

Faculty of Computer and  
Information Science  
University of Ljubljana  
Survey of Activities in 2010

# Contents

Foreword **3**

## **ABOUT FRI 4**

General Information **6**

How to Reach Ljubljana **7**

## **EDUCATIONAL PROGRAMS 10**

University study program computer and Information Science **13**

Professional study program Computer and Information Science **16**

University study program Computer Science and Mathematics **18**

Interdisciplinary University study program Administrative Information Systems **20**

Doctoral programs **22**

## **RESEARCH ACTIVITIES 24**

Laboratory for Computer Graphics and Multimedia **26**

Laboratory for Biomedical Computer Systems and Imaging **29**

Laboratory of Adaptive Systems and Parallel Processing **32**

Laboratory for Computer Architecture **35**

Computer Communications Laboratory **38**

Computer Structures and Systems Laboratory **42**

Information Systems Laboratory **46**

Laboratory for e-Media **51**

Data Technology Laboratory **53**

Laboratory for Algorithms and Data Structures **57**

Laboratory for Architecture and Signal Processing **59**

Software Engineering Laboratory **62**

Computer Vision Laboratory **65**

Visual Cognitive Systems Laboratory **68**

Artificial Intelligence Laboratory **74**

Laboratory for Cognitive Modeling **78**

Bioinformatics Laboratory **82**

Laboratory for Mathematical Methods in Computer and Information Science **87**

Laboratory for Cryptography and Computer Security **90**



Prof. Dr. Nikolaj Zimic

## Foreword

This booklet provides some basic information about the Faculty of Computer and Information Science at the University of Ljubljana. The Faculty is the leading institution in the field of Computer and Information Science in Slovenia. Since its first study program in computer science began in 1973, it has had a lengthy roster of alumni, some of whom have achieved distinction in academic and professional circles in Slovenia and abroad. The Faculty has a number of active research groups that attract funding from various EU programs and bilateral state programs as well as funding from Slovenian and foreign industry.

Due to the high demand for graduates in the area of Computer and Information Science in Slovenia, the Faculty has avoided the trend of declining enrollment as in some other engineering and science disciplines. We actively promote the study of computer and information science by offering free summer workshops for high school students, and during the academic year we provide help to selected high schools with after-class activities. Besides the core of computer science, recently implemented study programs designed according to the Bologna principles enable an interdisciplinary approach to computer science education and should help to attract students from diverse backgrounds. We also aim at further opening our studies and making them accessible to international students. In 2012, part of the Master Studies and the entire Doctoral Program will be conducted in English, including lectures and coursework.

In the age of globalization the Faculty faces increasing competition in all areas. In recent years we have expanded our research competence to a wider spectrum of promising technical areas by attracting experienced researchers and teachers. Currently, the Faculty's most pressing problem is the shortage of space. The construction of the new Faculty building and associated facilities already started in 2010 and is expected to be finished in 2013.

I hope that this booklet will forge new links to the international Computer Science community, which is a prerequisite for the Faculty to successfully continue its mission. I am inviting those readers who find some interesting material in the booklet to establish contacts with our Faculty members.

*Nikolaj Zimic*

*Dean and Professor of Computer and Information Science*

# About FRI

## General Information

Dean **Prof. Dr. Nikolaj Zimic** (from 1. 10. 2010), **Prof. Dr. Franc Solina**  
Associate Dean for Education **Prof. Dr. Neža Mramor Kosta** (from 1. 10. 2010), **Prof. Dr. Radko Osredkar**  
Associate Dean for Research **Prof. Dr. Blaž Zupan** (from 1. 10. 2010), **Doc. Dr. Janez Demšar**  
Associate Dean for Development **Assoc. Prof. Dr. Marko Robnik Šikonja** (from 1. 10. 2010),  
**Prof. Dr. Nikolaj Zimic**  
Head of administration **Nives Macerl**

### Address:

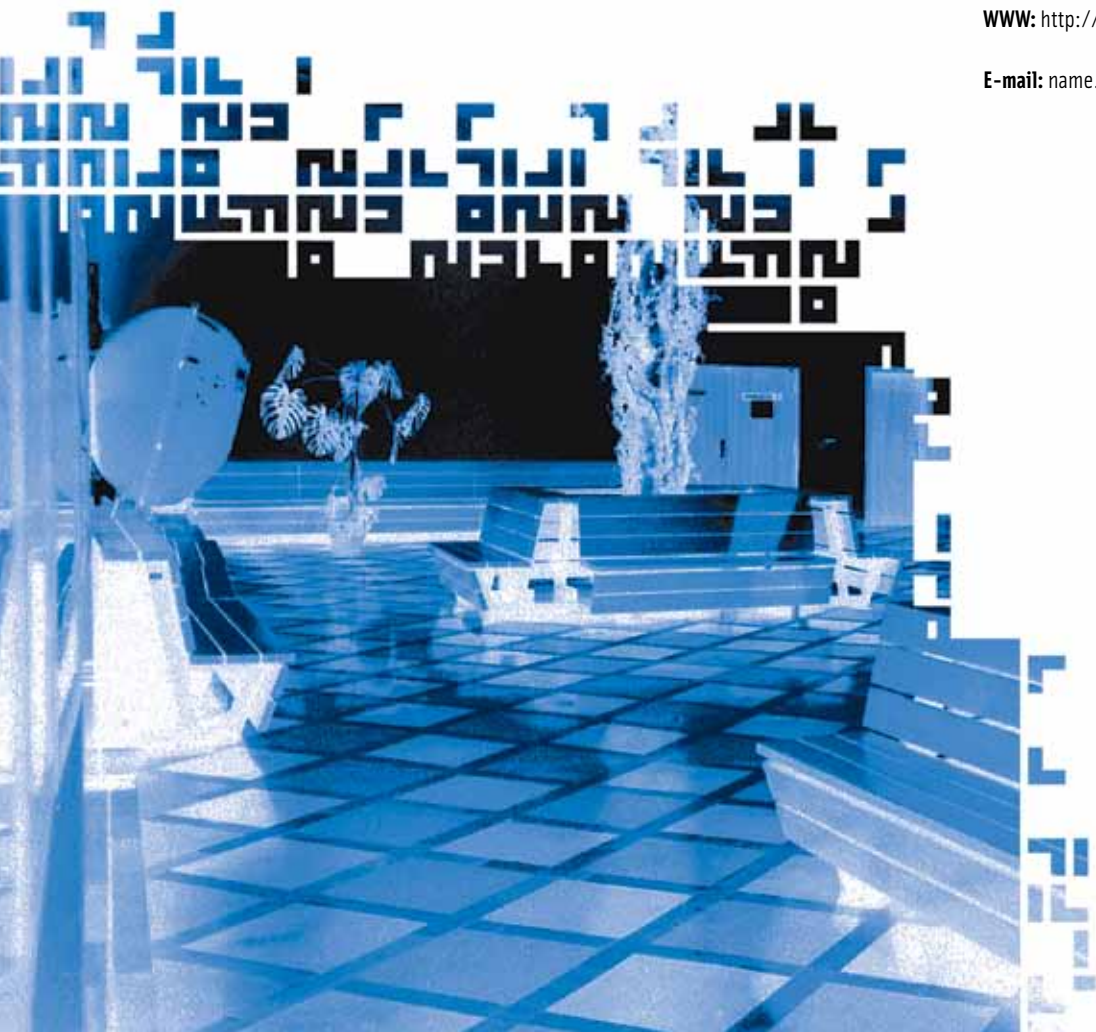
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## FRI

The Faculty of Computer and Information Science was established in 1996 after the former Faculty of Electrical Engineering and Computer Science split up into two faculties. However, the undergraduate program in computer science at the University of Ljubljana was established in 1973, first as an elective program after the second year of electrical engineering study, and since 1982 as an independent four year program.

Up to now more than 1986 students have completed the undergraduate program in computer science and obtained university degree. At the graduate level more than 320 Master's degrees (M.Sc.) and 103 the Doctoral degrees (Ph.D.) in Computer and Information science have been awarded. Currently, there are about 1700 undergraduate and 120 graduate students at the Faculty. The Faculty has 137 employees, of which 120 are teaching and research staff.

The building which houses FRI is shared with the Faculty of Electrical Engineering. FRI has 7 teaching laboratories equipped with a total of about 135 networked personal computers and shares with the Faculty of Electrical Engineering 19 lecture halls. The research laboratories are equipped with about 530 personal computers or workstations. The Faculty's central computer serves as the main e-mail and web server. The Faculty's local network is connected to the Internet through the University of Ljubljana network, "Metulj" (Butterfly), and the Academic Research Network of Slovenia (ARNES). Practically all classrooms are covered by wireless network. The Faculty has a joint library with the Faculty of Electrical Engineering. It houses a large collection of books, textbooks and journals and offers access to several on-line services and databases. Both faculties also share a publishing department which is engaged primarily in publishing textbooks for students in the Slovenian language (original and translated).

## How to Reach Ljubljana

### BY AIR

The Ljubljana airport at Brnik is about 20 km North-West from the center of Ljubljana (see Figure 2). It has fairly good connections with other European airports (Frankfurt, Munich, London, Zurich, Copenhagen, Paris, etc.) and is 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 with a good road system and visitors should not encounter problems on their trip.

### BY AIR AND RAIL

*Via Austria:* By plane to Vienna, Graz or Klagenfurt airport and by train or car to Ljubljana (direct trains go twice daily on weekdays)

*Via Germany:* By plane to Munich and by train or car to Ljubljana (a direct train goes once every day)

*Via Croatia:* By plane to Zagreb and by train or car to Ljubljana

*Via Italy:* By plane to Venice or Trieste and by train or car to Ljubljana

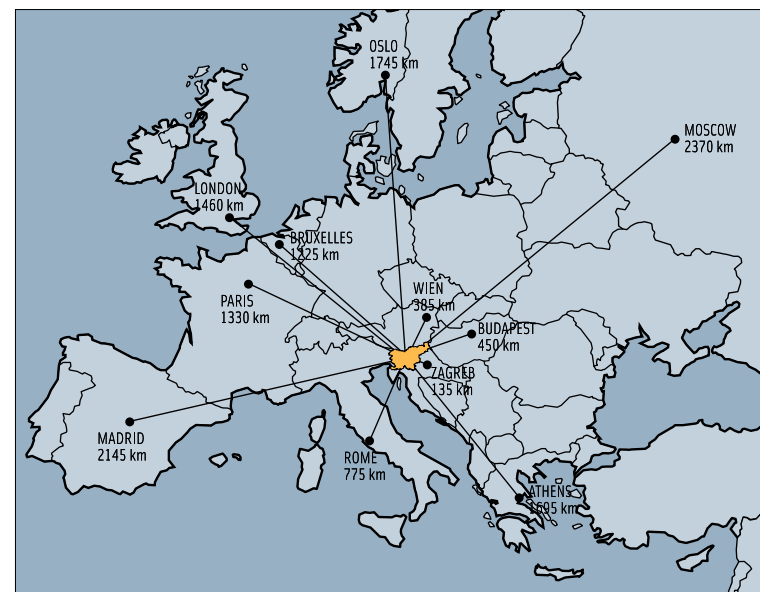


Figure 1: Slovenia in Europe

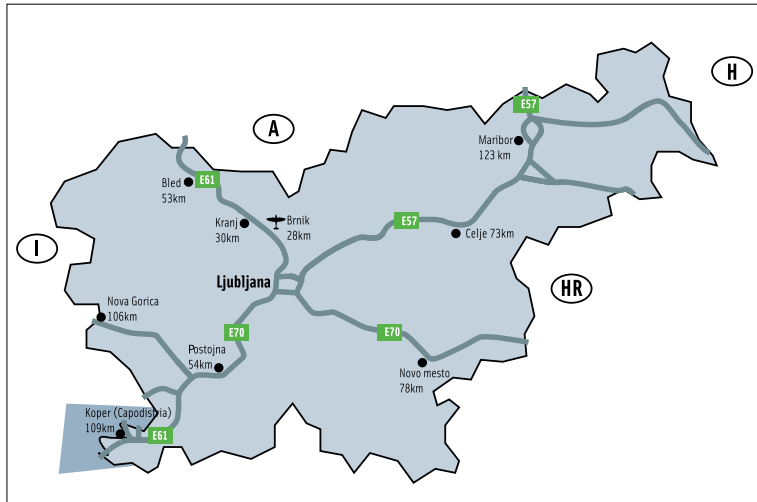


Figure 2: Map of Slovenia

### BY RAIL

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



Figure 3: Ljubljana – the Faculty is located within the highlighted area (detailed in Figure 4)

### LOCATION OF FRI IN LJUBLJANA

FRI is located in the South-West of Ljubljana (Figure 3) within walking distance of most hotels in the center of Ljubljana. To reach the Faculty from the center take bus lines 1 (direction “Mestni log”) or 6 (direction “Dolgi most”). How to reach FRI by car and where to park your car is shown in Figure 4.

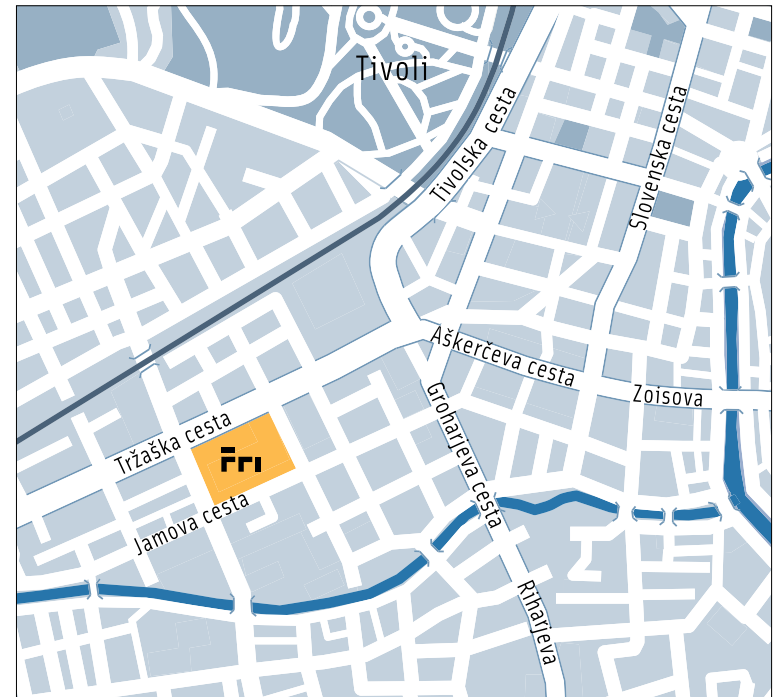


Figure 4: Detailed map of Ljubljana – the location of the Faculty is indicated by the highlighted yellow square

# Educational Programs

The academic year at the University of Ljubljana consists of the fall and the spring semester. The courses in the fall semester begin on October 1st and last for 15 full weeks. The spring semester courses start in the second half of February and end in the beginning of June, according to the current academic calendar of the University of Ljubljana. There are three examination periods: winter (from the end of the fall until the beginning of the spring semester), spring (a full month after the spring semester) and fall (from mid August until the end of September). Courses consist of lectures, problem solving classes (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 60 ECTS. In most study programs the work load is uniformly distributed among the courses, the majority of the courses at all levels have 6 ECTS.

The Faculty of Computer and Information Science participates in several international educational programs, such as the European Union SOCRATES/ERASMUS program and the CEEPUS program which encourage student and teacher mobility between European universities. The study programs of the Faculty of Computer and Information Science are registered with the European Federation of National Engineering Associations (FEANI) and meet the criteria for the title EUR ING.

## UNDERGRADUATE PROGRAMS

The Faculty of Computer and Information Science offers the following 3 year first degree programs,

- university study programme Computer and Information Science
- professional study programme Computer and Information Science
- interdisciplinary university study programme Computer Science and Mathematics (together with the Faculty of Mathematics and Physics)
- interdisciplinary university study program Administrative Information Systems (together with the Faculty of Administration)

All four first degree programs began running in the academic year 2009 – 2010, when the first year courses were first offered. In the academic year 2010/2011 the full professional study program Computer and Information Science was offered, while the university study programs will be introduced gradually over the following two academic years with the second year courses introduced in the academic year 2010/2011 and the third year course in the academic year 2011/2012.



At the second degree level, the following two programs are or will be offered in the upcoming academic years

- Computer and Information Science commencing in the academic year 2011/2012.
- The interdisciplinary program 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 in Budapest, University of Zagreb and Comenius University in Bratislava)

In addition to these new programs, which follow the Bologna guidelines, three old undergraduate educational programs are still running. These programs will be gradually replaced by the yearly progression of the new programs in the upcoming academic years. Accordingly, the second year courses of these programs were offered for the last time in the academic year 2009/2010. These programs are:

- a four-year undergraduate program (six semesters of lectures, 15 weeks of work in industry, 6 months of undergraduate thesis work), which leads to the title “Dipl. Eng. of Computer and Information Science”,
- a four-year “university” program (eight semesters of lectures, 6 months of Undergraduate thesis work), which leads to the title “University Dipl. Eng. of Computer and Information Science”, and
- a four year interdisciplinary “university” program (eight semesters of lectures, 6 months of undergraduate thesis work), which leads to the title “University Dipl. Eng. of Computer Science and Mathematics”.

## University study program Computer and Information Science

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

The first two years consist mainly of core-curriculum courses including mathematics and the theoretical foundations of computer science, with one major elective course and one general elective course in the fourth semester. In the third year, elective modules including three courses each are offered. The student is required to choose two modules and, in addition, one general elective course.

The study program concludes with an undergraduate thesis with a work load of 6 ECTS in the last semester.

### FIRST YEAR COURSES:

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

### SECOND YEAR COURSES:

Semester	Title	ECTS
Fall	Algorithms and Data Structures	6
	Computer Systems Architecture	6
	Probability and Statistics	6
	Introduction to Artificial Intelligence	6
	Introduction to Information Systems	6
Spring	Theory of Informations and Systems	6
	Operating Systems	6
	Computer Systems Organization	6
	General elective	6
	Major elective	6

**SECOND YEAR MAJOR ELECTIVES:**

Title	ECTS
Mathematical Modeling	6
Principles of Programming Languages	6
Computer technologies	6

**THIRD YEAR COURSES**

Semester	Title	ECTS
Fall	Communication and Project Management	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: Organization 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 Networks Modeling
- 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 Computer

*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



# Professional study program

## Computer and Information Science

This is an application oriented study program leading to the degree “diplomirani inženir računalništva in informatike (VS)”, abbr. “dipl. ing. rač. (VS)”

The first year consists of core-curriculum courses, while the remaining two years are structured so that the students can choose from of list of major electives according to their individual interests and preferences. The courses are grouped into semesters, and the student is required to choose a total of 5 courses corresponding to 30ECTS in each semester, respecting the required prerequisites for each course. The total work load of the program is 180 ECTS out of which 66 ECTS are mandatory courses, 90 ECTS are major electives, 12 ECTS are general electives, 6 ECTS is practice within the industry and 6 ECTS is the undergraduate thesis

The general electives are chose from the available study programs at the University of Ljubljana.

### FIRST YEAR COURSES:

Semester	Title	ECTS
Fall	Introduction to Computer Science	6
	Programming I	6
	Computer Architecture	6
	Mathematics	6
	Discrete Structures	6
Spring	Programming II	6
	Databases	6
	Computer Communications	6
	Operating Systems	6
	Introduction to Probability and Statistics	6

### SECOND YEAR COURSES:

Semester	Title	Prerequisites	ECTS
Fall	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

Spring	User Interfaces		6
	Compilers and Virtual Machines	<i>Algorithms and Data Structures I</i>	6
	Algorithms and Data Structures II	<i>Algorithms and Data Structures I</i>	6
	Testing and Quality	<i>Algorithms and Data Structures I</i>	6
	Information Systems Development	<i>Information Systems</i>	6
	Multimedia Content Production	<i>Graphic Design</i>	6
	Digital Signal Processing		6
	Web Technologies	<i>Algorithms and Data Structures I, Communications Protocols and Network Security</i>	6
	Input-Output Systems	<i>Algorithms and Data Structures I</i>	6
	Digital Logic Design	<i>Computer Organization, Digital Circuits</i>	6
	Data Mining	<i>Algorithms and Data Structures I, Artificial Intelligence</i>	6

### THIRD YEAR COURSES:

Semester	Title	Prerequisites	ECTS	
Fall	Project practicum		6	
	Software Engineering	Algorithms and Data Structures I	6	
	Information Systems Strategic Planning	Information Systems Development	6	
	Multimedia Technologies	Digital Signal Processing	6	
	Parallel and Distributed Systems and Algorithms	Algorithms and Data Structures I	6	
	System Software	Algorithms and Data Structures I	6	
	Process Automation	Input-Output Systems	6	
	Embedded Systems	Input-Output Systems	6	
	Robotics and Machine Perception	Input-Output Systems, Computer Graphics, Artificial Intelligence	6	
	Game Technology and Virtual Reality	Algorithms and Data Structures I, Computer Graphics, Artificial Intelligence	6	
	Decision Systems	Data Mining	6	
	Numerical Methods		6	
	Spring	Industrial Practice		18
		Diploma Thesis		6

# University study program Computer Science and Mathematics

This program is oriented towards theoretical computer science and topics in modern discrete and computational mathematics that are closely connected to it. The program leads to the degree “diplomirani inženir računalništva in matematike (UN)”, abbr. “dipl. ing. rač. mat. (UN)”.

The first two years contain mandatory core-curriculum courses. The third year contains three mandatory courses, one elective module from the University program Computer and Information Science, major electives with a total work load of 5 ECTS and general electives with a total load of 10 ECTS. The study program concludes with an undergraduate thesis with a work load of 6 ECTS in the last semester.

## FIRST YEAR COURSES:

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

## SECOND YEAR COURSES:

Semester	Title	ECTS
Fall	Algorithms and Data Structures	6
	Computer Systems Architecture	6
	Analysis 3	5
	Introduction to Artificial Intelligence	6
	Combinatorics	7
Spring	Optimization Methods	7
	Operating Systems	6
	Principles of Programming Languages	6
	Computer Communications	6
	Topics in Mathematics	5

## THIRD YEAR COURSES:

Semester	Title	ECTS
Fall	Numerical methods	7
	Communication and Project Management	6
	Probability and Statistics	10
	Elective module, courses 1 and 3	12
Spring	Elective module, course 2	6
	Major elective	5
	General electives	10
	Undergraduate thesis	6

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

- General Topology
- Algebraic Curves
- Introduction to Geometric Topology
- Affine and Projective Geometry
- Coding Theory and Cryptography
- Financial Mathematics 1
- Game Theory
- Mathematical Modeling
- Numerical Methods II

The general elective courses are chosen from the study programs at the University of Ljubljana.

# Interdisciplinary University study program Administrative Information Systems

The study program is offered jointly by the Faculty of Administration and the Faculty of Computer and Information Science and leads to the title “diplomirani upravni informatik”.

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

The first years consists of core courses in both fields with 6 ECTS of elective subjects, while the second and third year courses provide the students with a broad understanding of the study fields. The program 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
Elective subjects	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 subjects	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
Thesis	16

## Doctoral programs

The Faculty of Computer and Information Science offers or participates in the following third degree programs leading towards the degree Doctor of Sciences.

- Computer and Information Science
- Interdisciplinary doctoral program Biosciences, offered jointly with the Biotechnical Faculty, Faculty of Electrical Engineering and the Faculty of Mechanical Engineering
- Humanistics and Social Sciences, offered jointly with the Faculty of Arts, and the Faculty of Social Sciences.

### DOCTORAL PROGRAM IN COMPUTER AND INFORMATION SCIENCE

The doctoral program is comprised of

- three required courses
- two elective courses from computer and information science
- two elective courses from either computer and information science or other courses offered at the University of Ljubljana
- five seminars

Year 1	Overview course	Elective course from CS	Elective course		Scientific Skills I	Seminar I
Year 2	Elective from CS	Elective course	Research work		Scientific Skills II	Seminar II
	Research work					Seminar III
Year 3	Research work					Seminar IV
	PhD dissertation preparation					Seminar V
	5 ECTS	5 ECTS	5 ECTS	5 ECTS	5 ECTS	5 ECTS

### REQUIRED COURSES

The purpose of the **Overview course** is to verify whether the PhD student has a sufficient background in computer science and informatics, as covered by selected undergraduate courses and included in the standard US Graduate Record Examination Subject Test for Computer Science. The other two required courses are **Scientific Skills I** and **Scientific Skills II**, with topics like paper writing, writing project proposals, preparing good oral and poster presentation, copyright and patent law, ethics in science and similar.

### ELECTIVE COURSES

The candidate chooses two of six available elective courses from the list.

- Architectures and algorithms for parallel computing
- Artificial Intelligence
- Computer Systems
- Informatics
- Selected Topics from Software Development
- Topics in Mathematics and Natural Sciences

The other two elective courses can be chosen from the above list, from courses from the undergraduate program and from other courses offered at the University of Ljubljana.

### SEMINARS

There are five seminars, one in each of the first five semesters of the study program. At these seminars the students present their work (e.g. papers, project proposals, posters, theses) to each other and to their mentors.

# Research

Research activities (as well as most Undergraduate, Master and Doctoral theses research) at the Faculty of Computer and Information Science are performed in eighteen research laboratories which are organized in six groups.

The main sources of research funding are the Slovenian Research Agency, the Ministry of Higher Education, Science and Technology, the Ministry of Defense, European Union programs (COST, 6th and 7th FP), and various bilateral programs with the USA, France (Proteus), Austria, Czech republic, Norway, Portugal, Greece and UK (ALINK). The Ministry of Higher Education, Science, and Technology, together with the Slovenian Research Agency also supports the majority of postgraduate students by means of individual scholarships. Many application projects are financed by Slovenian companies.

Besides being at the forefront of basic computer science, our researchers are active in a number of fields of potential interest to partners from industry and government, such as

- microcomputer systems, fuzzy and neuro-fuzzy controllers,
- process informatics and programmable technologies
- GRID technologies and parallel processing
- short SIMD processing
- intelligent RFID systems
- cryptography, security, privacy, digital identity management, intrusion detection
- digital libraries and multimedia information retrieval
- 3D design, visualization and animation, video editing
- 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 (insurance companies, police, banking)
- data mining, machine learning, data visualization
- mobile robotics, applications of AI 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, genomics, drug development
- biomedical computer systems and imaging

For more information consult the Web pages of individual laboratories (<http://www.fri.uni-lj.si/en/laboratories/>), or visit the web page with the list of current projects (<http://www.fri.uni-lj.si/en/research/projects/>)



# Laboratory for Computer Graphics and Multimedia

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## RESEARCH ACTIVITIES

The laboratory for Computer Graphics and Multimedia is involved in activities related to multimedia technologies, computer-based education and learning, human-computer interaction, multi-touch technologies, and virtual/augmented reality. The laboratory is a member of the international consortium CoLoS, together with 18 Universities around the world. The main area of interest of the CoLoS consortium is supporting the conceptual learning of natural sciences with computers and multimedia.

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

- digital libraries and multimedia information retrieval,
- natural user interfaces,
- standards and specifications for educational content,
- e-learning environments and virtual laboratories.

Additionally, we are also active in the development of virtual and augmented reality applications, interactive learning systems, and didactic simulations and visualization of natural phenomena.

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.

## 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 natural user interface research the laboratory also has depth sensing equipment - Kinect.

## RESEARCH PROJECTS

**ASPECT:** Adopting Standards and Specifications for Educational Content (ECP-2007-EDU-417008). European Project, Best Practice Network, eContentplus Programme, European Commission (2008–2011).

**ETNOKATALOG:** retrieval of semantic data from folk song and music, based on melodic and metro-rhythmic analysis (J6-0145). Basic Research Project, Slovenian Research Agency (2008–2011).

**SAKE:** Web Architecture as a Learning Technology for Constructivist e-Learning (3211-09-000541). Structural Funds Project, European Regional Development Fund and Slovenian Ministry of Higher Education, Science and Technology (2009-2010).

**DIDIKTA:** analysis and development of ICT usage didactics in teaching and learning (V5-0425). Target Research Programme, Slovenian Research Agency and Slovenian Ministry of Education (2008–2010).

**Click to homeland:** a multimedia presentation of cultural heritage of Slovenian emigrants. Target Research Programme, Slovenian Research Agency and Government's Office for Slovenians Abroad (2010–2012).



Multi-touch table

## SELECTED PUBLICATIONS

M. Marolt, M. Lefeber. It's time for a song - transcribing recordings of bell-playing clocks. Proceedings of ISMIR 2010, Utrecht, The Netherlands. 2010.

J. Južna, A. Kavčič. Packaging standards for electronic learning materials. Proceedings of the International Conference Enabling education and research with ICT, SIRIKT 2010, Kranjska Gora, April 2010, pp. 644-650. 2010.

M. Marolt. Probabilistic Segmentation and Labeling of Ethnomusicological Field Recordings. Proceedings of ISMIR 2009, Kobe, Japan. 2009.

C. Bohak, M. Marolt. Calculating Similarity of Folk Song Variants with Melody-based Features. Proceedings of ISMIR 2009, Kobe, Japan. 2009.

M. Marolt. Non-Negative Matrix Factorization with Selective Sparsity Constraints for Transcription of Bell Chiming Recordings. Proceedings of Sound and Music Computing Conference 2009, Porto, Portugal. 2009.

M. Privošnik. Evolutionary optimization of emergent phenomena in multi-agent systems using heuristic approach for fitness evaluation. Proceedings of 2009 IEEE Congress on Evolutionary Computation, IEEE Press Piscataway, NJ, USA, pp. 1829-1834. 2009.

A. Kavčič. Informatization of learning and training in Slovenian armed forces. Proceedings of the Eurocon 2009, pp. 326-331. 2009.

A. Kavčič. Specifications and standards for use of educational digital content. Research, reflections and innovations in integrating ICT in education, Vol. 1, Badajoz: Formatex, pp. 577-581. 2009.

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M. Marolt. A Mid-Level Representation for Melody-based Retrieval in Audio Collections. IEEE Transactions on Multimedia, December 2008, Vol.10, Issue 8, pp. 1617-1625. 2008.

R. Timmers, M. Marolt, A. Camurri, G. Volpe. Listeners' emotional engagement with performances of a Scriabin étude: an explorative case study. Psychology of Music 34: 481-510. 2006.

A. Kavčič. Fuzzy User Modeling for Adaptation in Educational Hypermedia. IEEE Transactions on Systems, Man, and Cybernetics, Part C, November 2004, Vol. 34, No. 4, pp. 439-449. 2004.

M. Marolt. A Connectionist Approach to Transcription of Polyphonic Piano Music. IEEE Transactions on Multimedia, June 2004, Vol.6, Issue 3, pp. 439- 449. 2004.

M. Marolt. Networks of Adaptive Oscillators for Partial Tracking and Transcription of Music Recordings. Journal of New Music Research, Vol. 33, No. 1. 2004.

# Laboratory for 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 a high 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,
- develop performance measures and protocols to evaluate detection techniques, develop 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/ltstadb/> and
- <http://www.physionet.org/challenge/2003/>.

From 2007 the database is publicly available. See also:

- <http://lbc.si.fri.uni-lj.si/database/>.

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/ltstadb/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.

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

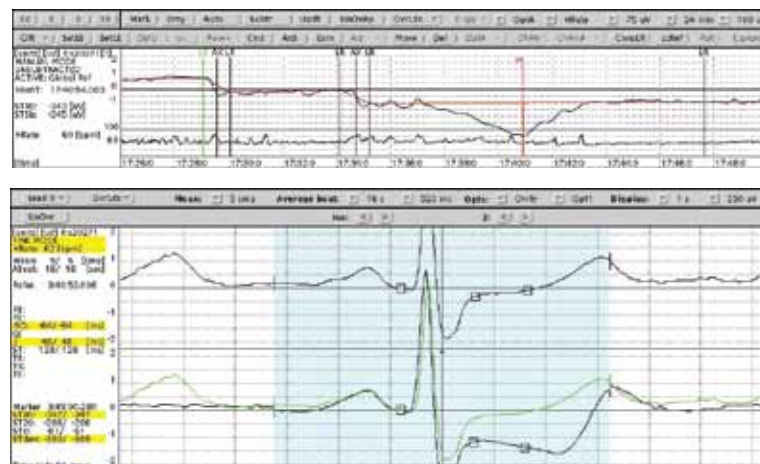
The laboratory owns two high-speed electroencephalographic recording devices to record and monitor electroencephalogram (EEG) signals.

## RESEARCH PROJECTS

Metabolic and inborn factors of reproductive health, birth (P30124). Slovenian Research Agency (2004–2014).

## SELECTED PUBLICATIONS

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.



SEMIA, Version 3.0, semi-automated interactive graphic editing tool to annotate ambulatory ECG records

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.

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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.

F. Jager. Guidelines for Assessing Performance of ST Analysers. *Journal of Medical Engineering & Technology*, 22(1):25–30, 1998.



# Laboratory of Adaptive Systems and Parallel Processing

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## RESEARCH ACTIVITIES

The main research topics include: soft computing, adaptive systems, parallel programming/processing, information theoretic modelling, and natural computing algorithms. Within these areas we are mainly focused on problems where the lack of theoretical knowledge prevents exact solutions and the size of the problems demands a parallel programming and/or processing approach.

The first paradigm requires learning by example and methods based on natural computing algorithms which comprise artificial neural networks, evolutionary algorithms, fuzzy logic and other biologically inspired algorithms. Current work focuses on natural based modelling of sub-cell structures with Boolean networks and new efficient methods for data clustering.

For the second paradigm we are focusing on parallel cluster programming by using MPI and OpenMP libraries, and parallel processing within different Grid environments like Condor and Microsoft HPC Server. We are also involved in the programming of natural computing algorithms on graphical processors using NVIDIA CUDA tools and libraries.

## EQUIPMENT

nVidia Tesla C2050 GPU Computing Processor, Computing cluster, FPGA design boards

## RESEARCH PROJECTS

Synergy of the technological systems and processes (P2 – 0241). Basic Research Programme (with the Faculty of Mechanical engineering, University of Ljubljana), 2009-2013.



Nvidia Tesla C2050 GPU computing processor and computing cluster

Modeling of complex dynamic problems with the methods of soft computing (BI-PL/10-11-014). Bilateral Polish-Slovenian project, Slovenian Research Agency, (2010-2011).

Salus high bay rack warehouse control system, Ljubljana, Slovenia. Industrial research project, Iskra Impuls, 2010-2011.

## LABORATORY GUESTS

Bartłomiej Beliczynski and Maciej Twardy, Warsaw University of Technology, Institute of Control and Industrial Electronics, Poland. 10. 6. 2010 – 17. 6. 2010. Work on bilateral project.

## RESEARCH VISITS

Andrej Dobnikar and Nejc Ilc, Warsaw University of Technology, Institute of Control and Industrial Electronics, Poland. 11. 9. 2010 – 17. 9. 2010. Work on bilateral project.

Jernej Zupanc: Northeastern University, Boston, USA, August 2009 – May 2010. Work towards PhD.

Jernej Zupanc: Max-Planck-Institut fuer biologische Kybernetik, Tuebingen, Germany, Nov 2010 – Mar 2011. Work towards PhD.

## SELECTED PUBLICATIONS

C. Silva, U. Lotrič, B. Ribeiro, A. Dobnikar: Distributed Text Classification with an Ensemble Kernel-based Approach, IEEE Transactions on System Man And Cybernetics, Part C, 40: 287-297, 2010.



Graphs of initial (left) and trained (center) fully recurrent neural network and speedups achieved on parallel architectures with respect to a standalone computer (right)

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I. Jeras, A. Dobnikar: Algorithms for computing preimages of cellular automata configurations, *Physica D*, 233: 95-111, 2007.

M. Trebar, Z. Šušterič, U. Lotrič: Predicting mechanical properties of elastomers with neural networks, *Polymer*, 48: 5340-5347, 2007.

B. Šter, A. Dobnikar: Modelling the environment of a mobile robot with the embedded flow state machine, *J. intell. Robot syst.*, 46: 182-199, 2006.

U. Lotrič: Wavelet Based Denoising Integrated into Multilayered Perceptron. *Neurocomputing*, 62: 179-196, 2004.

B. Šter: An Integrated Learning Approach to Environment Modelling in Mobile Robot Navigation. *Neurocomputing*, 57: 213-238, 2004.

B. Šter, A. Dobnikar: Adaptive Radial Basis Decomposition by Learning Vector Quantization. *Neural Processing Letters*, 18(1): 17-27, 2003.

I. Gabrijel, A. Dobnikar: On-line identification and reconstruction of finite automata with generalized recurrent neural networks. *Neural Networks*, 16(1): 101-121, 2003.

## Laboratory for Computer Architecture

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### RESEARCH ACTIVITIES

Research activities cover computer architectures, software-hardware co-design, parallel processing, embedded systems, programmable logic, radiofrequency identification and soft computing.

The majority of research work is dedicated to short SIMD processing and the integration of these new processing facilities into high-level programming languages. Currently, the most significant activities focus on the development of syntax and semantics extensions to the ANSI C in such a way that we could use short SIMD processing facilities in the C programming language and the development of its vectorizing compiler which is capable of automatically extracting short SIMD parallelism from loops. We call it "MMC (multimedia C) language". We have also introduced a new data-dependence test for array references with linear subscripts. It is a simple method which can be used to filter out data dependences with a sufficiently large distance between memory references. By checking the distance between the memory references we can filter out data dependences that do not prohibit potential SIMD vectorization and that can be excluded from further, possibly more accurate and expensive, tests. This method is based on checking the minimum and maximum distances between two memory references within the iteration space rather than searching for the existence of an integer solution to the dependency equation. This results in greater accuracy and also in a reduction of the time cost as it computes only the bounds of an integer affine function.

The part of research work is directed toward the development of special computer hardware which, through its programmable ALU, is capable of performing custom selected functions. We are also developing an embedded system with two RISC microprocessors, which is implemented in field-programmable gate.

The latest research activities include studies of radiofrequency identification technology (RFID) used in supply chain management, and wireless tracking of objects to acquire the information used in classification and prediction models. This part of research includes the use of neural networks, support vector machines and some other methods applicable in the design of intelligent RFID systems.

### RESEARCH PROJECTS

RFID-F2F, RFID from Farm to Fork. CIP-ICT-PSP European project, European Commission (2010-2012).

Medical Image Compression (BI-BA/10-11-026). Slovenian-Bosnian Bilateral Collaboration Project (with University of Banja Luka), Slovenian Research Agency (2010-2011).

### RESEARCH VISITS

Mira Trebar: University of Wolverhampton, School of Computing and Information Science, UK, 2. 3. 2010 – 6. 3. 2010. Research collaboration including RFID technology and discussions for further work on the accepted EU project.

### INVITED TALKS

Mira Trebar: RFID – a technology of opportunities, 5. 11. 2010, an invited paper at 8<sup>th</sup> Symposium on Industrial Electronics INDEL – 2010, Banja Luka, Bosnia and Herzegovina.

### SELECTED PUBLICATIONS

Z. Babić, A. Avramović, P. Bulić. An iterative logarithmic multiplier. *Microprocess. Microsyst.*, 2010, doi: 10.1016/j.micpro.2010.07.001, pp. 1-11, 2010.

P. Bulić, Z. Babić, A. Avramović. A simple pipelined logarithmic multiplier. *28<sup>th</sup> IEEE International conference on computer Design ICCD 2010 : embedded systems.*, pp. 235-240, 2010.

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M. Trebar, N. Steele. Application of distributed SVM architectures in classifying forest data cover types. *Comput. electron. agric.*, vol. 63, no. 2, 2008.

M. Trebar, Z. Šušterič, U. Lotrič. Predicting mechanical properties of elastomers with neural networks. *Polymer (Guildf.)*, vol. 48, iss. 18, 2007.

V. Gustin, P. Bulic, Learning Computer Architecture Concepts with the FPGA-Based ‘Move’ Microprocessor, *Computer Applications in Engineering Education*, vol. 14, no. 2, 2006.

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P. Bulić, V. Guštin. An Extended ANSI C for Processors with a Multimedia Extension. *International Journal of Parallel Programming*, Vol. 31, No. 2, pp. 107–136. 2003.

# Computer Communications Laboratory

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## RESEARCH ACTIVITIES

The main research interests of our laboratory members are distributed systems design and development, computing clouds and grid architectures, service oriented architecture with related technologies, network security and security policies, communication protocols, formal validation and testing, computer networks design, and agile methodologies in the development of software and information systems.

In 2010, we have researched most actively the following areas:

- In the area of e-learning, we have built our virtual laboratory in a cloud for teaching computer communications and other courses. The infrastructure of eleven servers was used by 350 students, each of them with at least three virtual machines. We are continuously improving the virtual lab and evaluating the students' feedback. At the same time we are researching the pedagogical aspects of introducing e-learning in a cloud (e.g. Virtual Computing Lab) into the teaching process: how to enable our students to perform complex exercises that include multiple servers, diverse network topologies and other resources 24/7, regardless of their location.
- In the area of distributed systems architecture, we have studied system integration techniques with Service Oriented Architecture principles. We have studied the usability of these architectures in digital identity management systems, in Enterprise Application Integration, and in e-learning systems.
- In cooperation with University of Ljubljana's IT department we are researching identity management and application integration technologies and systems.



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

- In the area of agile methodologies, we have studied the impact of test-first programming on productivity, code complexity, tests properties (branch coverage) and the mutation score indicator.

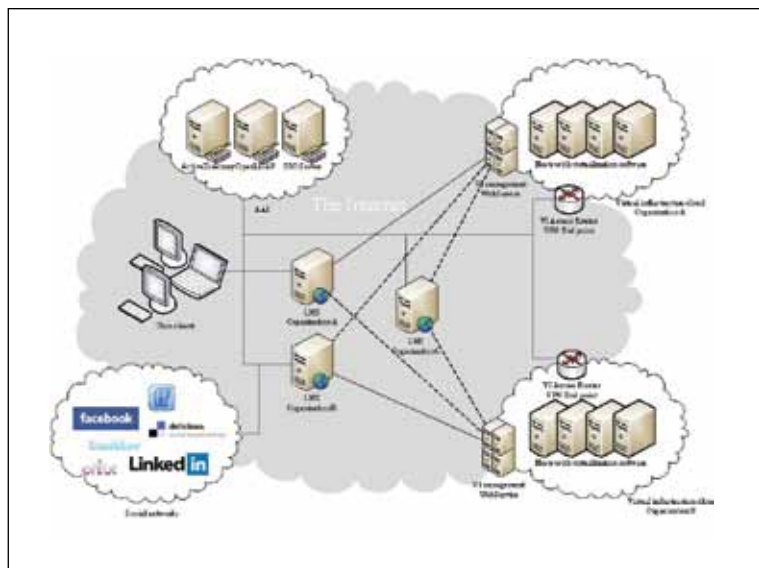
## EQUIPMENT

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 Infiniband DDR network switch, two 24-port and two 48-port Dell Gigabit Switches, a 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, 11 Dell PowerEdge QuadCore R200 servers each with four Gigabit Ethernet ports and an Infiniband SDR 10 Gb/s connection, 4 Dell Power Edge DualCore Servers and 2 Dell PowerEdge Dual Xeon Processor servers, 4 802.11b/g/n wireless Access Points, various mobile devices, ActivCard SmartCard readers and smart cards.

*Software:* network management tools and utilities, VMware virtualization tools, Nexenta and Openfiler storage appliance software, databases and development tools, Redmine project management software, Moinmoin Wiki, Microsoft development tools and utilities; several open-source Java development tools and utilities including Mobile Phone development utilities, ...

## RESEARCH PROJECTS

SAKE: Web Architecture as a Learning Technology for Constructivist e-Learning (3211-09-000541). Structural Funds Project, European



Virtual laboratory in a cloud: architecture

Regional Development Fund and Slovenian Ministry of Higher Education, Science and Technology (2009-2010).

Enterprise Application Integration at University of Ljubljana. Industry-Funded Project, University of Ljubljana (2007-2010).

System and information infrastructure at University of Ljubljana. Industry-Funded Project, University of Ljubljana (2010-2011).

## SELECTED PUBLICATIONS

M. Ciglarič, S. Mavsar. Raziskovanje omrežnih napadov: muholovec Simx, *Elektroteh. vestn.*, 2010, letn. 77, št. 4, pp. 173-178.

M. Ciglarič, A. Krevl, M. Jeličič, A. Brodnik. Laboratory as a Service: Architecture, Implementation and Experiences, *Asia-Pacific Collaborative education Journal*, vol. 6, no. 2, 2010.

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M. Ciglarič, A. Krevl, M. Pančur. Comparison of attacks on IPv4 and IPv6 protocols. V: SCHREURS, Jeanne (ur.). *Euromedia'2009*. Ostend: Eurosis-ETI, cop. 2009, str. 122-127.

M. Bačić Babac, A. Babac, M. Ciglarič. Verifying Epistemic Properties of Multi-agent Systems via Action-based Temporal Logic *Proc. International Conference on Intelligent Agents, Web Technology and Internet Commerce -IAWTIC'2008*. December 2008. IEEE, cop. 2008.

A. Krevl, M. Ciglarič. A framework for developing distributed location based applications. *Proc. 20th International Parallel and Distributed Processing Symposium*, 2006, Rhodes Island, Greece. Piscataway: IEEE, 2006.

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M. Pančur, M. Ciglarič, M. Trampuš, T. Vidmar. Towards empirical evaluation of test-driven development in a university environment. In: ZAJC, B., TKALČIČ, M.(eds.). *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, cop. 2003, vol. 2, pp. 83-86.

# Computer Structures and Systems Laboratory

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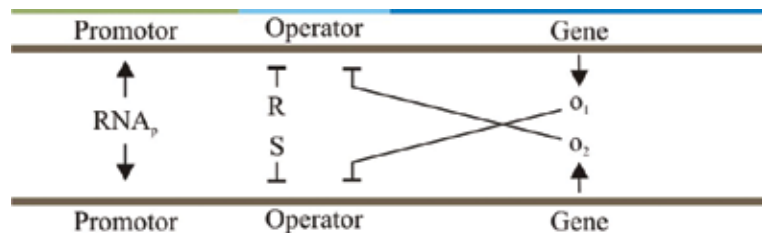
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## RESEARCH ACTIVITIES

The primary activities of the Computer Structures and Systems Laboratory are, besides teaching, devoted to scientific research and development projects with various industrial partners.

The principal scientific research directions of the laboratory are alternative processing platforms of the future. A lot of effort is dedicated to the research of Quantum Dot Cellular Automata. Our results have been published in some of the most respectable journals in the field such as Nanotechnology. Our interests are also in the field of processing in biological systems (synthetic biology). Our goal is to realize the basic logical primitives like memorizing cells and logical gates of different types with the aid of the National Institute of Chemistry of Slovenia. Members of our laboratory mentored the students from University of Ljubljana who attended the iGEM 2010 competition and won a grand prize. Our research activities in the field of alternative processing methods are also committed to fuzzy logic, especially fuzzy time, fuzzy automata, as well as the implementation



Two parts of DNA strand functioning as RS latch, where RNAP represents RNA polymerase, R and S input proteins and o1 and o2 output proteins

of different fuzzy algorithms, such as fire spread prediction models, fuzzy controllers for household devices, fuzzy animats, solving logistic problems with fuzzy logic etc. Our research activities are partially financed from European funds (ESF) and partially from the national research fund (ARRS).

In addition to scientific research the members of the laboratory actively cooperate with different industrial partners. We offer them our knowledge in the field of fuzzy systems design, intelligent algorithms design, product optimization, efficiency analysis, reliability analysis, product development (hardware and software), etc. Our past and present industrial partners are Gorenje d.d., Iskratel d.o.o., Konel d.d., OurSpace d.o.o., ComLand d.o.o., TMG-BMC d.o.o. We have also cooperated with government institutions such as the Dr. Franc Derganc General Hospital, the Slovenian National Assembly, the Slovenian Ministry of Defense, etc.

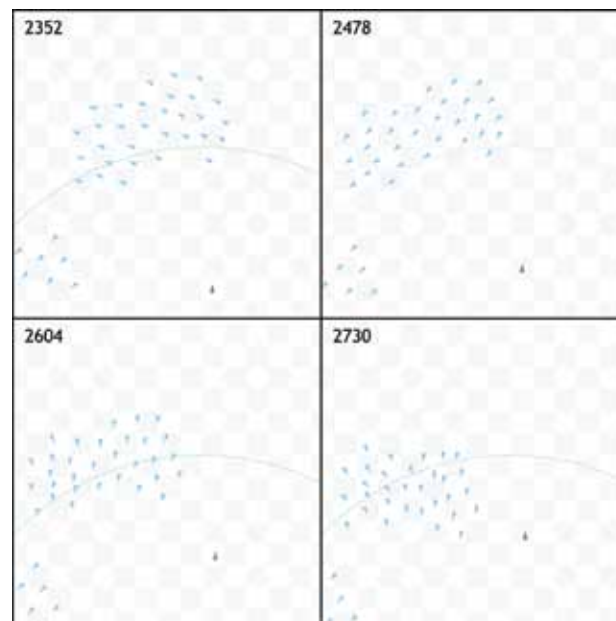
## RESEARCH PROJECTS

Development of a new algorithm for the extrapolation of properties of skeletal muscles from an analogue signal. Industry-Funded Project, TMG-BMC d.o.o. (2010).

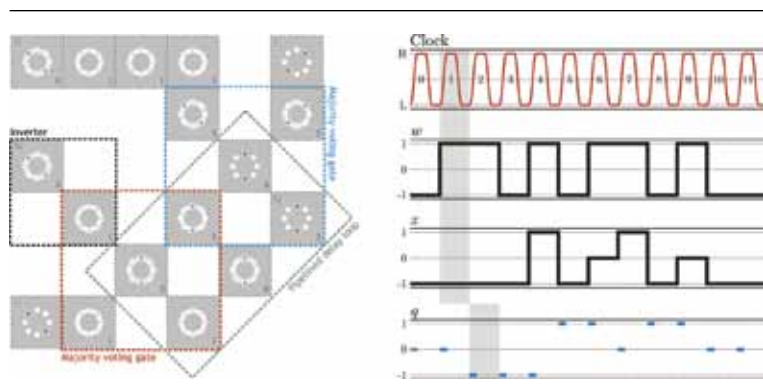
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Pervasive computing (P2-0359). Research Programme, Slovenian Research Agency (2009-2011).

Optimization of resiliency and fast convergence in the Ethernet network environment (03/FRI-IT/ES-2006). Industry-Funded Project, Iskratel d.o.o. (2006-2010).



Fuzzy logic based bird flocking simulation displaying behaviour typical for pigeon flocks, where birds, while performing turns, change their position in the flock



The balanced ternary quantum-dot cellular automata memorizing cell WX, with prerequisite  $w \neq 0$ , and the corresponding simulation results for the sequence of read/write operations: read, write (-1), write (-1), read, write (1), read, write (0), write (1), read, write (0), read, read

## LABORATORY GUESTS

Mihail Scopchanov, Technical University of Varna, Varna, Bulgaria. June 2010. Lecture: Informatisation of industrial processes.

## RESEARCH VISITS

Miha Mraz, Primož Pečar: National Technical University, Kharkiv Polytechnical Institute, June 2010. Nonlinear filtering of biomedical signals on the basis of rank ordered statistics.

Miha Moškon: Technical University of Varna, Varna, Bulgaria, September 2010. Nuclear Power Generation Competence Centre.

## INVITED TALKS AND LECTURES

Miha Moškon: Solving Vaguely Defined Assignment Problems, 23. 9. 2010, an invited lecture at Technical University of Varna, Varna, Bulgaria.

## SELECTED PUBLICATIONS

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, accepted for publication in *Journal of Advanced Transportation*.

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

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.

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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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N. Zimic and M. Mraz. Decomposition of a Complex Fuzzy Controller for the Truck&Trailer Reverse Parking Problem. *Mathematical and Computer Modelling*, 43(5-6):632-645, 2006.

I. Lebar Bajec, N. Zimic and M. Mraz. Simulating flocks on the wing: the fuzzy approach. *Journal of Theoretical Biology*, 233(2):199-220, 2005.

I. Lebar Bajec, P. Trunk, D. Oseli and N. Zimic. Virtual coronary cineangiography. *Computers in Biology and Medicine*, 33(3):293-302, 2003.

M. Mraz. The design of intelligent control of a kitchen refrigerator. *Mathematics and Computers in Simulation*, 56:259-267, 2001.

J. Virant, N. Zimic and M. Mraz. T-type fuzzy memory cell. *Fuzzy Sets and Systems*, 102:175-183, 1999.

M. Mraz, N. Zimic and J. Virant. Intelligent bush fire spread prediction using fuzzy cellular automata. *Journal of Intelligent and Fuzzy Systems*, 7:203-207, 1999.

# Information Systems Laboratory

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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 organisation 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 like Marand, RCC-IRC Celje, Datalab, Comland, and IPMIT. We have also developed a Unified methodology for system development – EMRIS for Government Centre for Informatics and methodology for strategic planning for Telekom (Slovenian telephony operator).

*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. In the period between 2004 and 2008 we published several methodologies that focus on how to build strategic plans for information systems. In the last edition we integrated an enterprise architecture framework, which enables the design of strategic enterprise architecture during

plan development. These methodologies are based on many years of practical experiences in developing strategic plans for a wide range of organisations. We developed strategic plans for the following organisations: the Employment Service of Slovenia, KAD (financial institution), Elektro Ljubljana (electricity distribution operator), ELES (Slovenian electric power transmission company), Slovenian electric distribution operators association, Informatika, d.d., Mobitel (Slovenian mobile telephony operator) and government institutions. Recently, we also developed enterprise architecture for Iskratel (telephony and networks solutions developer). In the context of IT/IS planning we focus our research on: enterprise architecture, IS/IT architectures, information systems reengineering, business process reengineering, electronic business, COBIT and other standards.

*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.

*Intelligent Agents and Multi-Agent Systems.* In this area we do research on the development of agents – autonomous entities capable of acting in its environment. The research encompasses: research on mutual communication among agents using ACL and use of rules in several aspects, modelling multi-agent systems, using agent oriented modelling languages (AML, AUML) and other agent based methodologies. We focus on the utilization of intelligent agents and multi-agent systems for business systems and their information systems.

*Semantic web and knowledge discovery.* Research on Semantic Web as the next step in the evolution of the Internet is focused on ontologies, rules, rule engines and Semantic Web languages.

*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. We have also developed data mining decision support system based on Oracle Data Mining API and Engine. In the area of applied research we have created several strategic reports on different models of introduction of data mining to information systems.

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

*SOA – Service Oriented Architecture.* Service-Oriented Architecture (SOA) is a collection of loosely-coupled, distributed services



which communicate and interoperate via agreed standards. A service is a mechanism to enable access to one or more capabilities, where said access is provided using a prescribed interface and is exercised consistently with constraints and policies as specified by the service description. Services are independent and can run on different platforms. In this area we do research on how SOA focuses on business processes and how the information technology should support these processes with its main motivation to increase the capability of an organisation to address new business requirements in the short term by reusing existing business logic and data models, thus incurring only minimal cost, resource, and time overheads, while minimizing risks, especially when compared to rewriting entire application systems. From this topic one PhD thesis is being developed. Due to difficulties with complex systems which have become very demanding from the point of view of integration and maintenance, it has become the prevalent paradigm for information systems development. We developed IS reengineering and the development of SOA based enterprise architecture for Slovenian electricity distribution operators association.

#### LABORATORY GUESTS

Olegas Vasilecas, Gediminas Technical University, Lithuania. November 2009, Delo na skupnih raziskavah.

#### RESEARCH VISITS

Ana Šaša: KEIO Research Institute at SFC, KEIO University, 1. 10. 2010 – 30. 12. 2010. Research visit for postdoctoral project with the title: Multimedia data services enhanced SOA framework for advanced business process automation.

#### SELECTED PUBLICATIONS

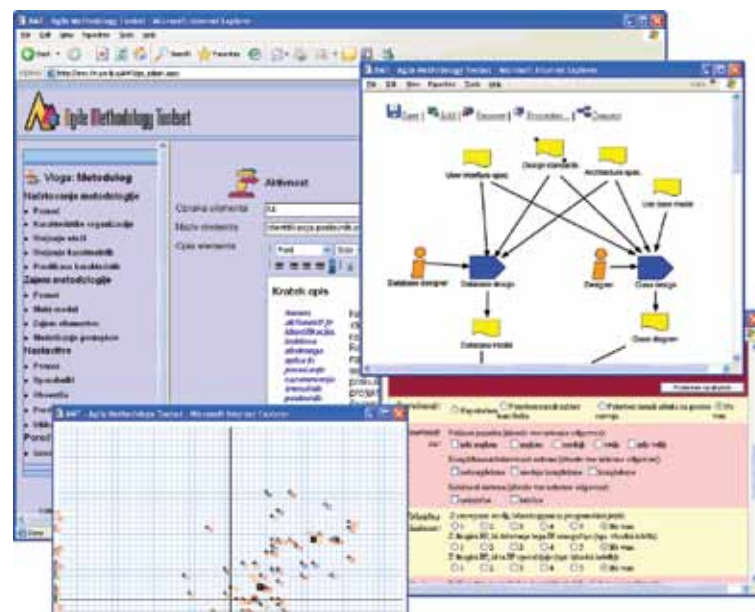
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A. Šaša, M. Krisper. Analytical patterns for enterprise architectures. *Uporabna informatika*, let. 18, št. 3, 2010.

A. Šaša. A model for business process automation in service oriented systems with knowledge management technologies. In: *Proceedings of the 2010 IEEE Sixth World Congress on Services (SERVICES 2010)*, pp. 136-139, 2010.



Screenshot of the AMT system

M. B. Jurič, A. Šaša, B. Brumen, I. Rozman. WSDL and UDDI extensions for version support in web services. *J. syst. softw.*, vol. 82, no. 8, str. 1326-1343, 2009.

M. Trkman and P. Trkman. A wiki as intranet : a critical analysis using the Delone and McLean model. *Online inf. rev.*, Vol. 33, no. 6, pp. 1087-1102, 2010.

D. Vavpotic, M. Bajec. An approach for concurrent evaluation of technical and social aspects of software development methodologies. In: *Information and software technology*, Vol. 51, no. 2, pp. 528-545, 2009.

Sasa, Ana; Juric, Matjaz; Krisper, Marjan: Service-Oriented Framework for Human Task Support and Automation, *IEEE Transactions on Industrial Informatics*, Vol. 4(4), November 2008.

R. Rupnik, M. Kukar and M. Krisper. Integrating data mining and decision support through data mining based decision support system. *J. comput. inf. syst.*, 2007, vol. 47, no. 3, str. 89-104, ilustr.

D. Vavpotič, M. Bajec and M. Krisper. Scenarios for improvement of software development methodologies. *Advances in information systems development*. Vol. 1, Bridging the gap between academia and industry. New York: Springer, cop. 2006. Technologies (IEEE-DEST 2007).

D. Vavpotič and M. Krisper. An approach for rapid creation of a virtual software development team. *V: Managing Worldwide Operations and Communications with Information Technology (IRMA 2007 Proceedings)*, Vancouver, 2007.

M. Krisper and A. Rožanec. Obvladovanje informatike v poslovnih sistemih : pomen strategije in arhitektur. *Uporab. inform. (Ljubl.)*, 2005, letn. 13, št. 4, str. 185-198.

D. Vavpotič, M. Bajec and M. Krisper. Measuring and improving software development methodology value by considering technical and social suitability of its constituent elements. In: O. Vasilecas, J. Zupančič (eds.). *Advances in theory, practice and education: Proc. 13th Intern. Conf. on IS Development*, pp. 228-238, Vilnius, Lithuania, 2004.

## Laboratory for e-media

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### RESEARCH ACTIVITIES

The e-media laboratory is actively involved in researching areas regarding security, privacy and trust management with an emphasis on cryptographic protocols, formal methods, and also security infrastructure systems like PKI and AAA.

In addition to this, the laboratory's research activities cover the quantitative modelling of human factors, 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 qualitative algebra.

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. 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).

### RESEARCH PROJECTS

SEMPOC - Simulation Exercise to Manage Power Cut Crises (JLS/2008/CIPS/024). European Project, European Commission (2009–2011).

Pervasive computing (P2-0359). Research Programme, Slovenian Research Agency (2009–2011).

Managing technical, business and social implications of Internet of things in Slovene environment (V2-1022). Target Research programme, Slovenian Research Agency, MVZT (2010–2011).

COST IS0605 - A Telecommunications Economics COST Network. International Project (2007–2011).

COST Agreement Technologies (Action IC0801). International Project (2008–2012).

#### LABORATORY GUESTS

Prof. Dr. Jose M. Sarriegi, University of Navarra / TECNUN. 29. 9. 2010 – 1. 10. 2010. Guest lecturing.

#### RESEARCH VISITS

Iztok Starc, B.Sc.; Institute for Informatics, University of Zurich, Switzerland. 20. 9. 2010 – 8. 10. 2010. Scientific exchange for project COST ISO605.

#### INVITED TALKS AND LECTURES

Denis TRČEK: Ergonomic trust management in pervasive computing environments - qualitative assessment dynamics. V: YAN, Jingzhi (ed.), LI, Xiaowei (ed.), DEBEVC, Matjaž (ed.), TJOA, A Min (ed.), HU, Bo (ed.). *ICPCA10*. [S. l.]: IEEE Press, cop. 2010, pp. 1-7.

#### SELECTED PUBLICATIONS

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

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

TRČEK, Denis, ABIE, Habtamu, SKOMEDAL, Åsmund, STARC, Iztok. Advanced framework for digital forensic technologies and procedures. *J Forensic Sci*, 2010, pp. 1-10, doi: 10.1111/j.1556-4029.2010.01528.x.

TRČEK, Denis, JÄPINNEN, Pekka. 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, 2010, pp. 147-168.

HERNANTES, Josune, TORRES, Jose M., LAUGE, Ana, SARRIEGI, Jose M., STARC, Iztok, ZUPANČIČ, Eva, TRČEK, Denis. Using GMB methodology on a large crisis model, FRENCH, Simon (ed.), TOMASZEWSKI, Brian (ed.), ZOBEL, Christopher (ed.). *Defining crisis management 3.0 : proceedings*, 2010, pp. 1-5.

TRČEK, Denis. Managing communications in critical infrastructures protection. *Proc.of the ICCEA 2010*, 2010. Vol. 1. Los Alamitos (California); Washington: IEEE Computer Society, cop. 2010, pp. 11-15.

## Data Technology Laboratory

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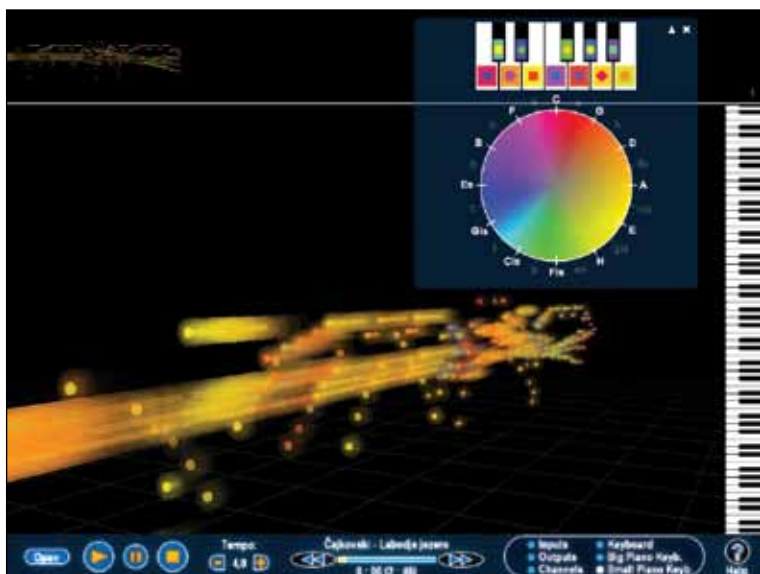
#### RESEARCH ACTIVITIES

The Data Technology Laboratory was founded in 2009 and is the youngest laboratory 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 and semantic web:

**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.

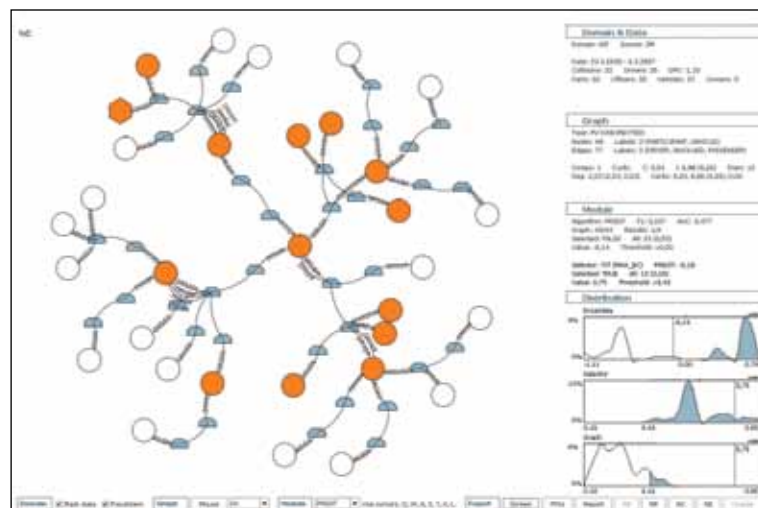
**Data visualization:** As the volume and complexity of data increases it becomes very difficult for users to effectively explore large-scale datasets. A possible solution for this problem is visualization



Realtime visualization of midi sequence

(graphical representation of data). Visualizing large amounts of data allows us to see patterns that may otherwise remain hidden and it allows us also 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, geovisualizations, 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.



Group of related traffic accidents

## LABORATORY GUESTS

Prof. dr. Veljko Milutinović, IEEE Fellow, University of Belgrade, School of Electrical Engineering. Lecture: Concept Modelling for Knowledge Search.

## SELECTED PUBLICATIONS

B. Žvanut and M. Bajec. A tool for IT process construction. In: Information and software technology. Apr. 2010, vol. 52, no. 4, pp. 397-410.

D. Lavbič, I. Lajovic and M. Krisper. Facilitating Information System development with Panoramic view on data. In: Computer Science and Information Systems, 2010. To be printed.

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D. Lavbič, O. Vasilecas and R. Rupnik. Ontology based Multi-Agent System to support business users and management. In: Technological and economic development of economy. 2010, vol. 16, no. 2, pp. 327-347.

M. Bajec, D. Vavpotič. A framework and tool-support for re-engineering software development methods. In: Informatica (Vilnius), 2008, vol. 19, no. 3, str. 321-344.

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Š. Furlan and M. Bajec. Holistic approach to fraud management in health insurance. In: *Journal of information and organizational sciences*, 2008, vol. 32, no. 2, pp. 99-114.

Š. Furlan and M. Bajec. Praksa slovenskih avtomobilskih zavarovalnic pri razreševanju zavarovalniških goljufij. In: *Zavarovalniški horizonti*, jul. 2009, vol. 5, no. 3, pp 29-41.

D. Lavbič and M. Krisper. Rapid ontology development. In: *The 19th European-Japanese Conference on Information Modelling and Knowledge Bases*, 2009, Maribor, Slovenia.

## Laboratory for Algorithms and Data Structures

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### RESEARCH ACTIVITIES

Our 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

Crisis Management Simulator (M2-0217). Target Research Programme, Slovenian Research Agency (2007–2009).

Parallel and Distributed Systems (P2-0095). Research Programme, jointly with Jozef Stefan Institute and Faculty of Electrical Engineering, University of Ljubljana. Slovenian Research Agency (2009-2012).

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P. Bulić, T. Dobravec. An approximate method for filtering out data dependencies with a sufficiently large distance between memory references. *J. supercomput.* 2009, doi:10.1007/s11227-009-0364-8.

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T. Ungerer, B. Robič, J. Šilc. A survey of processors with explicit multithreading. *ACM Comp Surveys* 35(1):29-63, 2003.

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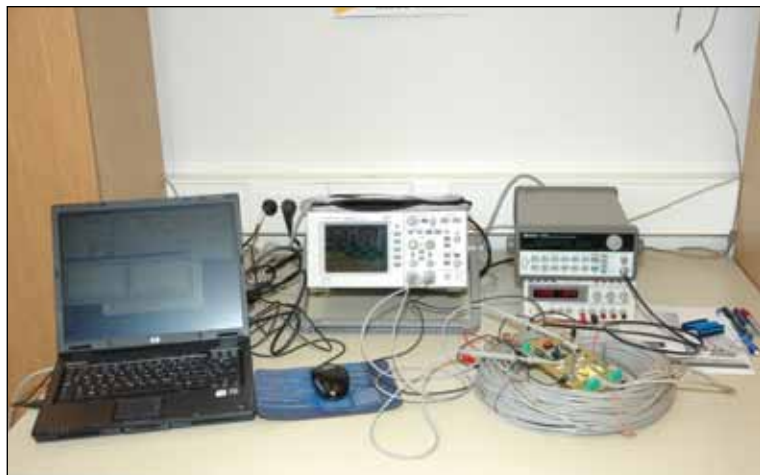
### RESEARCH ACTIVITIES

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:

1. *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.

2. *In Digital Signal Processing:* Design and development of algorithms, hardware and software. Complexity of the integer minimax approximation problem. Theoretical aspects and performance bounds for finite wordlength digital filters. In particular, bounds for minimax integer polynomial approximation over collections of non-overlapping intervals are being investigated. A general purpose finite wordlength FIR design program 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 analyzer that is now in production.

3. *In Speech Processing:* Speech recognition over telephone lines. Trainable high quality speech synthesis. Considerable experience has been acquired from collaborating in the COST-232 European project.



Measurement system that students use during I/O systems course.

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

ARM9 microcomputer system - education tool for computer science students. Joint project with Asyst Electronic Ltd. (2007-2009).

Parallel and Distributed Systems (P2-0095). Joint project with Jozef Stefan Institute and Faculty of Electrical Engineering, University of Ljubljana. Basic Research Project, Slovenian Research Agency (2009-2012).

## SELECTED PUBLICATIONS

R. Rozman, D. M. Kodek. Using asymmetric windows in automatic speech recognition. *Speech Communication*, vol. 49, no. 4, pp. 268-276, Apr. 2007.

D. M. Kodek and M. Krisper. Telescopic rounding for suboptimal finite wordlength FIR digital filter design. *Digital Signal Processing*, vol. 15, no. 6, pp. 522-535, November 2005.

D. M. Kodek. Performance limit of finite word length FIR digital filters. *IEEE Transactions on Signal Processing*, vol. 53, no. 7, pp. 2462-2469, Jul. 2005.

D. M. Kodek and 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, Dec. 2004.

D. Šonc. A version of the byte radix sort algorithm suitable for the implementation in hardware. *Proc. of Eurocon 2003 International Conference on Computer as a Tool*, Ljubljana, Slovenia, vol. 2, pp. 66-69, Sep. 22-24, 2003.

R. Rozman and D. M. Kodek. Improving speech recognition robustness using non-standard windows. *Proc. of Eurocon 2003 International Conference on Computer as a Tool*, Ljubljana, Slovenia, vol. 2, pp. 171-174, Sep. 22-24, 2003.

A. Štrancar, R. Rozman, D. M. Kodek. Parametrizacija govornega signala z dinamičnim določanjem dolžine okna. *Proc. of ERK 2003 Conference*, Portorož, Slovenia, pp. 481-484, Sep. 25-26, 2003.

D. M. Kodek and M. Krisper. An algorithm for computing the optimal cycle time of a printed circuit board assembly line. *Informatica (Ljubljana)*, vol. 27, no. 1, pp. 105-114, Apr. 2003.

R. Rozman, A. Štrancar, D. M. Kodek. Uporaba načela "deli in vladaj" v sistemih za razpoznavanje govora. *Proc. of ERK 2002 Conference*, Portorož, Slovenia, vol. B, pp. 239-242, Sep. 23-25, 2002.

D. M. Kodek. An approximation error lower bound for integer polynomial minimax approximation. *Electrotechnical Review*, vol. 69, pp. 266-272, 2002.

D. M. Kodek. Design of optimal finite wordlength FIR digital filters. *Proceedings of the 1999 European Conference on Circuit Theory and Design ECCTD'99*, vol. 1, pp. 401-404, Stresa, Italy, 1999.

D. M. Kodek. Limits of finite word length FIR digital filter design. *Proceedings of the 1997 IEEE International Conference on Acoustics, Speech, and Signal Processing ICASSP 97*, pp. 2149-2152, Munich, 1997.

D. M. Kodek. Conditions for the existence of fast number theoretic transforms. *IEEE Transactions on Computers*, C-30, pp. 359-361, 1981.

D. M. Kodek and K. Steiglitz. Comparison of optimal and local search methods for designing finite word length FIR digital filters. *IEEE Transactions on Circuits and Systems*, CAS-28, pp. 28-32, 1981.

D. M. Kodek. Design of optimal finite wordlength FIR digital filters using integer programming techniques. *IEEE Trans. on Acoustics Speech and Signal Processing*, vol. ASSP-28, no. 3, pp. 304-308, June 1980.

# 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 Software Quality Management, Software Metrics, Information Systems Development, Information Systems Audit and Control, Data Warehousing, and Graph Grammars. The staff has recently worked on two international projects within the EC TEMPUS and INCO-COPERNICUS programs, as well as on several development projects for the industry. The following areas of research are currently being pursued:

1. *In Software Quality Management:* Comparative studies of different software quality models (CMMI, ISO 9000 family of standards, SPICE, Bootstrap etc.). Adaptation of CMMI to the needs of small organizations. Personal and Team Software Process.

2. *In Software Metrics:* Different approaches to software measurements (e.g. GQM, bottom-up). Measuring performance of agile software development methods. Definition of appropriate metrics for the development of applications in a database environment.

3. *In Information Systems Audit and Control:* Investigation of systematic approaches (such as COBIT) to IT control and audit in order to help IT professionals in developing and maintaining information systems that would satisfy fiduciary, security and quality requirements.

4. *In Information Systems and Data Warehouses:* Agile methodologies for information systems development. Development of administrative and management information systems for higher education institutions. Information quality assessment and improvement.

5. *In Graph Grammars:* Graph grammars as a generalization of textual grammars. Parsing graph grammars and translating graph-

based languages. Using developed theories and tools for solving relevant problems in various computer science domains.

6. *In Web User Behavior Analysis:* Using stochastic model for user behavior analysis. Separating interleaved web sessions using graph search algorithms.

## RESEARCH PROJECTS

*E-student:* Web-based student records information system covering enrolment, examination records, degree records, and various statistical surveys. University of Ljubljana, partly supported by the Slovenian Ministry of Information Society (2001-2010).

## SELECTED PUBLICATIONS

V. Mahnič. Teaching Scrum through team-project work : students' perceptions and teacher's observations. *International Journal of Engineering Education*, 26(1): 96-110, 2010.

M. Požanel, V. Mahnič, M. Kukar. Separating interleaved HTTP sessions using a stochastic model. *Informatica (Ljublj.)*, 34(2): 199-205, 2010.

V. Mahnič, S. Georgiev, T. Jarc. Teaching Scrum in cooperation with a software development company. *Organizacija (Kranj)*, 43(1): 40-48, 2010.

M. Požanel, V. Mahnič, M. Kukar. Heuristic best-first search in separation of interleaved Web sessions. Workshop on Analysis of Complex Networks at ECML PKDD, *ACNE 2010*, pp. 63-74, Barcelona, Spain, 2010.

L. Fürst, M. Mernik, V. Mahnič. A parser for context-sensitive graph grammars, *Proc. 18th International Electrotechnical and Computer Conference ERK 2009*, pp. 255-258, Portorož, Slovenia, 2009.

V. Mahnič, N. Žabkar. Using COBIT Indicators for Measuring Scrum-based Software Development. *WSEAS Transactions on Computers*, 7(10): 1605-1617, 2008.

L. Fürst, S. Fidler, A. Leonardis. Selecting features for object detection using an AdaBoost-compatible evaluation function. *Pattern recognition letters*, 29(11): 1603-1612, 2008.

V. Mahnič. Teaching information system technology in partnership with IT companies. *Organizacija (Kranj)*, 41(2): 71-78, 2008.

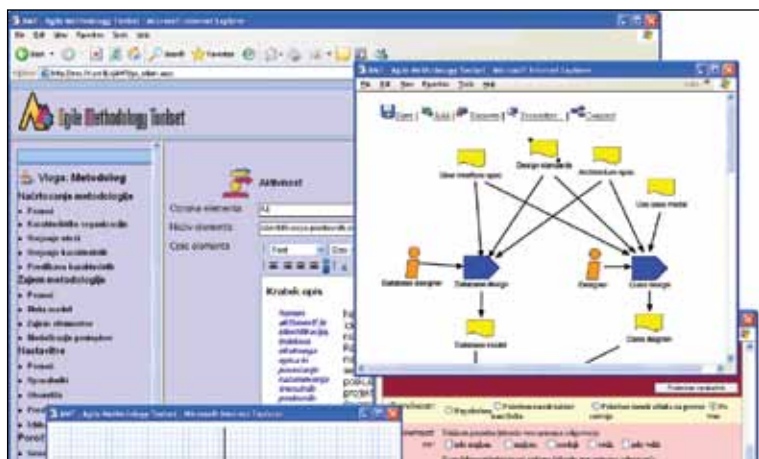
V. Mahnič, I. Vrana. Using stakeholder-driven process performance measurement for monitoring the performance of a Scrum-based software development process. *Electrotechnical review*, 74(5): 241247, 2007.

V. Mahnič, N. Žabkar. Introducing CMMI measurement and analysis practices into scrum-based software development process. *International journal of mathematics and computers in simulation*, 1(1): 65-72, 2007.

I. Rožanc, V. Mahnič. Teaching software quality with emphasis on PSP. *Organizacija*, 38(8): 454-464, 2005.

N. Žabkar, V. Mahnič. Assessing scrum-based software development process measurement from COBIT prospective. *New aspects*





e-Študent: web-based student records information system

of computers: *Proc. 12th WSEAS International Conference on Computers*, pp. 589-594, Heraklion, Greece, 2008.

V. Mahnič, I. Rožanc, M. Požnel. Using e-business technology in a student records information system. *Recent advances in e-activities: Proc. 7th WSEAS International Conference on E-Activities*, pp. 80-85, Cairo, Egypt, 2008.

M. Požnel, V. Mahnič. Data Webhouse: A tool for monitoring the use of a Web based information system. *Proc. 13th International Conference of European University Information Systems, EUNIS 2007*, Grenoble, France, 2007.

## Computer Vision Laboratory

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### RESEARCH ACTIVITIES

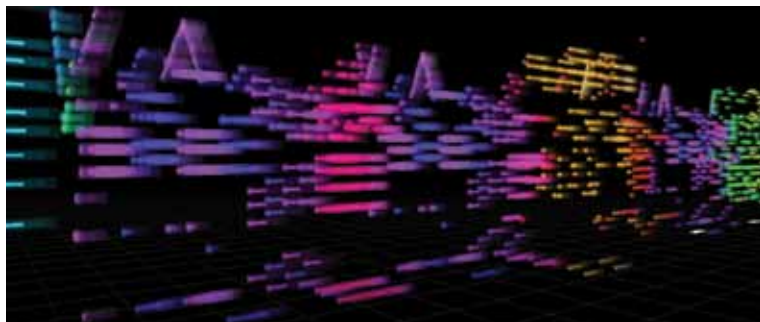
The laboratory is dedicated to research in computer vision and multimedia, with an emphasis on object segmentation, recognition and tracking, face detection, face and iris recognition, panoramic imaging, texture processing, medical imaging, range image interpretation, real-time and multimedia applications.

Analysis and tracking of objects in video sequences is applied to studies of human locomotion, roulette gaming instruments and golf. Superquadric models are used for range image interpretation and also for object tracking in sequences of intensity images. Possible applications of range image interpretation include automatic creation of CAD models for reverse engineering applications, creation of models for virtual reality applications, and part-based object recognition.

We have developed a novel method of visualizing concurrent tones in music with colours and we are studying how this method could be used in the context of music understanding and learning.

We are studying human face detection and recognition in difficult illumination conditions. We are interested in using such techniques for smart advertising and digital signage.

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. The art projects serve as an excellent frame for testing



Visualization of music with colours using a new method of interpretation of concurrent tones.

our research results in practical applications, in particular, we applied face detection in the installation “15 seconds of fame”, body position tracking in “Virtual skiing” and locomotion-based person identification in “Coincidence-matrix-dating club” project.

We are interested in the use of unconventional user interfaces based on computer vision in the context of computer games. In 2008 we established a GameTeam within the laboratory with a number of student members working on projects like a 3D Maze, Bubbles and a Virtual Painter.

We are involved in applications in the areas of biometry systems, image based computer forensics, gaming systems, visual quality control, surveillance applications and smart advertising.

## RESEARCH PROJECTS

Computer vision (P2-0214), Basic Research programme funded by the Slovenian Research Agency (2009–2014).

Managing technical, business and social implications of Internet of things in Slovene environment (V2-1022). Target Research programme, Slovenian Research Agency, MVZT (2010 – 2011).

## LABORATORY GUESTS

Prof. dr. Sergey V. Ablameyko, National Academy of Sciences of Belarus. 28. 2. 2010 – 3. 3. 2010. Lecture: Joint Interpretation of Remote Sensing Images and Digital Maps.

## SELECTED PUBLICATIONS

G. Derganc, P. Peer. Računalniško branje padavinskih grafov. Elektrotehniški vestnik 2010, letnik 77, št. 2/3, str. 149-154

P. Ciuha, B. Klemenc, F. Solina. Visualization of concurrent tones in music with colours. V: ACM MM 10 & co-located workshops. New York (NY): ACM, cop. 2010, str. 1667-1680

F. Solina, R. Ravnik. Georeferencing works of literature. V: V. Lužar - Stiffler, I. Jarec, Z. Bekić. 32nd International Conference on Information Technology Interfaces, June 21-24, 2010, Cavcat / Dubrovnik, Croatia. ITI 2010 : proceedings of the ITI 2010, (ITI ...

(Tisak)). Zagreb: SRCE University Computing Centre, cop. 2010, str. 249-253.

N. Bovcon. Umetnost v svetu pametnih strojev: novomedijska umetnost Sreča Dragana, Jake Železnikarja in Marka Peljhana, (Acta, 4). Ljubljana: Raziskovalni inštitut Akademije za likovno umetnost in oblikovanje, 2009. Str. 239.

P. Peer, B. Batagelj. Art - a perfect testbed for computer vision related research. V: M. Grgić, K. Delač, M. Ghanbari (Eds.), Recent advances in multimedia signal processing and communications, (Studies in computational intelligence, vol. 231). Berlin; Heidelberg: Springer, pp. 611-629, 2009.

L. Šajna, I. Kononenko. Multiresolution image parameterization for improving texture classification. EURASIP Journal on Advances in Signal Processing, 2008(1): 1-12, 2008.

P. Peer and L. G. Corzo. Local Pixel Value Collection Algorithm for Spot Segmentation in Two-Dimensional Gel Electrophoresis Research. Comparative and Functional Genomics, 7(1): 77-85, 2007.

F. Solina. 15 seconds of fame. Leonardo, 37(2):105–110+125, 2004.

J. Krivic, F. Solina. Part-level object recognition using superquadrics. Computer Vision and Image Understanding, 95(2): 105–126, 2004.

A. Jaklič, A. Leonardis and F. Solina. Segmentation and Recovery of Superquadrics. Volume 20 of Computational Imaging and Vision. Kluwer, Dordrecht, 2000.

B. Prihavec and F. Solina. User interface for video observation over the internet. Journal of Network and Computer Applications, (21):219–237, 1998.

A. Leonardis, A. Jaklič, and F. Solina. Superquadrics for segmentation and modeling range data. IEEE Transactions on Pattern Recognition and Machine Intelligence, 19(11):1289–1295, November 1997.

F. Solina and R. Bajcsy. Recovery of parametric models from range images: The case for superquadrics with global deformations. IEEE Transactions on Pattern Analysis and Machine Intelligence, 12(2):131–147, 1990.

# Visual Cognitive Systems Laboratory

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\* also with Computer Vision Laboratory. From June 2010 with University of Pennsylvania, Computational Perception and Cognition Laboratory.

\*\* also with Laboratory for Mathematical Methods in Computer and Information Science

\*\*\* 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, mobile computing devices, intelligent transportation systems, cognitive assistants, etc. The Visual Cognitive Systems Laboratory is involved in basic research of such systems, with emphasis on visual learning, recognition and categorisation. Other activities include panoramic imaging for mobile robotics and range image modelling and interpretation.

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, recognition and categorization, and goal specification, all of which are



An artificial cognitive system learning object affordances

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 a general framework for continuous learning of visual concepts by learning associations between automatically extracted visual features and linguistic descriptions of the scene. 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. 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. 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.

Our theoretical findings on visual 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 omnidirectional and stereo camera setups. We are also implementing direct interaction and object manipulation with a Katana HD6M light weighted robot arm with the aim of developing methods for robust and adaptive interaction of the robot with its environment that would enable studying object affordances. On the other hand, the research in mobile computing is being integrated and tested on the state of the art mobile phones, 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 categorise and recognise 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).

POETICON - The Poetics of Everyday Life: Grounding Resources and Mechanisms for Artificial Agents (FP7-ICT-215843-POETICON). FP7 ICT Programme Project, European Commission (2008-2010).

COGX - Cognitive Systems that Self-Understand and Self-Extend (ICT-215181). FP7 ICT Programme Project, European Commission (2008-2012).

Computer vision for mobile computing and interaction (J2-2221). Basic Research Project, Slovenian Research Agency (2009-2010).

Learning a large number of visual object categories for content-based retrieval in image and video databases (J2-3607). Basic Research Project, Slovenian Research Agency (2010-2013).

## LABORATORY GUESTS

David Hogg, School of Computing, University of Leeds, UK, 23. 4. 2010 - 25. 4. 2010. Collaboration on the CogX project.

Norbert Krüger, University of Southern Denmark, Denmark, 24. 4. 2010 - 27. 4. 2010. Collaboration on the CogX project.

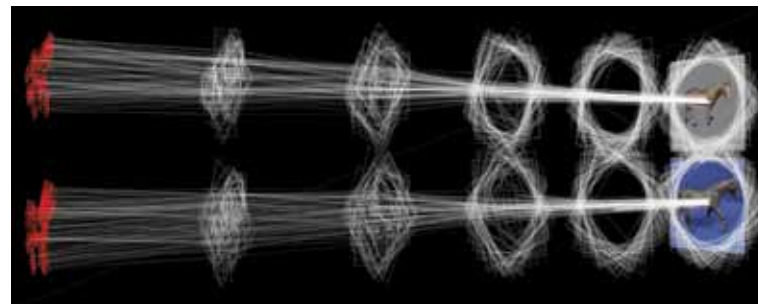
Ron Petrick, School of Informatics, University of Edinburgh, UK, 23. 4. 2010 - 26. 4. 2010. Collaboration on the CogX project.

## RESEARCH VISITS

Alen Vrečko: Albert-Ludwigs-Universität, Freiburg, Germany, 9. 3. 2010 - 11. 3. 2010. Collaboration on the CogX project.

Alen Vrečko: University of Birmingham, UK, 26. 5. 2010 - 3. 6. 2010. Collaboration on the CogX project.

Marko Mahnič, Alen Vrečko: University of Birmingham, UK, 12. 9. 2010 - 17. 9. 2010, Collaboration on the CogX project.



Object categorization by hierarchical matching to a prototype

Danijel Skočaj, Marko Mahnič, Alen Vrečko: Technische Universität Wien, Vienna, Austria, 29. 11. 2010 - 2. 12. 2010. Collaboration on the CogX project.

Sanja Fidler: UC Berkeley, USA, January 2010 - August 2010, Collaboration on POETICON project.

## INVITED TALKS AND LECTURES

Aleš Leonardis: Learning a Hierarchical Compositional Shape Vocabulary for Multi-class Object Representation, January 2010, an invited lecture at ETHZ, Switzerland.

Aleš Leonardis: Evaluating Multi-Class Learning Strategies in a Generative Hierarchical Framework for Object Detection, an invited talk at Workshop on Recent Trends in Computer Vision, University of Maryland, February 22, 2010, USA.

Aleš Leonardis: Learning a Hierarchical Compositional Shape Vocabulary for Multi-class Object Representation, an invited lecture at Johns Hopkins University, February 2010, USA.

Aleš Leonardis: Learning a Hierarchical Compositional Shape Vocabulary for Multi-class Object Representation, an invited lecture at George Mason University, February 2010, USA.

Aleš Leonardis: Learning a Hierarchical Compositional Shape Vocabulary for Multi-class Object Representation, an invited lecture at University Southern Denmark, May 2010, Denmark.

Aleš Leonardis: Visual representations of objects in artificial cognitive systems and learning hierarchical representations of object categories, an invited lecture at Robotic international Summer School, Dubrovnik, June 2010, Croatia

Aleš Leonardis: Learning a Hierarchical Compositional Shape Vocabulary for Multi-class Object Representation, an invited lecture at K.U. Leuven, November 2010, Belgium.

Aleš Leonardis: Learning a Hierarchical Compositional Shape Vocabulary for Multi-class Object Representation, an invited lecture at Karlsruhe Institute of Technology, December 2010, Germany.

**SELECTED PUBLICATIONS**

J. L. Wyatt, A. Aydemir, M. Brenner, M. Hanheide, N. Hawes, P. Jensfelt, M. Kristan, G. J. Kruijff, P. Lison, A. Pronobis, K. Sjö, 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.

O. Drbohlav, A. Leonardis. Towards correct and informative evaluation methodology for texture classification under varying viewpoint and illumination. *Comput. vis. image underst.*, 2010, vol. 114, no. 4, pp. 439-449.

R. Perko, A. Leonardis. A framework for visual-context-aware object detection in still images. *Comput. vis. image underst.* 2010, vol. 114, no. 6, pp. 700-711.

S. Fidler, M. Boben, A. Leonardis. A coarse-to-fine Taxonomy of Constellations for Fast Multi-class Object Detection. *ECCV 2010*.

S. Fidler, M. Boben, A. Leonardis. Learning Hierarchical Compositional Representations of Object Structure. In: *Object Categorization: Computer and Human Vision Perspectives*, Editors: S. Dickinson, A. Leonardis, B. Schiele and M. J. Tarr, Cambridge University Press, 2009.

S. Fidler, M. Boben, A. Leonardis. Evaluating multi-class learning strategies in a hierarchical framework for object detection. *Proc. Advances in Neural Information Processing Systems conference*, pp. 1-9, 2009.

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

M. Kristan, J. Perš, S. Kovačič and A. Leonardis. A Local-motionbased probabilistic model for visual tracking. *Pattern Recognition*, Vol. 42, No. 9, pp. 2160-2168, 2009.

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M. Jogan, E. Žagar, A. Leonardis. Karhunen-Loeve expansion of a set of rotated templates. *IEEE Transactions on image processing*, 2003, Vol 12, No 7, pp. 817– 825, 2003.

M. Jogan, A. Leonardis. Robust Localization using an Omnidirectional Appearance-based Subspace Model of Environment. *Robotics and Autonomous Systems*, Volume 45, Issue 1, pp. 51–72, Elsevier Science, 2003.

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A. Leonardis and H. Bischof. Robust recognition using eigenimages. *Computer Vision and Image Understanding*, 78(1):99–118, 2000.

H. Bischof and A. Leonardis. Finding optimal neural networks for land use classification. *IEEE Transactions on Geoscience and Remote Sensing*, 36(1):337–341, January 1998.

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A. Leonardis, A. Gupta, and R. Bajcsy. Segmentation of range images as the search for geometric parametric models. *International Journal of Computer Vision*, 14:253–277, 1995.

# Artificial Intelligence Laboratory

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## 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 information visualization. Research results concern the learning from noisy structured (attribute-based) and semi-structured data for classification, regression, constructive induction and discovery of attribute interactions, combining logical and numerical learning. A notable aspect of much of this research is its application to problems in systems control, game playing and analysis, ecological modeling, reconstruction of human control skill, robotics, intelligent tutoring systems and applications of AI in mechanical engineering.

In 2009, the laboratory's demo on autonomous robot learning by experimentation (<http://www.ailab.si/xpero/>, part of the XPERO project) was awarded the first prize at the European Exhibition in Future Emergent Technologies, Prague, April 2009. Our Research Program "Artificial Intelligence and Intelligent Systems", carried out in part by this laboratory, was in 2006 listed among the best research programs funded by the Slovenian research agency ARRS. Also in 2006, a former member of this laboratory Aleks Jakulin, received the prestigious best European AI dissertation award, sponsored by ECCAI for his dissertation Attribute Interactions in Machine Learning. This was already the second dissertation award, after Dorian Šuc, received by PhD students who did their work in the Artificial Intelligence



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 can autonomously learn by performing experiments in its environment. The demonstration won the first prize at the exhibition.

Laboratory. In 2007, Ivan Bratko received the national Zois award for outstanding scientific achievements. Dr. Aleksander Sadikov was elected by students as best lecturer in the interdisciplinary study program Computer Sc. and Mathematics in academic year 2009/10.

## RESEARCH PROJECTS

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

X-MEDIA – Large Scale Knowledge Sharing and Reuse Across Media (FP6-26978). FP6 IST Programme project, European Commission (2006-2010).

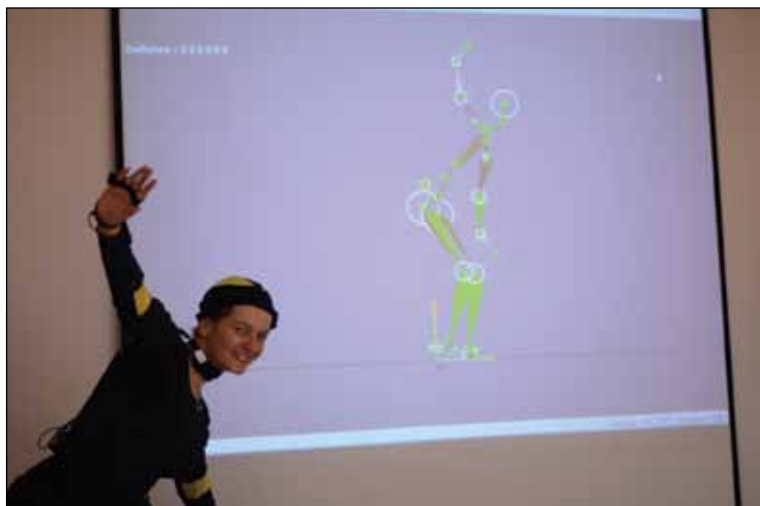
Prototype Recommender System. Application project for GURU d.o.o. (2010).

## LABORATORY GUESTS

Prof. Claude Sammut, University of New South Wales, Australia. 15. 2. 2010 – 19. 2. 2010.

## SELECTED PUBLICATIONS

D. S. Nau, M. Luštrek, A. Parker, I. Bratko, M. Gams. When is it better not to look ahead? *Artificial Intelligence* 174 (2010) 1323–1338.



Computer analysis of human movement with a motion-sensing suit.

I. Bratko. Comparison of Machine Learning for Autonomous Robot Discovery. In book: *Advances in Machine Learning I: Dedicated to the Memory of Professor Ryszard S. Michalski (Studies in Computational Intelligence)* edited by Jacek Koronacki, Zbigniew W. Ras, Slawomir T. Wierzchon, and Janusz Kacprzyk, Springer 2010, pp. 451-456

Z. Pečar, I. Bratko. The use of machine learning for assessing the performance of administrative districts in Slovenia. In book: *Data Mining in Public and Private Sectors: Organizational and Government Applications*, edited by A. Syvajarvi and J. Stenvall.Hershey; New York: Information Science Reference, 2010, pp. 67-82.

I. Bratko. Discovery of Abstract Concepts by a Robot. B. Pfahringer, G. Holmes, and A. Hoffmann (Eds.): *DS 2010 (Discovery Science)*, Springer, LNAI 6332, pp. 372--379. Springer, 2010.

I. Bratko, J. Žabkar, M. Možina. *Argument Base Machine Learning*. In book *Argumentation in Artificial Intelligence*, Edited by Iyad Rahwan, Guillermo Simari, Springer Verlag 2009, pp. 463-482.

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A. Sadikov, I. Bratko. LRTA\* works much better with pessimistic heuristics. *Proceedings of the Eighteenth European Conference on Artificial Intelligence (ECAI 2008)*, pp. 897-898, 2008.

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D. Vladušič, D. Šuc, I. Bratko, W. Rulka. Q2 learning and its application to car modeling. *Applied Artificial Intelligence* 20(8): 675-701, 2006.

A. Sadikov, I. Bratko. Learning long-term chess strategies from databases. *Machine Learning* 63(3): 329-340, 2006.

J. Žabkar, R. Žabkar, D. Vladušič, D. Čemas, D. Šuc, I. Bratko. Q<sup>2</sup> Prediction of ozone concentrations. *Ecological Modelling*, 191(1): 6882, 2006.

G. Leban, I. Bratko, U. Petrovič, T. Curk, B. Zupan. VizRank: finding informative data projections in functional genomics by machine learning. *Bioinformatics*, 21(3): 413-414, 2005.

T. Curk, J. Demšar, Q. Xu, G. Leban, U. Petrovič, I. Bratko, G. Shaulsky, B. Zupan. Microarray data mining with visual programming. *Bioinformatics*, 21(3): 396-398, 2005.

D. Šuc, D. Vladušič, I. Bratko. Qualitatively faithful quantitative prediction. *Artificial Intelligence*, 158(2): 189-214, 2004.

I. Bratko. *Prolog Programming for Artificial Intelligence*, third edition. Addison-Wesley/Pearson Education 2001; previous editions also translated into German, Italian, French, Slovene, Japanese, and Russian.

# Laboratory for Cognitive Modeling

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## RESEARCH ACTIVITIES

Laboratory for Cognitive Modeling (LKM) was officially founded in 2001. LKM carries out research in cognitive modeling, machine learning, neural networks, picture and data mining. Research results concern the modeling of noisy data related to cognitive, medical, biological and other processes. We are developing, testing and applying new approaches and algorithms for modeling from numeric, symbolic and pictorial data, and new approaches to building, evaluation and explanation of models, derived from data. Recent research is related to development of methods for evaluating the utility of ordinal attributes, for evaluating the reliability of single models' predictions in classification and regression, for evaluating the reliability of clustering, for explaining single predictions by arbitrary classification or regression model, and for efficient parametrization of images using a subset of possible image resolutions. LKM collaborates with psychologists, physicians, biologists, physicists and chemists. A notable aspect of much of this research is its application to problems in image analysis, medical diagnosis, ecological modeling, alternative medicine, and studies of consciousness.

## RESEARCH PROJECTS

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

Electricity load forecasting supported by prediction explanation and prediction reliability estimates (BI-PT/10-11-007). Bilateral Collaboration Project (Slovenia-Portugal), Slovenian Research Agency (2010–2011).

Integration of data mining and high-performance computer modelling for coronary artery disease, (BI-SR/10-11-020). Bilateral Collaboration Project (Slovenia-Serbia), Slovenian Research Agency (2010–2011).

Machine Learning of Imbalanced Data, (BI-CZ/10-11-008). Bilateral Collaboration Project (Slovenia-Czech Republic), Slovenian Research Agency (2010–2011).

## LABORATORY GUESTS

Prof. dr. Petr Savicky, University of Prague. 23. 8. 2010 – 3. 9. 2010 and 11. 11. 2010 – 23. 11. 2010. Research collaboration on Learning in Imbalanced Data.

Dr. Pedro Pereira Rodrigues and Raquel Sebastião (PhD student). 13. 9. 2010 - 22. 9. 2010. Research collaboration on data streams mining and electricity load forecasting.

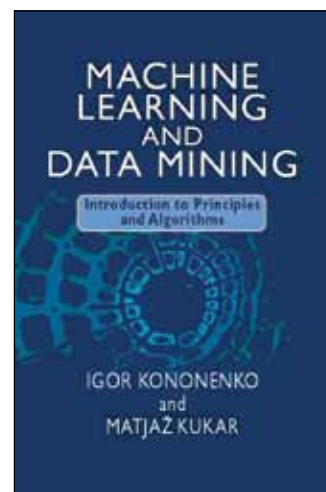
Ercan Canhas, MSc, University of Priština, Kosovo. 1.1. 2010 - 15. 9. 2010. PhD scholarship funded by EU, research in text mining.

## INVITED TALKS AND LECTURES

Darko Pevec, Zoran Bosnić: Estimating reliability of single classifications. Porto: Artificial Intelligence and Decision Support Laboratory, University of Porto, 23. 6. 2010.

Zoran Bosnić, Darko Pevec: Reliability, correction and explanation of individual predictions in machine learning. Porto: Artificial Intelligence and Decision Support Laboratory, University of Porto, 23. 6. 2010.

Matjaž Kukar: Heuristic best-first search in separation of interleaved Web sessions. Prague, Academy of Sciences of the Czech Republic, Institute of Computer Science, 14. 10. 2010.



The book by two members of LKM was published by Horwood and represents the appreciation of our research work.





We collaborate with several Universities and Institutes from Greece, Portugal, Spain, Czech Republic and Belgium.

## SELECTED PUBLICATIONS

I. Kononenko, M. Kukar: Machine Learning and Data Mining: Introduction to Principles and Algorithms, Horwood publ., 2007 (454 pages).

E. Štrumbelj, I. Kononenko: An efficient explanation of individual classifications using game theory. *J. Mach. Learn. Res.* 2010, 11[1]:1-18.

E. Štrumbelj, I. Kononenko, M. Robnik Šikonja. Explaining instance classifications with interactions of subsets of feature values. *Data & Knowledge Engineering*, 68(10):886-904, 2009.

I. Kononenko. Natural and Machine Learning, Intelligence and Consciousness, In: E. Žerovnik et al. (eds.) *Philosophical Insights about Modern Science*, NY: Nova Science publ., 239-258, 2009.

M. Robnik-Šikonja, I. Kononenko: Explaining classifications for individual instances. *IEEE Trans. Knowl. Data Eng.*, 2008, 20:589-600.

I. Kononenko: M. Robnik-Šikonja: Non-myopic feature quality evaluation with (R)ReliefF. In: LIU, H., MOTODA, H. (Eds.). *Computational methods of feature selection*. Boca Raton; London; New York: Chapman & Hall/CRC, 2008, pp. 169-191.

P. Savicky, M. Robnik Šikonja. Learning random numbers: a MATLAB anomaly, *Applied artificial intelligence*, 22(3):254-265, 2008.

Z. Bosnić and I. Kononenko. Comparison of approaches for estimating reliability of individual regression predictions. *Data & Knowledge Engineering*, 67 (3)504-516, 2008.

L. Šajn, I. Kononenko: Multiresolution image parametrization for improving texture classification. *EURASIP J. Adv. Signal Process.*, 2008, pp. 1-12.

M. Robnik-Šikonja, K. Vanhoof: Evaluation of ordinal attributes at value level. *Data Mining and Knowledge Discovery*, 14:225-243, 2007.

Z. Bosnić, I. Kononenko: Estimation of individual prediction reliability using the local sensitivity analysis. *Appl. Intell.*, 2007, 29(3)187-203

Z. Bosnić, I. Kononenko: Automatic selection of reliability estimates for individual regression predictions. *Knowl. eng. rev.*, 25(1)27-47, 2010.

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M. Kukar. Quality assessment of individual classifications in machine learning and data mining. *Knowledge and information systems*, 2006, 9(3) 364-384.

M. Robnik-Šikonja, I. Kononenko. Theoretical and Empirical Analysis of ReliefF and RReliefF, *Machine Learning Journal*, 53: 2369, 2003.

# Bioinformatics Laboratory

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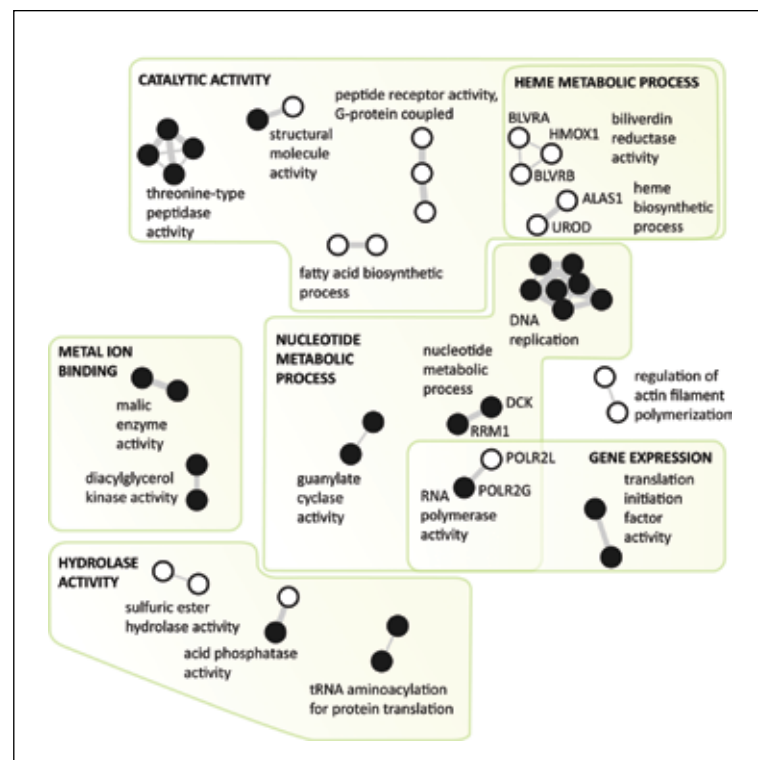
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## RESEARCH ACTIVITIES

Laboratory of Bioinformatics was established in 2010 as an off-spring of the Laboratory of Artificial Intelligence. Its research niche is the application of artificial intelligence, data mining and statistical methods to problems from bioinformatics, in particular system biology, functional genomics, chemogenomics and molecular medicine.

In collaboration with various partners worldwide, we are developing web-based data mining applications. A very popular one within the community of biologists that study a social amoeba *Dictyostelium discoideum* is dictyExpress (<http://www.ailab.si/dictyexpress>). dictyExpress is an interactive, web-based exploratory data analytics application that provides access to over 1,000 gene expression experiments from Baylor College of Medicine. Another of our popular software products is GenePath (<http://www.genepath.org>), known to be the only available software package that supports interactive epistasis analysis for gene network reconstruction from mutant-based experimental data. In collaboration with MRC Laboratory of Molecular Biology in Cambridge we are developing a computational pipeline for comprehensive analysis of next-generation high-throughput sequencing data (RNA-Seq and iCLIP) with the aim of modeling and understanding the molecular mechanisms associated with neurodegenerative diseases.



FragViz makes fragmented networks more interpretable by placing together similar components

The laboratory is also active in development of new data mining approaches, artificial intelligence methods and visualization techniques. One of our core activities is development of a major open-source data mining package Orange (<http://www.ailab.si/orange>), which interfaces with Python and also has an attractive and easy-to-use visual programming interface. Orange gained its popularity as the principal Python-based data mining tool and has a substantial community of users world-wide.

## RESEARCH PROJECTS

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

Qualitative modeling from data (J2-2194). Basic Research Project, Slovenian Research Agency (2009–2012).

CLIP: Mapping functional protein-RNA interactions to identify new targets for oligonucleotide-based therapy (ERC 206726 CLIP). European Research Council (2008–2013).

Modeling the transcriptome (Z7-3665). Basic Research Project, Slovenian Research Agency (2010–2012).

Knowledge technology approaches in drug discovery: analysis and experiment planning in high-throughput genetics (L2-1112). Research Application Project, Slovenian Research Agency (2008–2010).

Data and knowledge integration methods for network systems biology (J2-2197). Basic Research Project, Slovenian Research Agency (2009–2012).

Computational methods and tools for functional and chemogenomics of *Dictyostelium* (BI-ZDA/08-10-73). Bilateral Collaboration Project, Slovenian Research Agency (2008–2010).

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

## LABORATORY GUESTS

Sanja Brdar, University of Novi Sad, Serbia. 1. 10. 2009 – 30. 7. 2010. Basileous exchange.

Riccardo Beretta, University of Pavia, Italy. 15. 10. 2009 – 28. 2. 2010. Collaboration in bilateral project.

Jernej Ule, MRC Laboratory of Molecular Biology, Cambridge, UK. 13. 9. 2010 – 15. 9. 2010. Collaboration in European Research Council project CLIP.

## RESEARCH VISITS

Tomaž Curk: MRC Laboratory of Molecular Biology, Cambridge, UK, 27. 7. 2010 – 30. 7. 2010. Development of pipeline for iCLIP data analysis.

Gregor Rot: MRC Laboratory of Molecular Biology, Cambridge, UK, 16. 7. 2010 – 30. 7. 2010. Development of pipeline for iCLIP data analysis.

Blaž Zupan: University of Pavia, Italy, 13. 6. 2010 – 18. 6. 2010. Collaboration in bioinformatics for tissue engineering.

Janez Demšar: Graduate School of Medicine, Kyoto University, Japan, 1. 6. 2010 – 31. 8. 2010.

## INVITED TALKS AND LECTURES

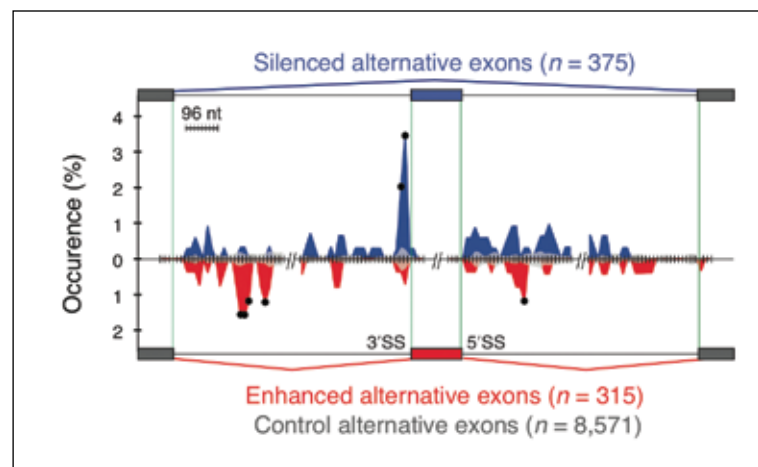
Tomaž Curk: Some aspects of iCLIP data analysis, Seminar on iCLIP bioinformatics, 29.7.2010, Darwin College, Cambridge, UK.

Gregor Rot: Random barcode evaluation and cluster discovery in iCLIP data, Seminar on iCLIP bioinformatics, 29.7.2010, Darwin College, Cambridge, UK.

Janez Demšar: Data Mining for Public Health; lectures at Kyoto University, Japan, July 2010.

Blaž Zupan: Epistasis analysis on data from synthetic genetic array, 9. 9. 2010 – 11. 9. 2010, From Phenotypes to Pathways: European Science Foundation Exploratory Workshop, Cambridge, UK.

Lan Žagar: Inference of epistasis from yeast genome-scale genetic interaction map, 26. 9. 2010, Learning from perturbation effects: a Workshop at 9th European Conference on Computational Intelligence, Ghent, Belgium.



RNA-maps constructed from massive iCLIP experimental data help us understand molecular mechanisms of gene splicing.

## SELECTED PUBLICATIONS

J. Demšar. Algorithms for subsetting attribute values with Relief. *Machine Learning*, 78(3): 421-428, 2010.

Z. Wang, M. Kayikci, M. Briese, K. Zarnack, N. M. Luscombe, G. Rot, B. Zupan, T. Curk, J. Ule. ICLIP predicts the dual splicing effects of TIA-RNA interactions. *PLoS biology*, 8(10), 2010.

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.

A. Parikh, E. R. Miranda, M. Katoh-Kurasawa, D. Fuller, G. Rot, L. Žagar, T. Curk, R. Sugang, R. Chen, B. Zupan, W. F. Loomis, A. Kuspa, G. Shaulsky. Conserved developmental transcriptomes in evolutionarily divergent species. *Genome biology*, 11(3), 2010.

M. Toplak, T. Curk, J. Demšar, B. Zupan: Does replication groups scoring reduce false positive rate in SNP interaction discovery? *BMC Genomics*, 11:58, 2010.

M. Štajdohar, M. Mramor, B. Zupan, J. Demšar. FragViz: visualization of fragmented networks. *BMC bioinformatics*, 11, 2010.

R. Franco-Duarte, L. Umek, B. Zupan, D. Schuller: Computational approaches for the genetic and phenotypic characterization of a *S. cerevisiae* wine yeast collection. *Yeast*, 26(12): 675-692, 2009.

P. Fey, P. Gaudet, T. Curk, B. Zupan, E. M. Just, B. Siddhartha, S. N. Mechant, Y. A. Bushmanova, G. Shaulsky, W. A. Kibbe, R. L. Chisholm. DictyBase - a *Dictyostelium* bioinformatics resource update. *Nucleic acids research*, 37: 515-519, 2009.

G. Rot, A. Parikh, T. Curk, A. Kuspa, G. Shaulsky, B. Zupan: dictyExpress: a *D. discoideum* gene expression database with an explorative data analysis web-based interface. *BMC Bioinformatics*, 10: 265, 2009.

T. Curk, U. Petrovic, G. Shaulsky, B. Zupan: Rule-based clustering for gene promoter structure discovery. *Methods of Information in Medicine*, 48(3): 229-235, 2009.

B. Zupan, J. Demšar. Open-source tools for data mining. *Clinics in laboratory medicine*, 28(1): 37-54, 2008.

M. Mramor, G. Leban, J. Demšar, B. Zupan. Visualization-based cancer microarray data classification analysis. *Bioinformatics*, 23(16): 2147-2154, 2007.

R. Bellazzi, B. Zupan. Towards knowledge-based gene expression data mining. *Journal of Biomedical Informatics*, 40(6): 787-802, 2007.

J. Demšar. Statistical comparisons of classifiers over multiple data sets. *Journal of Machine Learning Research*, 7: 1-30, 2006.

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N. Van Driessche, J. Demšar, E.O. Booth, P. Hill, P. Juvan, B. Zupan, A. Kuspa, G. Shaulsky. Epistasis analysis with global transcriptional phenotypes. *Nature Genetics*, 37(5): 471-477, 2005.

B. Zupan, J. Demšar J, I. Bratko, P. Juvan, J. A. Halter, A. Kuspa, G. Shaulsky. GenePath: a system for automated construction of genetic networks from mutant data. *Bioinformatics*, 19(3): 383-389, 2003.

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### RESEARCH ACTIVITIES

Members of the laboratory are involved in research in various fields of mathematics both with applications in computer and information science and also on pure mathematics basis:

- scientific computing and numerical solutions of differential equations, where we study methods for geometric integration of ordinary differential equations, as well as numerical simulations,
- graph theory, mostly topological and structural properties of graphs, and colorings problems of graphs, both in connection with graph symmetries and embedding properties,
- algebraic topology, in particular algebraic invariants of topological spaces with group actions, as well as computational topology and topological data analysis,
- nonlinear dynamical systems and their application in geometry,
- physics and mechanics, computational geometry and geometry of cycles (in cooperation with members of the Faculty of Electrical Engineering and the Faculty of Mathematics and Physics) with applications to surface modelling,

- commutative algebra and linear algebra, in particular, studying the variety of commuting nilpotent matrices over algebraically closed fields and certain classes of matrices over semirings,
- Brownian motion and martingales and their applications to analysis,
- semigroups and their interaction with automata theory and combinatorics; universal algebra.

Several members of the lab participate in the research groups of the Institute of Mathematics, Physics, and Mechanics. Members of the lab are involved in joint research work with other research groups at the Faculty of Computer and Information Science and the Faculty of Electrical Engineering and with several institutions from abroad. To mention a few: NTNU Trondheim, Norway, University of Hamburg, Germany, P. J. Šafarik University, Košice, Slovakia, University of Sevilla, Spain, Yokohama National University, Japan, Simon Fraser University, Canada, University of Melbourne, Australia.

We organize Mathematical seminar at FRI, where members of the laboratory and other researchers report on current work, connected to the research and teaching activities of the lab.

In cooperation with the Computer Structures and Systems Laboratory members of our laboratory are working on algorithms for developing and evaluating mechanical random generators.

## RESEARCH PROJECTS

Holomorphic mappings and foliations, harmonic analysis and hamiltonian systems (J1-2152). Basic Research Project, Slovenian Research Agency (2009-2012).

## LABORATORY GUESTS

Atsuhiko Nakamoto, Raiji Mukae, and Ryuichi Mori, Yokohama National University, Japan. 26. 2. 2010 – 3. 3. 2010.

Jan Jaworowski, Indiana University, Bloomington, Indiana, Usa. 30. 5. 2010 – 6. 6. 2010.

Eva Miliczka, Josef Šafarik University, Košice, Slovakia. 17. 5. 2010 – 31. 5. 2010.

Primož Škraba, INRIA (Institut national de recherche en informatique et automatique), Paris, France. 28. 5. 2010.

## RESEARCH VISITS

Polona Oblak: University College Dublin, 15. 9. 2010 – 22. 9. 2010. Lecture: On commuting graphs, at Algebra/Shannon seminar.

Polona Oblak: Moscow State University, 2. 12. 2010 – 7. 12. 2010. Lecture: Zero-divisor graphs, at Algebra Seminar.

## INVITED TALKS AND LECTURES

Neža Mramor Kosta: Parametric discrete Morse theory, Universidad de Sevilla, February 2010.

## SELECTED PUBLICATIONS

M. J. Chávez, G. Fijavž, A. Márquez, A. Nakamoto, E. Suárez. Geometric Realization of Möbius Triangulations, *SIAM J. Discrete Math.*, 2009, vol. 23, no. 1, p. 221-232.

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D. Bokal, G. Fijavž, D. R. Wood. The minor crossing number of graphs with an excluded minor. *Electron. J. Comb. (online journal)*, 2008, vol. 15, no. 1, r4 (13 p).

B. Mohar, E. Steffen, A. Vodopivec, Relating embedding and coloring properties of snarks, *Ars Mathematica Contemporanea* 1 (2008), 169-184.

A. Vodopivec, On embeddings of snarks in the torus, *Discrete Mathematics* 380 (2008), 1847--1849.

M. Vuk. Algebraic Integrability of the confluent Neumann system, *Journal of Physics A: Mathematical and Theoretical*, 41(39): 395201 (16pp), 2008.

G. Fijavž, D. Wood, Graph Minors and Minimum Degree, *Electron. J. Comb. (online journal)*, 2010, vol. 17, no. 1, r151 (30 p).

J. Jaworowski, N. Mramor-Kosta. The degree of maps of free G-manifolds. *J. fixed point theory appl. (Print)*, 2007, vol. 2, no. 2, str. 209-213.

G. Kudryavtseva, Ordered semigroups, upper-triangular reflexive relations and semigroups of languages. *Internat. J. Algebra Comput.* 20, (2010), no. 6, 823-832.

G. Kudryavtseva, V. Mazorchuk, Combinatorial Gelfand models for some semigroups and  $\mathbb{Q}\mathbb{Q}$ -rook monoid algebras. *Proc. Edinb. Math. Soc. (2)* 52 (2009), no. 3, 707-718.

# Laboratory for Cryptography and Computer Security

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## 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



SSmart cards enable us to securely store private keys.



With error-correcting codes it is possible to receive quality pictures sent by space-probes. We cite Barry Cipra: "Error-correcting codes are a kind of safety net--mathematical insurance against the vagaries of an imperfect material world."

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

## SELECTED PUBLICATIONS

A. Jurišić, P. Terwilliger and A. Žitnik, Distance-regular graphs with light tails, *Europ. J. Combin.* (2009), doi: 10.1016/j.ejc.2009.08.007.



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