRI, Ljubljana, Slovenia.

Janez Demšar: Award for extraordinary achievements in higher education (Slovenian Ministry of Education Science and Sport).

Janez Demšar: Award for research work (Slovenian Information Society).

Janez Demšar: Best teacher award by students of UL FRI, Ljubljana, Slovenia.

Blaž Zupan: Fulbright Scholarship awarded by J. William Fulbright Scholarship Board, 2013-2014.

Marinka Žitnik: Best paper/presentation at ISMB/CAMDA 2014 Conference, Boston, USA.

Marinka Žitnik, Blaž Zupan: Best poster award at RECOMB 2014 Conference, Pittsburgh, USA.

Marinka Žitnik, Niko Colnerič: Scholarship for the Research Cooperation of Doctoral Students in the USA awarded by Slovene Human Resources Development Fund, 2013-2014.

## ORGANIZATION OF WORKSHOPS AND SUMMER SCHOOLS

Data Mining without Programming, 21. 5. – 22. 5. 2014, Baylor College of Medicine, Houston, USA.

Summer School on Data Fusion (Zlivamo podatke), 7. 7. – 11. 7. 2014, University of Ljubljana, Slovenia.

Summer School Computer Science Unplugged (Računalništvo brez računalnika), 30. 6. – 4. 7. 2014, University of Ljubljana, Slovenia.

Summer School Magic in Scratch (Čaramo v Scratchu), 30. 6. – 4. 7. 2014, coorganized with the Faculty of Education), University of Ljubljana, Slovenia.

Course Programming for Everybody, within the EU Code Week, 14. 10. – 17. 10. 2014, University of Ljubljana, Slovenia.

Functional Genomics Workshop, 15. 10. – 16. 10. 2014, University of Ljubljana, Slovenia.

Data Mining without Programming, 16. 12. 2014, a hands-on workshop at BEST's BDTN, Ljubljana, Slovenia.

## MISCELLANEOUS

Bioinformatics laboratory is the initiator and an active participant of a number of outreach programmes at the Faculty. We have been among instigators of Faculty's Summer Schools, and are lately particularly active in popularizing the computer science in primary and high schools. The laboratory is actively involved in initiatives like Code Week and Django Girls, the national Beaver competition and related activities. We have developed new teaching material for kids (e.g., <http://vidra.fri.uni-lj.si>), organize professional development courses for teachers and participate in development of the new primary school curricula for computer science.

# Laboratory for Mathematical Methods in Computer and Information Science

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## RESEARCH ACTIVITIES

Members of the laboratory specialize in various mathematical topics and it is not possible to find a common research direction for all the laboratory members. Rather than that their cumulative research expertise should cover as large part of mathematical disciplines as possible. We focus on the following areas of mathematics:

- algebraic topology, in particular algebraic invariants of topological spaces with group actions, as well as computational topology and topological data analysis,

- coarse geometry,
- homotopy theory, uniqueness of decompositions of H- and coH-spaces,
- abstract algebra, (loop) near-rings, uniqueness of decompositions of modules over a ring,
- nonlinear dynamical systems and their application in geometry,
- commutative algebra and linear algebra, in particular, studying the variety of commuting nilpotent matrices over algebraically closed fields and certain classes of matrices over semi rings,
- scientific computing and numerical solutions of differential equations,
- graph theory, topological and structural properties of graphs, and graph coloring problems,
- graph representations, connected with problems in computational geometry.

Some members of the laboratory participate in research groups of the Institute of Mathematics, Physics, and Mechanics. We are also involved in joint research work with other research groups at the Faculty of Computer and Information Science, Faculty of Mathematics and Physics, Faculty of Electrical Engineering and also with several institutions from abroad. To name a few, NTNU Trondheim, Norway, University of Tuebingen, Germany, Moscow State University, Russia, P. J. Šafarik University, Košice, Slovakia, University of Sevilla, Spain, Yokohama National University, Japan, Simon Fraser University, Canada, University of Melbourne, Australia.

## RESEARCH PROJECTS

Applied and Computational Algebraic Topology (ACAT). European Science Foundation Project, European Commission (2011-2015).

## LABORATORY GUESTS

Hanife Isal, Middle Eastern Technical University (METU), Ankara, Turkey. 13. 4. – 23. 4. 2014. Joint research with Neža Mramor Kosta on the topic of perfect discrete Morse functions.

Barbara di Fabio, University of Bologna, Italy. 30. 10. 2014 – 30. 1. 2015. Exchange visit in the framework of the European Science Foundation research network Applied computational and algebraic topology, with the purpose of joint research work on stratified discrete Morse theory with Neža Mramor Kosta and Gregor Jerše.

Claudia Landi, University of Modena and Reggio Emilia, Italy. 15. 12. – 18. 12. 2014. Joint research work on topological data analysis with Neža Mramor Kosta and Gregor Jerše.

Helena Šmigoc, University College Dublin, Dublin, Ireland. 4. 6. – 13. 6. 2014. Work on graphs and eigenvalue problems with Polona Oblak.

## RESEARCH VISITS

Aleksandra Franc: KTH Royal Institute of Technology, Stockholm, Sweden, 3. 3. – 29. 8. 2014. Research on applications of topological complexity and other topological concepts in robotics.

Gašper Fijavž: Yokohama National University, Yokohama, Japan, 24. 3. – 30. 3. 2014. Research on odd minor embeddings with prof. Atsuhiko Nakamoto.

Neža Mramor Kosta: Department of Mathematics, Middle Eastern Technical University, Ankara, Turkey, 19. 10. – 30. 10. 2014. Research work on perfect discrete Morse functions.

Neža Mramor Kosta: Department of Mathematical Sciences, Aalborg University, Denmark, 15. 11. – 29. 11. 2014. Research on applications of discrete Morse theory to concurrency theory and directed algebraic topology.

## INVITED TALKS AND LECTURES

Gašper Fijavž: Threshold colorings of graphs, 27. 3. 2014, colloquium talk at Yokohama National University, Japan.

Aleksandra Franc: On topological complexity, 16. 4. 2014, talk at KTH Machine Learning Group, Stockholm, Sweden.

Neža Mramor Kosta: Discrete Morse functions on infinite complexes, 10. 11. – 14. 11. 2014, an invited talk at the conference Discrete, Computational and Algebraic Topology, University of Copenhagen, Denmark.

Neža Mramor Kosta: How can topology help to better understand data? 24. 11. 2014, an invited lecture at the Department of Mathematical Sciences, Aalborg University, Denmark.

## SELECTED PUBLICATIONS

M. Cencelj, D. Repovš, Ž. Virk. Multiple perturbations of a singular eigenvalue problem. *Nonlinear Analysis, Theory, Methods and Applications*, ISSN 0362-546X. [Print ed.], 9 pages, 2014.

G. Dolinar, A.E. Guterman, B. Kuzma, P. Oblak. Commutativity preservers via maximal centralizers. *Publicationes mathematicae*, ISSN 0033-3883, t. 84, vol. 3-4, pp. 439-450, 2014.

G. Fijavž, T. Pisanski, J. Rus. Strong traces model of self-assembly polypeptide structures. *MATCH Communications in Mathematical and in Computer Chemistry*, ISSN 0340-6253, vol. 71, no. 1, pp. 199-212, 2014.

G. Dolinar, A.E. Guterman, B. Kuzma, P. Oblak. Commuting graphs and extremal centralizers. *Ars mathematica contemporanea*, ISSN 1855-3966. [Print ed.], vol. 7, no. 2, pp. 453-459, 2014.

D. Franetič. A Krull-Schmidt theorem for infinite products of modules. *Journal of Algebra*, 407, 307-315, 2014.

A. Franc, P. Pavešič. Spaces with high topological complexity. *Royal Soc. Edinb.* 144A, pp. 761-773, 2014.

A. Franc. Problem umetnostne galerije (eng. Art Gallery Problem). Obzornik mat. fiz. 61, pp. 161-172, 2014.

G. Kudryavtseva, M.V. Lawson. The structure of generalized inverse semigroups related mappings. Semigroup forum, ISSN 0037-1912, vol. 89, iss. 1, pp. 199-216, 2014.

P. Oblak, H. Šmigoc. Graphs that allow all the eigenvalue multiplicities to be even. Linear Algebra and its Applications, ISSN 0024-3795. [Print ed.], vol. 454, pp. 72-90, 2014.

B. Orel, A. Perne. Chebyshev-Fourier spectral methods for nonperiodic boundary value problems. Journal of applied mathematics, ISSN 1687-0042, 2014, vol. 2014, article ID 572694, pp. 1-10, 2014.

Ž. Virk, A. Zastrow. The comparison of topologies related to various concepts of generalized covering spaces. Topology and its Applications, ISSN 0166-8641. [Print ed.], vol. 170, pp. 52-62, 2014.

## Laboratory for Cryptography and Computer Security

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Assistant <b>Janoš Vidali, PhD</b>	<a href="mailto:janos.vidali@fri.uni-lj.si">janos.vidali@fri.uni-lj.si</a>	8271
Assistant <b>Nuša Zidarič, MSc</b>	<a href="mailto:nusa.zidaric@fri.uni-lj.si">nusa.zidaric@fri.uni-lj.si</a>	8271

## RESEARCH ACTIVITIES

Our laboratory focuses on cryptography and computer security. We also study coding theory and statistical design.

With the dramatic development of telecommunications and information processing the demand for information is rapidly increasing. However, with the electronic revolution, information faces new and potentially more damaging security threats. It is namely much easier to intercept and alter electronic information than its paper predecessor, and besides, attack can be delivered remotely.

Information and computer security describes all measures taken to make services available and to prevent unauthorized use of electronic data, regardless whether it takes the form of disclosure, alteration and destruction of the data concerned, or verification of authenticity and data integrity, such as digital cash (carrier of value) and digital signature. Among preventive measures, cryptography provides the highest security in accordance with its flexibility for digital media. Cryptography and computer security influences cryptographic systems and applications for networks (Internet), finances (banks, stock market) and telecommunications. In particular we focus on public-key cryptosystems based on elliptic curves, algorithmic number theory, applications of finite fields and coding theory.

The main mathematical background for cryptology is algebraic combinatorics (including number theory and discrete mathematics), which is being used in two other important areas of our activity: statistical design theory and coding theory. The first one provides an optimal search for sample-sets and is being used, for example, in the design of digital communications. The second one constructs data carriers known as error-correcting codes (e.g. for CDs, wireless communication, satellites), since it is too expensive and inefficient to prevent all errors and it is easier to correct them (e.g. CD with a hole of 1mm in diameter still produces a perfect sound).

## EQUIPMENT

Xilinx Virtex 6 FPGA Evaluation Kit, VIA Artigo Pico-ITX A1000, VIA Amos-5000, VIA EITX-3000.

## RESEARCH PROJECTS

Security and Statistics of e-data. Po kreativni poti do praktičnega znanja, Ministry of Education, Science and Sport, Republic of Slovenia and European Social Fund, 2014.

## LABORATORY GUEST

Jovan Golić, Telecom Italia, Torino. 1. 1. – 4. 1. 2014. Identifying possibilities for cooperation in the field of applied cryptography.

## RESEARCH VISITS

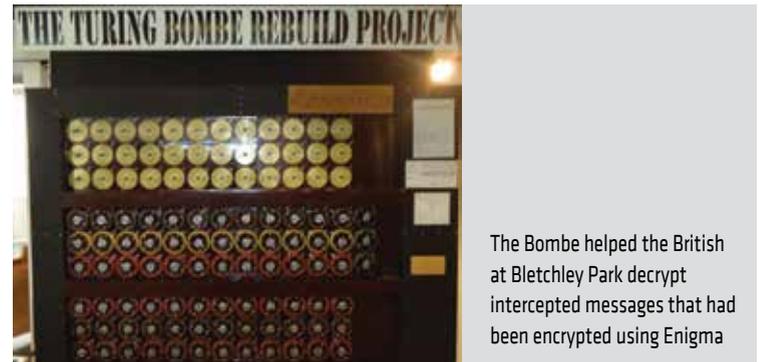
Aleksandar Jurišić: University of Waterloo, Waterloo, Canada, 13. 5. – 12. 7. 2014. Research visit to Prof. Chris Godsil and Prof. Alfred Menezes.

Aleksandar Jurišić: Villanova University, PA, USA, 2. 6. – 5. 6. 2014. Research visit to Prof. Andrew Woldar.

Aleksandar Jurišić: University of Queens, Kingston, Canada, 19. 6. – 21. 6. 2014. Research visit to Prof. Sebastian Cioaba.



Colossus was the first electronic computer, used by British codebreakers during World War II for cryptanalysis of the Lorenz cipher



The Bombe helped the British at Bletchley Park decrypt intercepted messages that had been encrypted using Enigma

Tilen Faganel, Mojca Mikac, Tadej Novak: University of Trento and Trento RISE, Trento, Italy, 27. 7. – 9. 8. 2014. Summer School on Security and Privacy in Digital Life, Prof. Jovan Golić.

## INVITED TALKS AND LECTURES

Aleksandar Jurišić: Graphs with three eigenvalues and finite geometries called GQ, 16. 5. – 17. 5. 2014, an invited talk at the 22nd Ontario Combinatorics Workshop, the York University, Canada.

Aleksandar Jurišić: Combinatorial structure of antipodal distance-regular graphs, 28. 5. 2014, a talk at the Algebraic Combinatorics Seminar at University of Waterloo, Waterloo, Ontario, Canada.

## SELECTED PUBLICATIONS

P. Nose. Security weaknesses of a signature scheme and authenticated key agreement protocols. *Inf. Process. Lett.* 114 (2014), 107-115, 2014.

X. Fan, N. Zidarič, M. Aagaard, G. Gong. Efficient hardware implementation of the stream cipher WG-16 with composite field arithmetic, in *Proceedings of the 3rd international workshop on Trustworthy embedded devices*, pages 21-34, ACM SIGSAC; 4. 11. – 8. 11. 2013, Berlin, Germany, 2013.

A. Jurišić, J. Vidali. Extremal 1-codes in distance-regular graphs of diameter 3. *Des. Codes Cryptogr.* 65 (2012), 29-47, 2012.

M. Deza, E. Deza, J. Vidali. Cones of Weighted and Partial Metrics. *Algebra 2010: Advances in Algebraic Structures* (2011), 177-197, 2011.

P. Nose. Security weaknesses of authenticated key agreement protocols. *Inf. Process. Lett.* 111 (2011), 687-696, 2011.

A. Jurišić, J. H. Koolen. Classification of the family AT<sub>4</sub>(q<sub>s</sub>, q, q) of antipodal tight graphs. *J. Combin. Theory (A)* 118 (2011), 842-852, 2011.

J. Vidali, P. Nose, E. Pašalič. Collisions for variants of the BLAKE hash function. *Inf. Process. Lett.* 110 (2010), 585-590 2010.

A. Jurišić, P. Terwilliger, A. Žitnik. The Q-polynomial idempotents of distance-regular graphs. *J. Combin. Theory (B)* 100 (2010), 683-690, 2010.

A. Jurišić, P. Terwilliger. Pseudo-1-homogeneous distance-regular graphs. *Journal of Algebraic Combinatorics* 28 (2008), 509-529, 2008.

A.E. Brouwer, A. Jurišić, J.H. Koolen. Characterization of the Patterson graph. *J. of Algebra* 320 (2008), 1186-1199, 2008.

K. Coolsaet, A. Jurišić. Using equality in the Krein conditions to prove nonexistence of certain distance-regular graphs. *J. Combin. Theory (A)* 115 (2008), 1086-1095, 2008.

## MISCELLANEOUS

A. Jurišić was one of the main organizers of the internacional conference Algebraic combinatorics: spectral graph theory, Erdos-Ko-Rado theorems and quantum information theory, University of Waterloo, Canada, 23. 6. – 27. 6. 2014

# Laboratory for ubiquitous systems

## Head:

Andrej Brodnik, PhD

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## RESEARCH ACTIVITIES

The prime research interest of the laboratory is efficient data handling in particular in distributed pervasive environments. The distributed environments store tera-bytes of data that 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 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 unstructured text is nowadays the most common data one can find. It includes everything from (human) genome, protein banks, stock prices, signals and all the way to the natural text. Our interest is efficiently construct index of such data and how to query the text though the index. The measure of efficiency includes cache hierarchy and possibility of a parallelism. Our research is spans from theory to the practical application. This span is also heavily present in the data deduplication research. Here we



Proxmark system for reading and writing contactless cards.

are primarily interested in on-line deduplication systems. In particular, we want to use the possibility of parallel processing but preserving the balance of stored data. The research results shall be applied to the distributed data storage systems like an 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 the use in agriculture. At last, but not least our research area is also Computer Science Education, where we are focusing on what and how to teach Computer Science. Target group are pupils in secondary school – gymnasium. We are preparing a new textbook for Informatics in gymnasium as well.

## EQUIPMENT

- 2x Proxmark III - an RFID tag reader and simulator
- 28x Raspberry Pi - 17 of these are being used as a cluster
- 1x BusPirate v4 - a serial communication interface supporting a number of protocols.
- 4x wireless access point (WRT160NL) - a wireless access point with USB running GNU/Linux
- 1x Synaps Technology Petra - a mobile phone with additional sensors and a wireless remote button
- 1x USB TV based on the RTL2832 chipset - a low-cost USB TV receiver useful for software defined radio
- 5x development system based on a Motorola 68HC11

## RESEARCH PROJECTS

CREA – Network of summer academies for the improvement of entrepreneurship in innovative sectors (H2020). European Commission (2015-2017).

Unified highly available and robust applicative platform for telecommunication services (Research voucher). Industry-Funded Project, IskraTEL (2013-2014).

Upgrade of nowcasting system NWCSAF and comparison EUMETSAT LSA DSSF for years 2011 – 2013. Applied project, Slovenian Environment Agency, 2014.

Sentinel2Agri4Slovenia – Application of Sentinel-2 time series data for crop identification and crop stress monitoring. ESA project, European Space Agency (2015-2016).

## LABORATORY GUESTS

Prof. Alejandro López-Ortiz, University of Waterloo, Canada. 10. 3. – 24. 3. 2014. 1st Lecture: Multi-Pivot Quicksort: Theory and Experiments; 2nd Lecture: List Update for Data Compression; 3rd Lecture: Dictionary, Binary search tree, Dictionaries for Multi-Dimensional Data.

Dr. Daniela Maftuleac, University of Waterloo, Canada. 10. 3. – 24. 3. 2014. Lecture: Shortest path problem in rectangular complexes of global non-positive curvature.

Prof. Miklós Krész, University of Szeged, Hungary. 20. 4. – 27. 4. 2014. Lecture: Dynamic network mining and business intelligence.

Annamária Szenkovits, University of Cluj, Romania. 6. 5. – 25. 5. 2014. Lecture: Model-based testing for reactive systems. Intelligent approaches.

Dr. Bogdán Zaválnij, University of Pecs, Hungary. 20. 5. – 1. 6. 2014. ERASMUS exchange. Lectures: Monte Carlo and Las Vegas methods and Different Coloring Methods - theoretical and experimental approach.

Prof. Roberto Grossi, University of Pisa, Italy. 2. 9. – 6. 9. 2014. Lecture: Topics in advanced data structures.

Prof. Bengt Nilsson, Malmö University, Sweden. 31. 8. – 6. 9. 2014. Lecture: Online strategies with applications to search and exploration.

Prof. Ian Munro, University of Waterloo, Canada. 31. 8. – 6. 9. 2014. Lecture: Succinct Data Structures.

## RESEARCH VISITS

Andrej Brodnik: Vilnius University, Institute of Mathematics and Informatics, Lithuania, 26. 11. – 30. 11. 2014. Collaboration in Doctoral school on Informatics education and educational software engineering research.

Andrej Brodnik: Schloss Dagstuhl, Leibniz-Zentrum für Informatik, Germany, 23. 2. – 28. 2. 2014. Collaboration in Seminar Data Structures and Advanced Models of Computation on Big Data.

Matevž Jekovec: King Abdullah University of Science and Technology, Saudi Arabia, 1. 3. – 5. 3. 2014. Collaboration on ERA revisited: Theoretical and Experimental evaluation.

Nataša Mori: Vilnius University, Institute of Mathematics and Informatics, Lithuania, 26. 11. – 30. 11. 2014. Collaboration in Doctoral school on Informatics education and educational software engineering research.

## INVITED TALKS AND LECTURES

Andrej Brodnik: Suggestions and criteria for writing computer science education doctoral thesis, 27. 12. 2014, an invited talk at the 5th International doctoral school on Informatics Education and Educational Software Engineering Research.

Andrej Brodnik: How to teach Theoretical Computer Science in High School, 1. 12. 2014, an invited talk at Vilnius University, Lithuania.

Andrej Brodnik: Waste wood recovery and reverse logistic, 9. 10. 2014, an invited talk at Szeged Workshop on Discrete Structures, University of Szeged, Gyula Juhász Faculty of Education, Hungary.

Andrej Brodnik: Teaching Limitations in Informatics, 6. 6. 2014, an invited talk at the 10th Bebras Workshop, Vilnius, Lithuania.

Gašper Fele-Žorž: Having fun with a Proxmox III, 13. 4. 2014, a lecture at EU intensive program HESUDI, Metropolia University of Applied Sciences, Helsinki, Finland.

Gašper Fele-Žorž: OpenWRT, 9. 4. 2014, a lecture at EU intensive program HESUDI, Metropolia University of Applied Sciences, Helsinki, Finland.

Educational Software Engineering Research, Druskininkai, Lithuania.

## SELECTED PUBLICATIONS

J. Vičič, A. Brondik. Multiple-cloud platform monitoring. *Elektrotehniški vestnik*, 81(3), pp. 94-100, 2014.

N. Kristan, D. Gostiša, G. Fele-Žorž, A. Brodnik. A high-availability Bebras competition system. *Proc. Informatics in schools: teaching and learning perspectives ISSEP-14*, pp. 78-87, Istanbul, 2014.

D. Križaj, A. Brodnik, B. Bukovec. A tool for measurement of innovation newness and adoption in tourism firms. *International journal of tourism research*, 16(2), pp. 113-125, 2014.

A. Todorović, M. D. Burnard, A. Tošič, A. Kutnar, A. Brodnik. Waste wood recovery and reverse logistic. *Proc. SWORDS 2014 - Szeged workshop on discrete structures*, 2014.

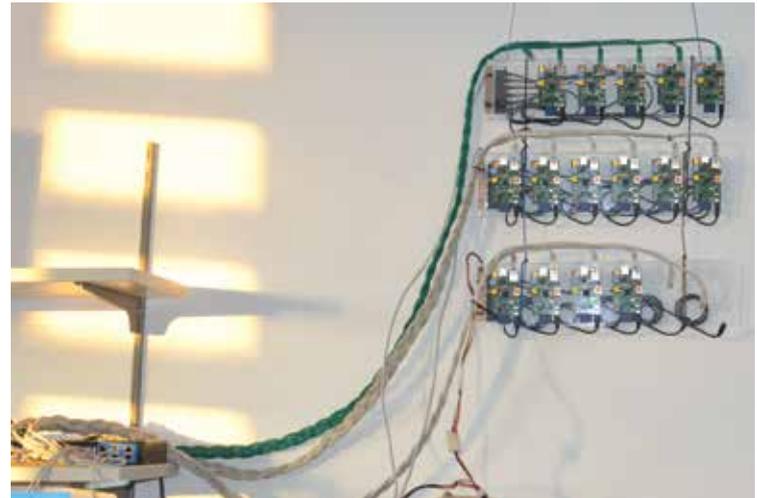
A. Tošič, D. Cerin, J. Bartelj, N. Radež, S. Cuder, T. Krivec, T. Štular, V. Jovičič, A. Brodnik. PAHIMA – Intelligent house raspberry. *Proc. 23rd Intl. Elektrotehniške in računalniške konference ERK 2014*, Vol. B, pp. 225, 2014.

A. Brodnik, S. Nikič. *Digital Forensic – essays by students 2013/2014*. Ljubljana: Faculty of Computer and Information Science, 2014.

I. Fister, A. Brodnik. *StuCoSReC: proceedings of the 2014 1st Student Computer Science Research Conference*. Koper: University of Primorska Press, 2014.

## MISCELLANEOUS

Mentoring and collaboration with students in Helsinki as part of the project HESUDI.



Raspberry cluster, currently showing the time 16:13 in binary (the lowest digits of seconds are missing).

Teaching Informatics at the Gymnasium Vič.

Teaching at educational seminar for teachers: Informatics is also a science, March 2014.

Conducting workshop Programming in a higher gear at the Summer School FRI.

Organization of ACM competitions: Bober, RTK and UPM.

Organization of the International Summer School: LADS3 2014 - Ljubljana Algorithms and Data Structures Summer School 2014.



# Outreach activities and events

Our researchers' work also includes teaching computer science at workshops and events. The faculty's aim is to develop computer and information science in Slovenia by organising workshops and events for all age groups throughout the year. Our objectives are to pique an interest in computer science among primary school students and to enhance the appeal of our studies to students, with special attention aimed at girls, who are encouraged to learn programming, and FRI students who want to perfect their knowledge in national and international competitions. Our overall aim is also to educate and build on the knowledge of computer science teachers through varied programmes and training sessions.

## **SUMMER SCHOOL**

Every year, computer workshops for primary school, secondary school and even university students are organised during the summer holidays.

Researchers familiarise participants with different fields and offer training and advancement in their skills. In 2014 we also held workshops on Android apps, Linux programming, working with the Raspberry Pi, robotic arms and databases. Our youngest participants were also taught to think in computer terms without a computer.

## **COMPUTER DAYS**

Computer days are workshops designed for primary and secondary school students. They take place at the Museum of Post and Telecommunications in Polhov Gradec. The 9 three-week workshops are delivered by our researchers.

Interest in the workshops has exceeded our expectations – more than 400 primary and secondary school students have registered from all over Slovenia. They attended workshops that included the Musical Corner, Drawing for Everyone; they were given the chance to experience their 15 seconds of fame, try out a multi-touch surface and meet the human robot Roomba among others.

## **RAILS GIRLS**

Rails Girls is a free workshop for girls who want to learn the basic tools to make their online ideas a reality. The faculty introduces them to the world of programming in a fun way and teaches them to develop their first web app. Last year, 167 female secondary school students as well as other girls who are still young at heart tried their hand at programming internet apps in Ruby on Rails.

## **INFORMATION DAYS**

The Faculty of Computer and Information Science is an institution that provides researchers with 20 different laboratories, where they have the means and the opportunity to develop their work on a daily basis as well

as update and improve computing mechanisms. With the goal being to generate huge interest in computer science, every year they share their findings, achievements and a wide range of projects with secondary schools students at Information days.

### **CODE WEEK**

As part of the Europe Code Week, we encouraged young and old people alike to code and attempted to encourage the children's interest in technology.

We made efforts to include all the age groups into six workshops. We started with primary school students in Python and Scratch with Lego WeDo and a workshop for secondary school students called Programming Lego Mindstorms. We also prepared a workshop for adults called Coding for Everyone, and brought the week to a close with Your New Friend Thymio for our youngest participants and a Django Girls workshop just for girls.

### **ADVANCED PROGRAMMES FOR TEACHERS**

We also organise training programmes for primary and secondary school teachers of computer and information science. In 2014 we organised training in Learning Programming and Robotics with Lego Mindstorms, Computer Science without Computers, and Learning Computer Science with the help of the Bebras Computational Thinking Challenge and Internet under the Microscope.

### **THE LJUBLJANA ALGORITHMS AND DATA STRUCTURES SUMMER SCHOOL**

This summer school is for postgraduate students and researchers who want to gain an in-depth knowledge and understanding of specific topics. It varies from year to year (the main topics last year were algorithms and data structures), but every year it hosts prestigious professors from the University of Ljubljana and other universities under the auspices of the Laboratory for Ubiquitous Systems.

### **CLOUD AND SECURITY SUMMER SCHOOL**

This summer school is for students from the FRI and other faculties who have basic background knowledge of computer science /programming and communications. It is organised by the Laboratory for Computer Communications and hosts a number of lecturers from Slovenia and abroad.

### **ROBO LEAGUE**

Robo league is a university challenge in mobile robotics which is attended every year by numerous students, but is also open to secondary school students too. The Laboratory for Adaptive Systems and Parallel

Processing organises the challenge, which is divided into three training sessions and a final.

### **BEBRAS COMPUTATIONAL THINKING CHALLENGE**

The Bober contest is a challenge is computational thinking and literacy that encourages logical reasoning, algorithmic thinking and problem-solving skills, and expands secondary school and university students' interest in computer science. In 2015 we hosted the nationals again, which not only included the organisational aspects but also the preparation of the problems to be solved in the competition.

### **ACM CONTESTS**

In cooperation with ACM Slovenia and some other similar institutions, our faculty also participates in the organisation of the RTK contests (the secondary school ACM contest in computer and information science) and the UPM (university programming marathon). In 2014 both national contests were held at the FRI.



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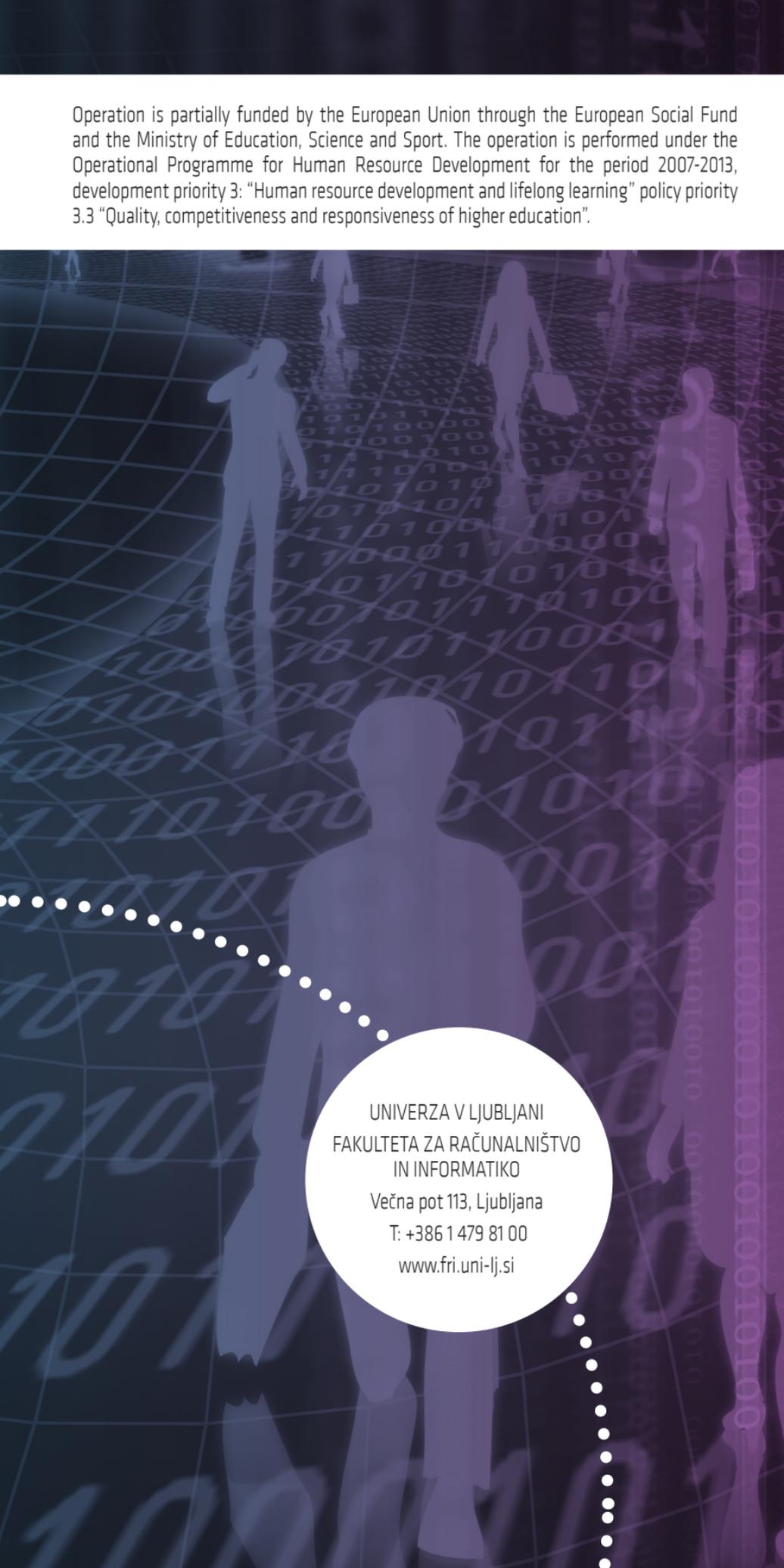
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The background features a grid of binary code (0s and 1s) in shades of blue and purple. Silhouettes of several people are scattered across the grid, some appearing to walk or stand. A white dotted line starts from the left edge and curves towards a white circular callout box in the lower center.

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