Faculty of Computer and Information Science

University of Ljubljana

Survey of Activities in 2006

# Contents

Prof. Dr. Franc Solina

# Foreword

*This booklet provides some basic information about the Faculty of Computer and Information Science of 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 a lengthy roster of alumni, some of which achieved distinction in academic and business 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 enrolment as in some other engineering and science disciplines. However, since the younger generations in Slovenia are smaller in size we have to attract promising students to our educational and research programs in the future from a larger geographical area. New study programs designed according to the Bologna principles should have a wider appeal and should help to make the exchange of students even easier.*

*In the age of globalization the Faculty faces increasing competition in all areas. We have to expand our research competence to a wider spectrum of promising technical areas. In 2006 we established a new Laboratory for Cryptography and Computer Security headed by the leading slovenian cryptographer. We plan to expand and strengthen the Faculty in the near future also in some other research areas by attracting experienced researchers. This expansion will be possible only when the Faculty's most pressing problem will be solved---the shortage of space. The location and architectural plans for the new Faculty building are already approved and construction is expected to begin in 2008.*

*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 will find some interesting material in the booklet to establish contacts with our Faculty members.*

*Franc Solina*
*Professor of Computer and Information Science and Dean*

# About FRI

## General Information

Dean **Prof. Dr. Franc Solina**
Associate Dean for Education **Prof. Dr. Radko Osredkar**
Associate Dean for Research **Prof. Dr. Blaž Zupan**
Associate Dean for Development **Prof. Dr. Nikolaj Zimic**
Head of administration **Lan Vošnjak**

**Address:**
University of Ljubljana
Faculty of Computer and Information Science
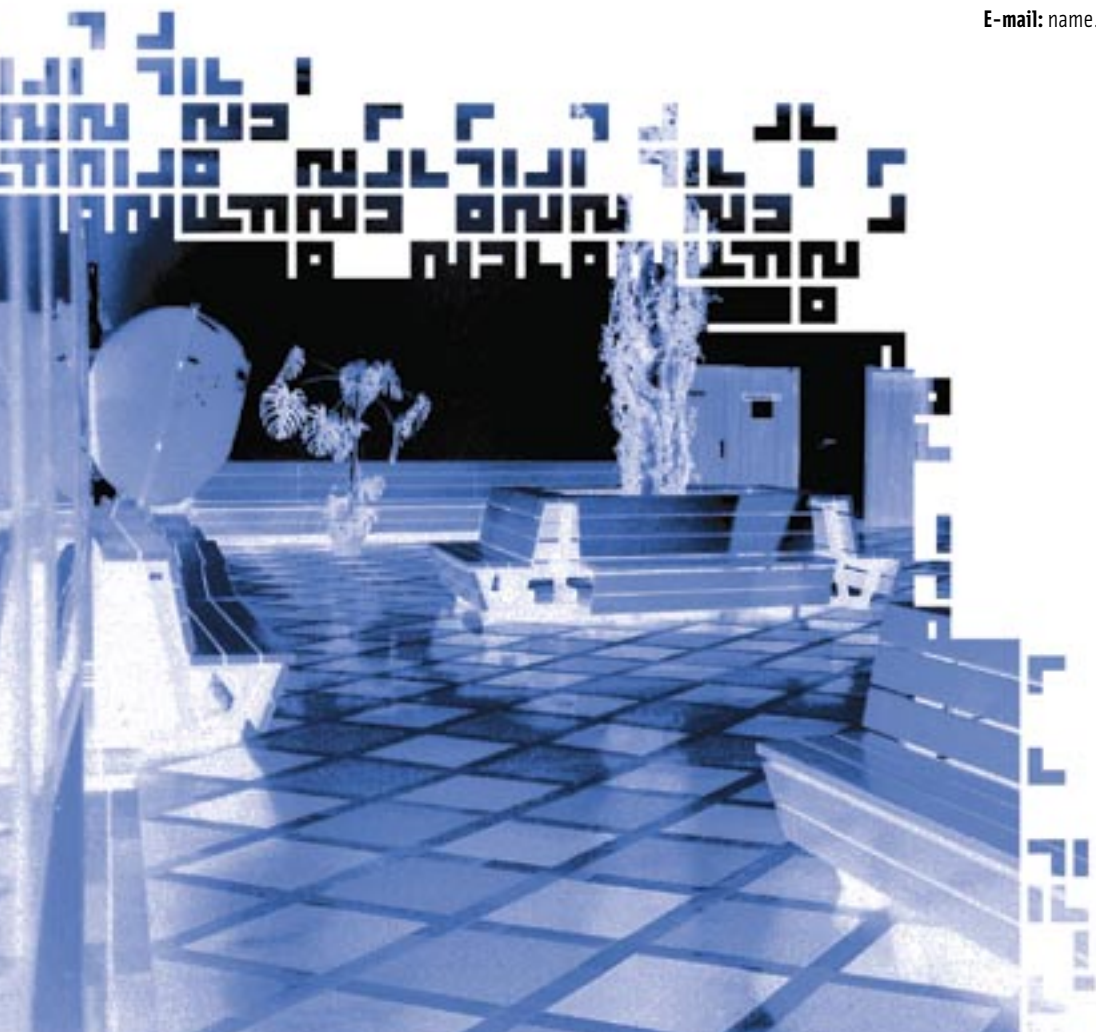Tržaška cesta 25
SI-1001 Ljubljana
Slovenia

**Phone:** +386 1 476 84 11

**Fax:** +386 1 426 46 47

**WWW:** http://www.fri.uni-lj.si/

**E-mail:** name.surname@fri.uni-lj.si (for all teaching and research staff)

## 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 305 Master's degrees (M.Sc.) and 93 the Doctoral degrees (Ph.D.) in Computer and Information science have been awarded. Currently, there are about 1656 undergraduate and 114 graduate students at the Faculty. The Faculty has 119 employees, of which 102 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
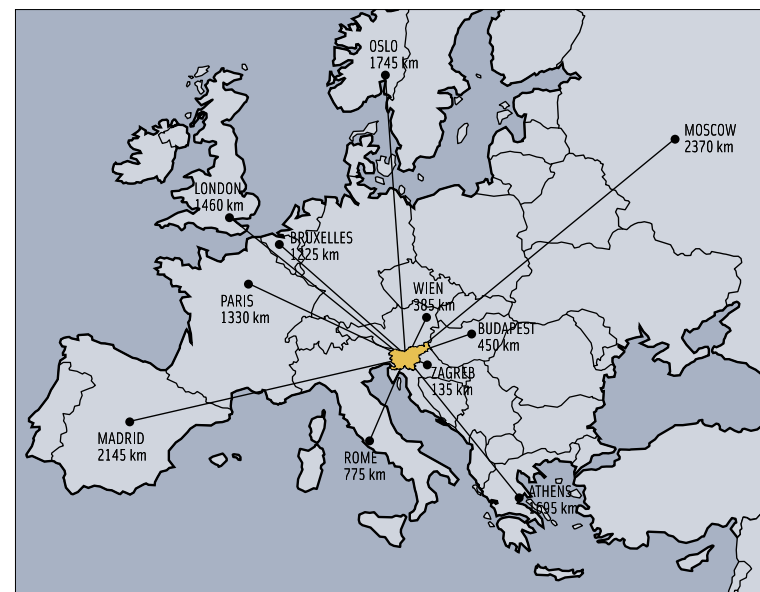


Figure 1: Slovenia in Europe
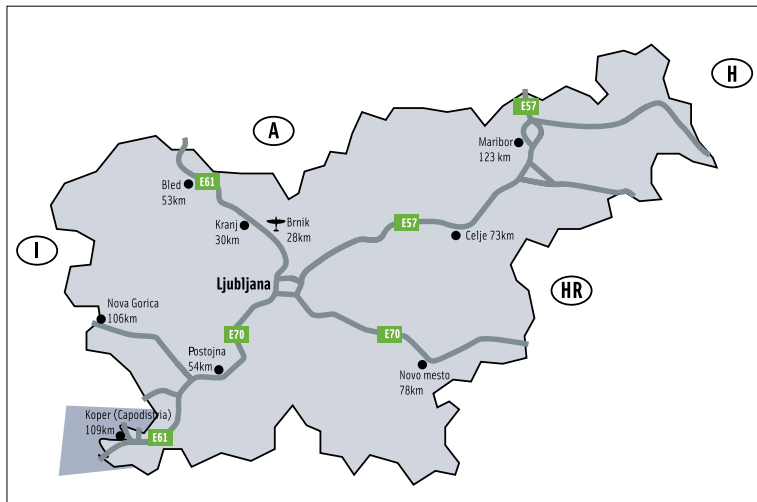
Figure 2: Map of Slovenia

## 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.
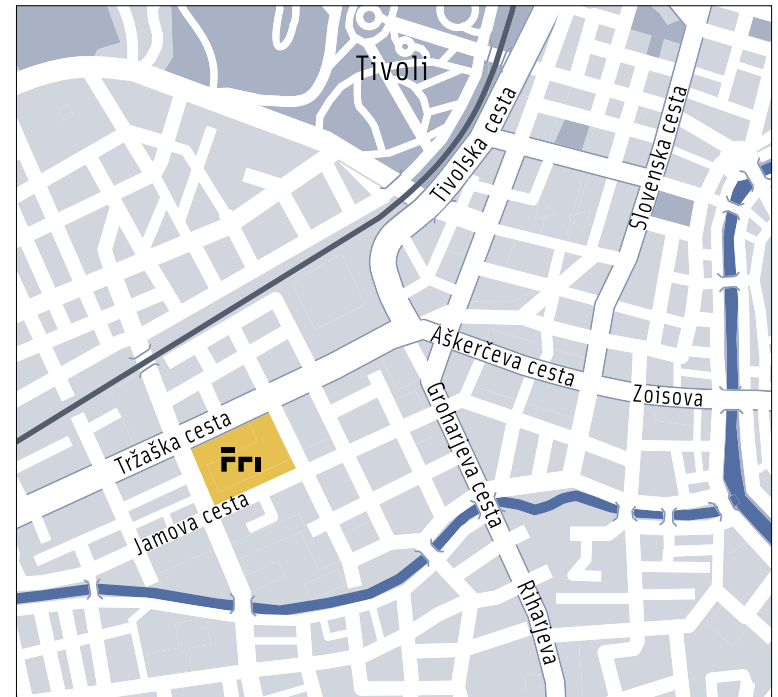


Figure 4: Detailed map of Ljubljana – the location of the Faculty is indicated by the highlighted yellow square

# Educational Programs

The academic year at the University of Ljubljana consists of fall and spring semesters. The courses in the fall semester begin on October 1st and end on January 15th. The spring semester courses start on February 15th and end on May 30th. There are three examination periods: winter (January 15th to February 15th), spring (June) and fall (September). Courses consist of lectures, problem solving classes (tutorials), and laboratory work. The weekly numbers of hours for each course shown in the following tables correspond to lectures, problem solving classes, and laboratory work, respectively. The average weekly course load for undergraduate students is cumulatively 25 hours. In the 2004/05 academic year an updated curriculum of the 8-semester (so called "university") programs is starting and the data refers to that program.

FRI 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

FRI offers three undergraduate educational programs:

*A four-year undergraduate program* (six semesters of lectures, 15 weeks of work in industry, 6 months of Diploma thesis work), which leads to the degree "Dipl. Ing. Of Computer and Information Science",

*A four-year "university" program* (eight semesters of lectures, 6 months of Diploma thesis work), which leads to the degree "University Dipl. Ing. Of Computer and Information Science", and

*A four year interdisciplinary "university" program* (eight semesters of lectures, 6 months of Diploma thesis work), which leads to the degree "University Dipl. Ing. of Computer Science and Mathematics".

The entry requirement for the three-year program is completion of a four-year secondary education. For the four-year "university" programs the national secondary school baccalaureate is mandatory. The three-year program is application oriented, while the four-year program offers more extensive and in depth theoretical knowledge. Only graduates of the four-year program can continue their education at the postgraduate level.

The first two undergraduate programs consists of a core-curriculum, which contains mainly mathematics and theoretical foundations of computer and information science courses, and three elective modules, entitled,

*Information Science,*

*Computer Systems, and*

*Computer Software.*

Students must choose one of the three modules after the first year in the three-year program and after the second year in the four-year "university" program.

## POSTGRADUATE PROGRAMS

Postgraduate programs at the Faculty of Computer and Information Science consist of four semesters of, followed by a Masters thesis, leading to a M.Sc. degree and subsequently by a Doctoral thesis leading to a Ph.D. degree in Computer and Information Science. Under specified conditions students can proceed from the required postgraduate courses to working directly on their Doctoral thesis, thus bypassing the Masters thesis. The Faculty offers two postgraduate programs:

*Computer and Information Science,*

*Information Systems and Decision Making.*

# Four-Year Undergraduate Program

## FIRST YEAR

| General Courses | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Discrete Mathematics | 3 | 3 | 0 | 3 | 3 | 0 | 14.5 |
| Introduction to Programming I | 3 | 0 | 3 | - | - | - | 7 |
| Introduction to Computer Architecture I | 3 | 0 | 3 | - | - | - | 7 |
| Application Software | 1 | 0 | 4 | - | - | - | 5.5 |
| Foreign Language (English) | 0 | 3 | 0 | - | - | - | 3.5 |
| Calculus I | - | - | - | 3 | 1 | 2 | 7.5 |
| Introduction to Programming II | - | - | - | 3 | 0 | 3 | 7.5 |
| Introduction to Computer Architecture II | - | - | - | 3 | 0 | 3 | 7.5 |
| **Total** | **10** | **6** | **10** | **12** | **4** | **8** | **60** |

## SECOND YEAR

| General Courses | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Calculus II | 3 | 3 | 0 | - | - | - | 7.5 |
| Introduction to Algorithms and Data Structures I | 3 | 1 | 2 | - | - | - | 7.5 |
| Introduction to Algorithms and Data Structures II | - | - | - | 3 | 1 | 2 | 7 |
| Business Economics | - | - | - | 2 | 2 | 0 | 4.5 |
| **Total** | **6** | **4** | **2** | **5** | **3** | **2** | **26.5** |

| Courses in Information Science | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Information Systems | 3 | 0 | 3 | - | - | - | 7.5 |
| Databases I | 3 | 0 | 3 | - | - | - | 7.5 |
| Databases II | - | - | - | 3 | 0 | 3 | 7 |
| Statistics and Data Analysis | - | - | - | 2 | 2 | 0 | 4.5 |
| Information Systems Design | - | - | - | 3 | 0 | 3 | 7 |
| **Total** | **6** | **0** | **6** | **8** | **2** | **6** | **33.5** |

| Courses in Computer Logic and Systems | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Logic Structures and Systems I | 3 | 0 | 3 | - | - | - | 7.5 |
| Digital Electronics I | 3 | 1 | 2 | - | - | - | 7.5 |
| Digital Electronics II | - | - | - | 3 | 1 | 2 | 7 |
| Input-Output Devices | - | - | - | 3 | 1 | 2 | 7 |
| Computer Systems Organization | - | - | - | 2 | 2 | 0 | 4.5 |
| **Total** | **6** | **1** | **5** | **8** | **4** | **4** | **33.5** |

| Courses in Computer Software | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Programming Languages | 3 | 1 | 2 | - | - | - | 7.5 |
| Introduction to Databases | 3 | 0 | 3 | - | - | - | 7.5 |
| Introduction to Information Systems | - | - | - | 3 | 0 | 3 | 7 |
| Introduction to Probability and Statistics | - | - | - | 2 | 2 | 0 | 4.5 |
| User Interfaces | - | - | - | 3 | 0 | 3 | 7 |
| **Total** | **6** | **1** | **5** | **8** | **2** | **6** | **33.5** |

## THIRD YEAR

| General Courses | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| System Software | 3 | 0 | 2 | - | - | - | 6 |
| Business Functions | 2 | 2 | 0 | - | - | - | 5 |
| Computer Communications | - | - | - | 3 | 0 | 3 | 7 |
| **Total** | **5** | **2** | **2** | **3** | **0** | **3** | **18** |

| Courses in Information Science | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Organization Theory | 2 | 2 | 0 | - | - | - | 5 |
| Accounting | 2 | 2 | 0 | - | - | - | 5 |
| Application Development Tools and Techniques | 3 | 1 | 2 | - | - | - | 6.5 |
| Legal and Social Aspects of Informatics | 2 | 0 | 0 | - | - | - | 2.5 |
| Project Management and Organiz. of Inform. Syst. | - | - | - | 3 | 1 | 2 | 7 |
| Inform. Syst. Standards and Quality Assurance | - | - | - | 2 | 0 | 1 | 4 |
| Communication Methods | - | - | - | 2 | 2 | 0 | 5 |
| Decision Systems | - | - | - | 3 | 0 | 3 | 7 |
| **Total** | **9** | **5** | **2** | **10** | **3** | **6** | **42** |

| Courses in Computer Logic and Systems | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Introduction to Computer Graphics | 2 | 0 | 2 | - | - | - | 5 |
| Introduction to Modelling and Simulation | 3 | 0 | 3 | - | - | - | 7 |
| Digital Signal Processing | 3 | 1 | 2 | | | | 7 |
| Real Time Systems | | | | 3 | 0 | 3 | 7 |
| Logic Structures and Systems II | | | | 3 | 0 | 3 | 7 |
| Computer Equipment Evaluation | - | - | - | 2 | 1 | 1 | 5 |
| Distributed Structures | - | - | - | 2 | 0 | 1 | 4 |
| **Total** | **8** | **1** | **7** | **10** | **1** | **8** | **42** |

| Courses in Computer Software | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Numerical Methods | 3 | 2 | 0 | - | - | - | 6 |
| Introduction to Modelling and Simulation | 3 | 0 | 3 | - | - | - | 7 |
| Programming Systems Design I | 3 | 0 | 2 | - | - | - | 6 |
| Programming Systems Design II | - | - | - | 3 | 1 | 2 | 7 |
| Introduction to Computer Graphics | - | - | - | 2 | 0 | 2 | 5 |
| Applications Development | - | - | - | 1 | 0 | 2 | 4 |
| Methods of Artificial Intelligence | - | - | - | 3 | 0 | 3 | 7 |
| **Total** | **9** | **2** | **5** | **9** | **1** | **9** | **42** |

## FOURTH YEAR

| General Courses | Fall | Spring |
|---|---|---|
| Practice | 15 weeks | |
| Diploma Thesis | | 6 months |
| **Total** | **15 weeks** | **6 months** |

# Four-Year "University" Undergraduate Program

## FIRST YEAR

| General Courses | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Calculus I | 3 | 3 | 0 | - | - | - | 6.5 |
| User Application Software | 1 | 0 | 3 | - | - | - | 4.5 |
| Discrete Structures | 3 | 2 | 0 | - | - | - | 5.5 |
| Physics | 3 | 3 | 0 | - | - | - | 6,5 |
| Programming I | 3 | 0 | 3 | - | - | - | 7 |
| Calculus II | - | - | - | 3 | 3 | 0 | 6.5 |
| Computer Technologies | - | - | - | 3 | 2 | 0 | 5.5 |
| Linear Algebra | - | - | - | 2 | 2 | 0 | 4.5 |
| Programming II | - | - | - | 3 | 0 | 3 | 7 |
| Switching Circuits and Systems | - | - | - | 3 | 0 | 3 | 6.5 |
| **Total** | **13** | **8** | **6** | **14** | **7** | **6** | **60** |

## SECOND YEAR

| General Courses | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Algorithms and Data Structures I | 3 | 0 | 3 | - | - | - | 7 |
| Computer Systems Architecture I | 3 | 0 | 3 | - | - | - | 7.5 |
| Foreign Language (English) | 0 | 3 | 0 | - | - | - | 3.5 |
| Introduction to Information Theory | 3 | 2 | 0 | - | - | - | 6 |
| Probability Theory and Statistics | 3 | 2 | 0 | - | - | - | 6 |
| Algorithms and Data Structures II | - | - | - | 3 | 0 | 3 | 6.5 |
| Computer Systems Architecture II | - | - | - | 3 | 0 | 3 | 6.5 |
| Computer Communications and Networks | - | - | - | 3 | 0 | 2 | 5 |
| Modeling and Simulation | - | - | - | 3 | 0 | 3 | 6 |
| Numerical Methods | - | - | - | 3 | 0 | 3 | 6 |
| **Total** | **12** | **7** | **6** | **15** | **0** | **14** | **60** |

## THIRD YEAR

| Common Courses | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Business Economics | 2 | 1 | 0 | - | - | - | 3.5 |
| **Total** | **2** | **1** | **0** | **-** | **-** | **-** | **3.5** |

| Information Science Module | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Databases I | 3 | 1 | 2 | - | - | - | 6.5 |
| Information Systems | 3 | 1 | 2 | - | - | - | 7 |
| Operating Systems Fundamentals | 3 | 0 | 3 | - | - | - | 6.5 |
| Software Development Project Management | 3 | 1 | 2 | - | - | - | 6.5 |
| nformation Systems Development | - | - | - | 3 | 1 | 2 | 6 |
| Decision Models and Systems | - | - | - | 3 | 3 | 0 | 6 |
| Operations Research | - | - | - | 2 | 0 | 2 | 4.5 |
| Multimedia Systems | - | - | - | 2 | 0 | 1 | 3.5 |
| Theory of Organization | - | - | - | 2 | 0 | 0 | 4.5 |
| Databases II | - | - | - | 3 | 1 | 2 | 6.5 |
| **Total** | **12** | **3** | **9** | **15** | **5** | **7** | **57.5** |

| Computer Systems Module | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Graphic Techniques and Procedures | 3 | 0 | 3 | - | - | - | 6.5 |
| Logic Design Methods | 3 | 0 | 3 | - | - | - | 7 |
| Computer Organization | 3 | 0 | 3 | - | - | - | 6.5 |
| Operating Systems | 3 | 0 | 3 | - | - | - | 6.5 |
| Digital Electronics | - | - | - | 3 | 0 | 3 | 6.5 |
| Distributed Systems and Technologies | - | - | - | 3 | 1 | 2 | 7 |
| Input-Output Devices and Systems | - | - | - | 3 | 0 | 3 | 6.5 |
| Fundamentals of Information Systems | - | - | - | 2 | 0 | 1 | 3.5 |
| System Software | - | - | - | 3 | 0 | 3 | 6.5 |
| **Total** | **12** | **0** | **12** | **14** | **1** | **12** | **56.5** |

| Computer Software Module | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Operating Systems I | 3 | 0 | 3 | - | - | - | 6.5 |
| Fundamentals of Databases | 3 | 1 | 2 | - | - | - | 6.5 |
| Theoretical Fundamentals of Computer Science I | 3 | 3 | 0 | - | - | - | 7 |
| Project Management | 3 | 1 | 2 | - | - | - | 6.5 |
| Operating Systems II | - | - | - | 3 | 0 | 3 | 6.5 |
| Principles of Programming Languages and Symbolic Programming | - | - | - | 3 | 3 | 0 | 7 |
| Computer Graphics | - | - | - | 3 | 0 | 3 | 6.5 |
| Fundamentals of Information Systems | - | - | - | 2 | 0 | 1 | 3.5 |
| Theoretical Fundamentals of Computer Science II | - | - | - | 3 | 3 | 0 | 6.5 |
| **Total** | **12** | **5** | **7** | **14** | **6** | **7** | **56.7** |

## FOURTH YEAR

| Common Courses | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Computer Systems Performance and Evaluation | 3 | 0 | 3 | - | - | - | 6.5 |
| Business Functions | - | - | - | 2 | 1 | 0 | 3.5 |
| **Total** | **3** | **0** | **3** | **2** | **1** | **0** | **10** |

| Information Science Module | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Methods of Communication | 3 | 0 | 3 | - | - | - | 6.5 |
| Design and Management of Information Systems | 3 | 1 | 2 | - | - | - | 6.5 |
| Business Analysis | 2 | 0 | 2 | - | - | - | 4 |
| Electronic Business | 3 | 0 | 3 | - | - | - | 6.5 |
| Distributed Information Systems | - | - | - | 3 | 0 | 3 | 7 |
| Information Systems Technology | - | - | - | 3 | 0 | 3 | 7 |
| Artificial Intelligence | - | - | - | 3 | 2 | 1 | 7 |
| Information Society | - | - | - | 3 | 0 | 2 | 5.5 |
| **Total** | **11** | **1** | **10** | **12** | **2** | **9** | **50** |

| Computer Systems Module | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Soft Computing Methods | 3 | 3 | 0 | - | - | - | 6.5 |
| Optical- and Nanotechnologies- | 3 | 0 | 3 | - | - | - | 6.5 |
| Digital Signal Processing | 3 | 0 | 3 | - | - | - | 7 |
| Seminar | 0 | 0 | 3 | - | - | - | 3.5 |
| Parallel Architecture of Computers | - | - | - | 3 | 0 | 3 | 7 |
| Process Informatics | - | - | - | 3 | 0 | 3 | 6.5 |
| Computer Reliability and Diagnostics | - | - | - | 3 | 0 | 3 | 6.5 |
| Telematics | - | - | - | 3 | 3 | 0 | 6.5 |
| **Total** | **9** | **3** | **9** | **12** | **3** | **9** | **50** |

| Computer Software Module | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Digital Signal Processing | 3 | 0 | 3 | - | - | - | 6 |
| Machine Perception | 3 | 0 | 3 | - | - | - | 6 |
| Artificial Intelligence I | 3 | 2 | 1 | - | - | - | 6 |
| Compilers | 3 | 0 | 2 | - | - | - | 5.5 |
| Intelligent Distributed Software Technologies | - | - | - | 3 | 0 | 3 | 7.5 |
| Software Technology | - | - | - | 3 | 0 | 3 | 7 |
| Knowledge Engineering | - | - | - | 3 | 2 | 0 | 6 |
| Artificial Intelligence II | - | - | - | 3 | 1 | 1 | 6 |
| **Total** | **12** | **2** | **9** | **12** | **3** | **7** | **50** |

# Four-Year "University" Interdisciplinary Program "Computer Science and Mathematics"

## FIRST YEAR

| Course | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Calculus 1 | 3 | 3 | 0 | - | - | - | 8 |
| Discrete Mathematics 1 | 3 | 2 | 0 | - | - | - | 7 |
| Computer Lab | 1 | 0 | 3 | - | - | - | 6 |
| Introduction to Programming 1 | 2 | 0 | 2 | - | - | - | 6 |
| Calculus 2 | - | - | - | 3 | 3 | 0 | 8 |
| Discrete Mathematics 2 | - | - | - | 3 | 3 | 0 | 8 |
| Introduction to Programming 2 | - | - | - | 2 | 0 | 2 | 6 |
| Linear Algebra 1 | - | - | - | 2 | 2 | 0 | 6 |
| Tutorial | 0 | 0 | 2 | 0 | 0 | 2 | 5 |
| **Total** | **9** | **5** | **7** | **10** | **8** | **4** | **60** |

## SECOND YEAR

| Course | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Linear Algebra 2 | 2 | 2 | 0 | - | - | - | 5 |
| Numerical Methods 1 | 2 | 0 | 2 | - | - | - | 5 |
| Algorithms and Data Structures 1 | 3 | 0 | 3 | - | - | - | 7 |
| Computer Architectures 1 | 3 | 0 | 3 | - | - | - | 7 |
| Theory of Programming Languages | 2 | 0 | 2 | - | - | - | 5 |
| Algorithms and Data Structures 2 | - | - | - | 3 | 0 | 3 | 7 |
| Calculus 3 | - | - | - | 3 | 3 | 0 | 7 |
| Combinatorics | - | - | - | 3 | 3 | 0 | 7 |
| Numerical Methods 2 | - | - | - | 2 | 0 | 2 | 5 |
| Declarative Programming | - | - | - | 2 | 0 | 2 | 5 |
| **Total** | **12** | **2** | **10** | **13** | **6** | **7** | **60** |

## THIRD YEAR

| Course | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Introduction to Data Bases | 3 | 1 | 2 | - | - | - | 6 |
| Probability and Statistics | 3 | 3 | 0 | - | - | - | 7 |
| Computability Theory | 3 | 3 | 0 | - | - | - | 7 |
| Operating Systems | 3 | 0 | 3 | - | - | - | 7 |
| Optimization | - | - | - | 3 | 0 | 3 | 7 |
| Computational Complexity | - | - | - | 3 | 3 | 0 | 7 |
| Computational Geometry | - | - | - | 3 | 0 | 3 | 7 |
| Computer Graphics | - | - | - | 3 | 0 | 3 | 7 |
| Elective* | - | - | - | 2 | 2 | 0 | 5 |
| **Total** | **12** | **7** | **5** | **14** | **5** | **9** | **60** |

## FOURTH YEAR

| Course | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Cryptography and Coding Theory 1 | 2 | 2 | 0 | - | - | - | 5 |
| Artificial Intelligence 1 | 3 | 2 | 1 | - | - | - | 6 |
| Communication Theory | 2 | 2 | 0 | - | - | - | 4.5 |
| Elective* | 6 | 6 | 0 | - | - | - | 15 |
| Cryptography and Coding Theory 2 | - | - | - | 2 | 2 | 0 | 5 |
| Artificial Intelligence 2 | - | - | - | 3 | 1 | 1 | 5 |
| Alternative Models of Computation | - | - | - | 2 | 2 | 0 | 4.5 |
| Elective* | - | - | - | 6 | 6 | 0 | 15 |
| **Total** | **13** | **12** | **1** | **13** | **11** | **1** | **60** |

## ELECTIVE COURSES

| Course | Fall | | | Spring | | | Credits |
|---|---|---|---|---|---|---|---|
| Symbolic Computing | 2 | 0 | 2 | - | - | - | 5 |
| Algorithms for Discrete Structures | 2 | 0 | 2 | - | - | - | 5 |
| Topics in Data Analysis | 2 | 0 | 2 | - | - | - | 5 |
| Logic in Computer Science | 2 | 2 | 0 | - | - | - | 5 |
| Scientific Communication | 2 | 2 | 0 | - | - | - | 5 |
| Computer Perception | 2 | 0 | 2 | - | - | - | 5 |
| Real Time Systems | 2 | 0 | 2 | - | - | - | 5 |
| Soft Computing | 2 | 2 | 0 | - | - | - | 5 |
| System Performance Analysis | 2 | 0 | 2 | - | - | - | 5 |
| Case Studies in Data Mining | 2 | 0 | 2 | - | - | - | 5 |
| Approximative Algorithms | - | - | - | 2 | 2 | 0 | 5 |
| Graph Theory | - | - | - | 2 | 2 | 0 | 5 |
| Operational Research | - | - | - | 2 | 0 | 2 | 5 |
| Dynamical Systems | - | - | - | 2 | 2 | 0 | 5 |
| Topics in Data Structures | - | - | - | 2 | 0 | 2 | 5 |
| Computer Architectures 2 | - | - | - | 2 | 0 | 2 | 5 |
| Machine Learning | - | - | - | 2 | 2 | 0 | 5 |
| Pattern Recognition | - | - | - | 2 | 0 | 2 | 5 |
| Computer Vision | - | - | - | 2 | 0 | 2 | 5 |
| Human Machine Interaction | - | - | - | 2 | 2 | 0 | 5 |
| Modeling and Simulation | - | - | - | 2 | 0 | 2 | 5 |
| Fault Tolerance and Computer System Diagnostics | - | - | - | 2 | 2 | 0 | 5 |
| Distributed Systems and Technologies | - | - | - | 2 | 0 | 2 | 5 |
| Distributed Information Systems | - | - | - | 2 | 0 | 2 | 5 |

# Computer and Information Science Postgraduate Program

The postgraduate curriculum in Computer and Information Science is comprised of:

*six required courses (30 hours, 6 ECTS each),*

*four elective courses (30 hours, 6 ECTS each),*

*two seminars (75 hours, 15 ECTS each).*

The total postgraduate course work consists of 450 hours.

## FIRST YEAR

| Courses | Fall | Spring |
|---|---|---|
| Selected Topics in Symbolic Computation and Computer Arithmetics | 30 hours | |
| Analysis of Algorithms | 30 hours | |
| Theory of Computer Languages | | 30 hours |
| Theory of Computational Procedures | | 30 hour |
| Elective Course | 30 hours | |
| Elective Course | | 30 hours |

## SECOND YEAR

| Courses | Fall | Spring |
|---|---|---|
| Architecture and Organization of Computers | 30 hours | |
| Theory of Information Systems | | 30 hours |
| Elective Course | 30 hours | |
| Elective Course | | 30 hours |
| Seminar | 75 hours | 75 hours |

## ELECTIVE COURSES (30 HOURS, 6 ECTS EACH)

Selected Topics in Computer Architecture

Reliability of Computer Systems

Multiprocessor Architectures and Parallel Algorithms

Artificial Intelligence Methods

Digital Signal Processing

Cellular Automata and Parallel Processing

Neural Networks

Integrated Computer Support of Manufacturing

Databases

Concepts for Modeling of Visual Information

Special Course in Information Science

Special Course in Operations Research

Special Course in Programming Technology

Methods of Applied Mathematics

Selected Topics in Combinatorial Mathematics

Machine Learning

Logic

Approximation and Randomized Algorithms

Cryptography and Computer Security

Differential and Computational Geometry

System Methods

Distributed and Decentralized Information Systems

Decision Systems

Interpersonal Relations and Communication

Information Systems Development Tools

Project Management

Multimedia Techniques

Selected Topics of Economics

Automation of New Public Management

Information Systems in Natural Sciences and Technology

Information Systems and Public Administration

Reengineering of Business Processes

Information Systems Quality and Standardization

Information Systems Sociology – Information Society

Statistical Information Systems

Reliability of Computer Systems

Visual Information Handling

Operational Research in Information Science

Fuzzy Logic Based Decision Making

Portfolio Management

Macroeconomics Modeling

Computer Networks with Services

Computer Supported Cooperative Work

Data Mining and Knowledge Discovery in Databases

Evolutionary Computing

Intelligent Agents

Electronic Business

Computer Structures and Nanotechnologies

Embedded Systems

Numerical Linear Algebra

Topology in Computer Science

One- and Multi-Dimensional Biomedical Signal Processing

# Information Systems and Decision Making Postgraduate Program

The program (a total of 450 hours) is comprised of the following: two required courses (60 hours, *12 ECTS* each),

*a combination of three to five elective courses* (Main elective courses of 60 hours, *12 ECTS* each, other elective courses 30 hours, *6 ECTS* each),

*seminar* (150 hours, *30 ECTS*).

| Semester | Courses |
| --- | --- |
| 1 | Functions and Decision Making (Required course) |
|  | Elective courses |
| 2 | Information Systems (Required course) |
|  | Elective courses |
| 3 | Information Systems Development (Main elective course) |
|  | Management and Theory of Organization (Main elective course) |
|  | Information Systems Management in Business Systems (Main elective course) |
|  | Elective courses |
|  | Seminar |
| 4 | Master's thesis (30 ECTS) |

### ELECTIVE COURSES (30 HOURS EACH)

Elective courses (see page 24) are common to both postgraduate programs, i.e., Computer and Information Science and Information Systems and Decision Making.

# Research

Research activities (as well as most Diploma, Master, and Doctoral theses research) at FRI are performed in fifteen research laboratories which are organized in six groups.

The main sources of research funding are Slovenian Research Agency, the Ministry of Higher Education, Science and Technology, Ministry of Defense, European Union programs (6th FP, COST) and various bilateral programs: USA-Slovenian, French-Slovenian (Proteus), Austrian-Slovenian, Czech-Slovenian, Norwegian-Slovenian, Portuguese-Slovenian, and UK-Slovenian (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.

For more information consult the Web pages of individual laboratories which are all accessible from the Faculty's home page (http://www.fri.uni-lj.si/en/laboratories/).

## SOFTWARE GROUP

Laboratory for Computer Graphics and Multimedia
Laboratory for Biomedical Computer Systems and Imaging

## COMPUTER LOGIC, SYSTEMS AND NETWORKS GROUP

Laboratory for Adaptive Systems and Parallel Processing
Laboratory for Computer Architecture
Computer Communications Laboratory
Computer Structures and Systems Laboratory

## INFORMATICS GROUP

Information Systems Laboratory

## THEORETICAL COMPUTER SCIENCE GROUP

Laboratory for Algorithms and Data Structures
Laboratory for Architecture and Signal Processing
Software Engineering Laboratory

## ARTIFICIAL INTELLIGENCE GROUP

Computer Vision Laboratory
Visual Cognitive Systems Laboratory
Artificial Intelligence Laboratory
Laboratory for Cognitive Modeling

## MATHEMATICS AND PHYSICS GROUP

Laboratory for Mathematical Methods in Computer and Information Sciences

# Laboratory for Computer Graphics and Multimedia

**Head:** Professor Dr. Saša Divjak

**Fax:** (+386 1) 42 64 647

**Phone:** (+386 1) 47 68 + ext.

**WWW:** http://www.fri.uni-lj.si/lgm_en

| Staff | E-mail | Ext. |
|---|---|---|
| Professor Dr. Saša Divjak | sasa.divjak@fri.uni-lj.si | 750 |
| Assistant Professor Dr. Matija Marolt | matija.marolt@fri.uni-lj.si | 483 |
| Assistant Dr. Roman Dorn | roman.dorn@fri.uni-lj.si | 758 |
| Assistant Dr. Marko Privošnik | marko.privosnik@fri.uni-lj.si | 483 |
| Assistant Dr. Alenka Kavčič | alenka.kavcic@fri.uni-lj.si | 483 |
| Researcher Jernej Južna | jernej.juzna@fri.uni-lj.si | 483 |
| Researcher Janez-Franc Vratanar | janez.vratanar@ fri.uni-lj.si | 483 |

## RESEARCH ACTIVITIES

Laboratory of Computer Graphics and Multimedia is involved in activities related to multimedia technologies, computer-based education and learning, human-computer interaction, 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 CoLoS consortium is computer supported conceptual learning of natural sciences. The laboratory also cooperates with Microsoft in introducing new software technologies.

The main ongoing research activities in the laboratory are dedicated to development of multimedia tools and applications, grid computing, and educational applications, especially interactive learning and didactic simulation of natural phenomena. Therefore, 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.

Research on emergent multi-agent systems focuses on construction of cooperative behaviour in complex systems using evolutionary computation and emergence to design global behaviour of the systems. In music information retrieval researches, the focus is on extraction of higher-level cognitive parameters (melody, harmony, rhythm) from audio signals as well as on searching and organizing audio collections. The research from the field of adaptive hypermedia deals with the problems of describing user's knowledge considering the uncertainty in its description and focuses on educational systems, which can adapt their functional features to the individual user.

In the past, members of the laboratory cooperated with other research groups in the development of military training systems, medical imaging applications, various simulation tools for computer supported industrial automation, including robotized environments, and computer supported quality control and management systems.

## RESEARCH PROJECTS

MELT - a Metadata Ecology for Learning and Teaching (ECP-2005-EDU-038103), eContentplus Programme, European Commission, 2006 - 2008.

ETHNOMUSE: multimedia digital archive of Slovenian folk music and folk dance culture (V2-0216), CRP Project, Slovene Research Agency, 2006 - 2008.

ERI: e-materials for computer science and informatics (3311-06-297038), Ministry of Education and Sport, and European Social Fund, 2006 - 2007.

e-VIZUS: Informatization of learning and training in Slovenian Armed Forces (M5-0164), CRP Project, Slovene Research Agency, 2006 - 2007.

Second Click on Slovene - a multimedia CD for learning Slovene as a foreign language, project with American Embassy in Ljubljana, 2006 - 2007.

Digital archive of Slovenian folk songs, project with Science Research Centre of the Slovenian Academy of Sciences and Arts, 2006 - 2007.

HSci - Hands on Science (110157-CP-1-2003-1-PT-COMENIUS-C3), Socrates Comenius Project, European Commission, 2003 - 2006.

AgentGrid: Design of multi-agent systems using GRID (V2-0129), CRP Project, Slovene Research Agency, 2004 - 2006.

Technologies for education and development of innovative environments (3311-04-855017), Centres of Excellence, Ministry of Education and Sport, and European Regional Development Fund, 2004 - 2006.

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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.

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A. Kavčič, A. Kašnik, J. Zemljarič-Miklavčič, T. Jerman, P. Liberšar. Learning Slovenian through Multimedia. *HSci 2004: Proceedings of the 1st International Conference on Hands on Science 2004,* Ljubljana, Slovenia. pp. 221-226. 2004.

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M. Marolt. Networks of Adaptive Oscillators for Partial Tracking and Transcription of Music Recordings, *Journal of New Music Research,*

# Laboratory for Biomedical Computer Systems and Imaging

**Head:** Professor Dr. Franc Jager

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://mimi.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Professor **Dr. Franc Jager** | franc.jager@fri.uni-lj.si | 780 |
| Assistant **Dr. Aleš Smrdel** | ales.smrdel@fri.uni-lj.si | 860 |
| Junior Researcher **Gašper Fele-Žorž, B. Sc.** | gasper.felezorz@fri.uni-lj.si | 860 |

## 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 the physiological phenomena,

use of the computer in modeling and understanding of physiologic re-la-tion-ships,

locally and remotely monitoring physiologic events, graphically displayed anatomic details and physiologic functions, visualizing and representing biomedical signal and imaging data,

developing standardized databases to study physiologic mechanisms and to evaluate performance and robustness of recognition techniques,

characterizing data, and establishing the detection criteria and recognition techniques to automatize as much as possible the analysis of bioelectric patterns, examinations, procedures, and medical practice, in order to improve the quality and reliability of the examinations,

interpret the data and the results qualitatively and quantitatively,

develop performance measures and protocols to evaluate detection tech-ni-ques,

develop biomedical information technologies and software.

The principal research topic currently underway is the development and evaluation of recognition algorithms for accurate detecting of tran-sient ischaemic events in biomedical data using the LTST DB (Long-Term ST Database).

The second research topic is maintaining, updating and distribution of 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-annotated transient ischaemic and non-ischaemic ST events. The database is intended to serve as a reference set in

evaluating the performance of ST analyzers, and as a reference set to study physiologic mechanisms responsible for ischeamia. See: http://www.physionet.org/physiobank/database/ltstdb/ and http://www.physionet.org/challenge/2003/.

The next research topic is 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 examinee human annotations of the LTST DB is under GNU General Public Licence and is available from http://www.physionet.org/physiobank/database/ltstdb/semia/.

The next research topic is the characterization of temporal patterns of transient ischaemic events and time-frequency representations of diag-nostic parameters in ambulatory ECG signals. The goals are to dif-fer-entiate physiologic mechanisms generating ischaemia and predicting impending ischaemia.

Another important contribution of the laboratory to the world community is interactive graphic tool EVAL_ST to evaluate performance and robustness of ischaemia analysers. The tool is under GNU General Public Licence and is available from http://www.physionet.org/physiotools/eval_st/.

Another topic concerns the investigation and assessment of effective methods for monitoring patients affected by cardiovascular diseases, outside the specialized cardiac units, through computer analysis and the interpretation of non-invasive bio-signal data, with the ultimate goal of cardiac telemonitoring via the Internet.

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. Maintaining 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.

## RESEARCH PROJECTS

Maintaining, updating and distribution of the Long Term ST Database (LTST DB), (2002–); research partners: Beth Israel Deaconess Medical Center, Boston, USA, and CNR Institute of Clinical Physiology, Pisa, Italy; (Data-base is vailable from: Laboratory of Biomedical Computer Systems and Imaging, Faculty of Computer and Information Science, Ljubljana, contact: Dr. Franc Jager); Samples of the database are available from: http://www.physionet.org/physiobank/database/ltstdb/.

Metabolic and inborn factors of reproductive health, birth, Research program (B3-0124), Slovene Research Agency (2004–2009).

## LABORATORY GUESTS

Ana Michole, Ms.C., graduate student, University of Zaragoza, Spain. 1. 4. – 30. 6. 2006. Research work on doctoral thesis.
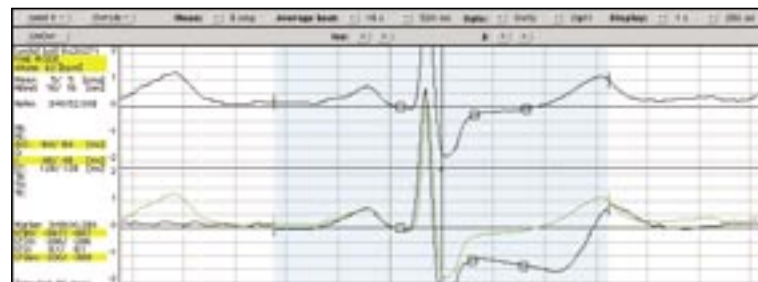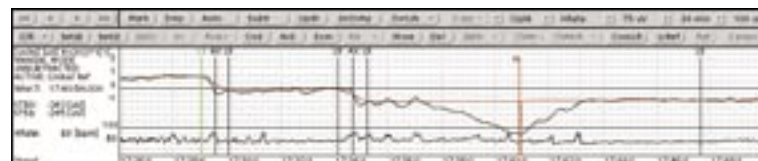


SEMIA, Version 3.0, semi-automated interactive graphic editing tool to annotate ambulatory ECG records.

## RESEARCH VISITS

Franc Jager: Laboratory for Computational Physiology, Division of Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, USA, 25. 3. – 1. 4. 2006. Joint writing of the book Advanced Methods and Tools for ECG data Analysis, and member of a doctoral thesis defense committee – following of the progress of a candidate.

Franc Jager: Division of Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, USA, 24. 7. – 1. 8. 2006. Member of a doctoral thesis defense committee – thesis defense of the candidate.

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F. Jager, A. Taddei, M. Emdin, G. Antolič, R. Dorn, G.B. Moody, B. Glavič, A. Smrdel, M. Varanini, M. Zabukovec, S. Bordigiago, C. Marchesi, R.G. Mark. The Long-Term ST Database: A Research Resource for Algo-rithm Development and Physiologic Studies of Transient Myocardial Ischemia. *Proc. Computers in Cardiology*, Boston, USA, 2000.

F. Jager: Feature Extraction and Shape Representation of Ambulatory ECG using the Karhunen Loeve Transform. *Electrotechnical review*, 69(2):83–89, 2002.

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

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F. Jager, A. Amrdel and R.G. Mark. An Open-Source Tool to Evaluate Performance of Transient ST Segment Episode Detection Algorithms. *Proc. Computers in Cardiology*, pp. 585-588, Chicago, USA, 2004.

A. Minchole, B. Skarp, F. Jager and P. Laguna. Ischemia Detector on the Long-Term ST Database with Body Position Cencallation. *Proc. Computers in Cardiology*, pp. 853-856, Lyon, France, 2005.

A. Smrdel and F. Jager. Diurnal Changes of Heart Rate and Sympatho-Vagal Activity for Temporal Pattens of Transient Ischemia. *Proc. Computers in Cardiology*, pp. 857-860, Lyon, France, 2005.

# Laboratory of Adaptive Systems and Parallel Processing

**Head:** Professor Dr. Andrej Dobnikar

**Fax:** (+386 1) 4768 369

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://laspp.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Full Professor **Dr. Andrej Dobnikar** | andrej.dobnikar@fri.uni-lj.si | 382 |
| Assistant Professor **Dr. Branko Šter** | branko.ster@fri.uni-lj.si | 783 |
| Assistant Professor **Dr. Uroš Lotrič** | uros.lotric@fri.uni-lj.si | 874 |
| Junior Researcher **Jernej Zupanc** | jernej.zupanc@fri.uni-lj.si | 875 |

## RESEARCH ACTIVITIES

Main research activities are concentrated around the following topics:

Neural networks in data mining, prediction, recognition and control problems,

Evolutionary algorithms in optimization problems,

Identification of dynamic systems with Recurrent neural networks,

Fuzzy and Neuro-Fuzzy controllers,

Process Informatics and Programmable Technologies,

Cellular structures and Complex Systems,

Knowledge extraction from large databases,

Parallel processing/programming in GRID environments

## RESEARCH PROJECTS

Intelligent data mining in GRID technology. A Slovenian-Portugal Bilateral Project (2006-2007).

Data mining of rubber mixing and testing data bases with soft computing methods. L2-6460: Slovenian Research Agency and Savatech, d.o.o., Kranj (2004-2007).

Relating the Physical Properties of Polymeric Materials by Parallel Implementation of Soft Computing Methods, L2-6143: Slovenian Research Agency and Savatech, d.o.o., Kranj (2004-2007).

## LABORATORY GUESTS

Prof. dr. Bernardete Ribeiro, University of Coimbra, Portugal, September 2006. Research collaboration on "Intelligent data mining in GRID technology".

Catarina Silva, University of Coimbra, Portugal, September 2006. Research collaboration on "Intelligent data mining in GRID technology".

## RESEARCH VISITS

Andrej Dobnikar: University of Coimbra, Portugal, May 2006. Lecture "Machine Nature" (Erasmus).

Andrej Dobnikar: University of Coimbra, Portugal, November 2006. Research collaboration on Intelligent data mining in GRID technology.

Uroš Lotrič: University of Coimbra, Portugal, November 2006. Research collaboration on Intelligent data mining in GRID technology.

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Computing cluster

U. Lotrič, A. Dobnikar. Matrix Formulation of Multilayered Perceptron with a Denoising Unit. *Electrotechnical Review*, 70(4): 221-226, 2003.

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

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Fuzzy control system based on video-cameras

# Laboratory for Computer Architecture

**Head:** Associate Professor Dr. Veselko Guštin

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://www.fri.uni-lj.si/en/laboratories/computer_logic_systems_networks_group/lab_computer_architecture/

| Staff | E-mail | Ext. |
|---|---|---|
| Associate Professor **Dr. Veselko Guštin** | veselko.gustin@fri.uni-lj.si | 384 |
| Lecturer **Dr. Mira Trebar** | mira.trebar@fri.uni-lj.si | 254 |
| Assistant  Professor **Dr. Patricio Bulić** | patricio.bulic@fri.uni-lj.si | 361 |

## RESEARCH ACTIVITIES

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

The main 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 are development of syntax and semantics extensions to the ANSI C in such a way that we could use short SIMD processing facilities in C programming language and development of its vectorizing compiler which is capable to automatically extract 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. We have named this test the D-test. It is appropriate for the vectorization for modern SIMD microprocessors and is more accurate than existing tests. The test takes into account the architectural properties of modern SIMD microprocessors and allows the existence of those data dependences in the loops that do not prohibit the vectorization for the SIMD microprocessors.

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 array (Xilinx Spartan III).

## RESEARCH PROJECTS

Integrated Multimedia Wireless Applications in Hospitals (L2-6234), Slovene Research Agency, (2004-2006).

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P. Bulic, V. Gustin, On Dependence Analysis for SIMD Enhanced Processors, *VECPAR 2004. 6th International Conference on High Performance Computing for Computational Science: Revised Selected Papers and Invited Talks, Lecture Notes in Computer Science, LNCS* 3402, 2005.

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

**Head:** Associate Professor dr. Tone Vidmar

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://lrk.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Associate Professor **Dr. Tone Vidmar** | tone.vidmar@fri.uni-lj.si | 378 |
| Associate Professor **Dr. Mojca Ciglarič** | mojca.ciglaric@fri.uni-lj.si | 377 |
| Assistant **Dr. Matjaž Pančur** | matjaz.pancur@fri.uni-lj.si | 277 |
| Researcher **Andrej Krevl, B. Sc.** | andrej.krevl@fri.uni-lj.si | 794 |

## RESEARCH ACTIVITIES

Main research interests of laboratory members are distributed systems design and development – especially grid architectures, communication security and policies and other security issues, formal validation and testing techniques of communication protocols and distributed processes, computer networks design, content networks and peer-to-peer systems, mobile computing, agile methodologies in development of software and information systems and service oriented architecture with related technologies.

In 2006, we have researched most actively the following areas:

In the area of grid systems we were researching protocol analysis and the possibilities of executing some popular data-mining algorithms in grid environment.

In the area of software development methodologies, we were researching the properties of agile methodologies, especially test-driven development. Within a group of our students, we conducted some experiments, comparing the efficiency of test-first and test-last programming and statistically evaluated the results.

In the area of distribute systems architecture, we studied the suitability of Service Oriented Architecture for use in the military systems and possibilities of integrating these services with location awareness and different sensors for developing a next generation sensor mesh. We have also studied usability of these architectures in Network Centric Operations and Warfare.

The joint research with Medical Centre Ljubljana, Dept. of Infectious Diseases was inititated with an aim of establishing a centralized info point for collecting data on patients with viral hepatitis C.

## EQUIPMENT

Besides the typical office equipment, Computer Communications Laboratory is equipped with a few pieces of advanced networking / distributed systems hardware and software equipment. Hardware: a 20 Gb/s Infiniband network switch, two 24-port Gigabit Switches Dell, Dell Power Vault NAS 745 (4 x 250 GB + 6 x 400 GB), 6 Dell Power Edge Servers, IBM eServer xSeries 336, several PC-based servers, Wireless WiFi and BlueTooth Access Points, various mobile devices, ActiveCard SmartCard readers and smart cards.

*Software:* network management tools and utilities, Oracle 10g and PostgreSQL database and development tools, SharePoint Portal Server, Microsoft development tools and utilities; several open-source Java development tools and utilities including Mobile Phone development utilities, Alchemi grid, Activ Pack for Windows, VMWare and Windows Virtual Server R2 …

## PROJECTS

In the past, Laboratory of Computer Communications members have been engaged in several projects from the areas of computer network structure, architecture, design and management (University of Ljubljana network backbone), computer network security, information systems design and management and distributed systems design. In 2006, the Laboratory members took part in

VIKING – Secure Information-Communication Infrastructure of the Next Generation, (Slovenian Target Research Program), supported by Ministry of Defense and Slovenian Research Agency, 2004-2006. 404-03-16/2004/124.

Relating the Physical Properties of Polymeric Materials by Parallel Implementation of Soft Computing Methods, supported by Slovenian Research Agency and Sava d.d., 2004-2007. L2-6143-1539-04.

Clinical paths data mining with soft computing, supported by Slovenian Research Agency and The University Clinic of Respiratory and Allergic Diseases Golnik, 2004-2007. L2-6460-1539-04.

Formal Analysis of Advanced Grid Infrastructure Protocols. A Slovenian–Croatian Intergovernmental Science and Technology Cooperation Project (2006–2007), supported by Slovenian Research Agency. BI-HR/06-07-029.

Management and Control of University System Infrastructure, University of Ljubljana, 2005 – 2006.

Centralized Identity Management System for Students and Employees, University of Ljubljana, 2006-2007.

Integration of information applications, University of Ljubljana, 2006-2007.

## LABORATORY GUESTS

Marina Bagić, University of Zagreb, Faculty of of Electrical Engineering and Computing. Research collaboration on Formal Analysis of Advanced Grid Infrastructure Protocols. 22. 12. 2006 – 12. 1. 2007.

Communication infrastructure within the Laboratory

## RESEARCH VISITS

Mojca Ciglarič, Andrej Krevl. University of Zagreb, Faculty of of Electrical Engineering and Computing. 6. 10. 2006. Research collaboration on Formal Analysis of Advanced Grid Infrastructure Protocols.

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M. Trampuš, M. Ciglarič, T. Vidmar. Formalizacija varnostnih politik (Security policy Formalization). *Electrotech. Review,* 2005, Vol. 72, No. 5, pp. 309-315.

M. Ciglarič. Content networks : distributed routing decisions in presence of repeated queries. *Int. j. found. comput. sci.,* 2004, Vol. 15, No. 3, pp. 555-566.

M. Ciglarič, M. Pančur. Vključevanje varnostnih mehanizmov v okolje GRID. V: ZAJC, Baldomir (ur.). *Zbornik trinajste mednarodne Elektrotehniške in računalniške konference ERK 2004,* Portorož, Slovenija. Ljubljana: IEEE Region 8, Slovenian IEEE Section, 2004, vol. B, pp. 47-50.

M. Trampuš, M. Ciglarič, M. Pančur, T. Vidmar, A. Krevl, P. Rome, Ž. Aksentič, G. Berginc: Using smart cards as a secure storage for digitally signed documents. V: ZAJC, Baldomir (ur.), TKALČIČ, Marko (ur.). *The IEEE Region 8 EUROCON 2003 : computer as a tool :* 22-24. September 2003, Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia : proceedings. Piscataway: IEEE, cop. 2003, vol. 2, str. 74-78.

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

M. Trampuš, M. Ciglarič, M. Pančur, T. Vidmar. Are E-commerce users defenceless?. V: *IPDPS, International Parallel and Distributed Processing Symposium*, April 22-26, 2003, Nice, France. *Proceedings :* e-zbornik. Los Alamitos [etc.]: IEEE Computer Society, 2003, str. [1-7].

M. Pančur, M. Ciglarič, M. Trampuš, T. Vidmar: Comparison of Frameworks and Tools for Test-Driven Development, *Proc. of the IASTED Int. Symposia Applied Informatics,* ACTA Press, Feb. 2003, Innsbruck, Austria.

# Computer Structures and Systems Laboratory

**Head:** Professor Dr. Niko Zimic

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://lrss.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Professor **Dr. Niko Zimic** | niko.zimic@fri.uni-lj.si | 395 |
| Associate Professor **Dr. Miha Mraz** | miha.mraz@fri.uni-lj.si | 372 |
| Assistant Professor **Dr. Iztok Lebar Bajec** | iztok.bajec@fri.uni-lj.si | 785 |
| Assistant **Andrej Jazbec, M.Sc.** | andrej.jazbec@fri.uni-lj.si | 787 |
| Assistant **Primož Pečar** | primoz.pecar@fri.uni-lj.si | 786 |
| Research Assistant **Miha Janež** | miha.janez@fri.uni-lj.si | 371 |
| Technical Assistant **Vito Čehovin** | vito.cehovin@fri.uni-lj.si | 371 |
| Retired Professor **Dr. Jernej Virant** | jernej.virant@fri.uni-lj.si | 395 |

## RESEARCH ACTIVITIES

The principal scientific research directions of the Computer Structures and Systems Laboratory are fuzzy logic applied to distributed processing and processing platforms of the future. With respect to these the most recent research is dedicated to the modelling of the dynamics of organized groups of moving entities (e.g. flocking birds) and to the design of the ternary quantum-dot cell.

One of the past research studies in fuzzy logic based modelling and simulation was the design and development of a software application for computer assisted prediction of wind-driven wild-land fire for the Slovenian Ministry of Defence. Lately, however, the members of the laboratory have been using fuzzy logic for modelling bird flocks. They have recently published an article in the Journal of Theoretical Biology that presents a highly believable bird flocking model that is based on simple linguistic descriptions. Indeed, the simulations performed by using their model show that when performing turns, the simulated birds change position so that a bird at the head of a flock will be in the rear of the flock if the latter turns 180 degrees, which is a behaviour that can typically be observed in pigeon flocks.

Lately a substantial amount of time is being devoted to the design of the ternary quantum-dot cell, an extension of the binary quantum-dot cell that allows for the construction of quantum-dot cellular automata capable of performing ternary logic operations. The obtained results have been published in some of the most renowned journals in the field, such as IOP's Nanotechnology, Elsevier's Microelectronic Engineering as well as accepted for publication in the International Journal of Unconventional Computing.

In addition to the scientific research the members of the laboratory actively cooperate with different industrial partners, usually on projects related to wireless computer networks, performance evaluation or reliability diagnostics. Recently they have been cooperating with the FH Joanneum GmbH, Austria and the Department of Intensive Internal Medicine of the General Hospital "dr. Franc Derganc", Nova Gorica through a joint project named Mobile Medical Monitoring; a Bluetooth based system designed to diminish the insecurity when patients are transferred from the intensive care to ordinary ward units. Currently the system is undergoing extensive live-testing in the General Hospital "dr. Franc Derganc".

## RESEARCH PROJECTS

Optimization of products MG6111, CS6111, and ESxxxx. Industry-Founded Project, funded by Iskratel d.o.o., Slovenia  (2005–2006).

Wireless communication platforms, Industry-Founded Project, funded by European Structural Funds and Iskra Sistemi d.o.o., Slovenia (2005–2007).

Specification of wireless communication protocols for medical applications, Slovene Government-Founded R&D Project, funded by Slovene Research Agency and OurSpace d.o.o. (2004–2007).

Optimization of Ethernet network resiliency time. Industry-Founded Project, funded by Iskratel d.o.o., Slovenia (2006–2007).

Application of fuzzy logic to defence systems management, A Science for Peace and Security Target Research Project (M2-0170), Slovene Research Agency (2006–2010).
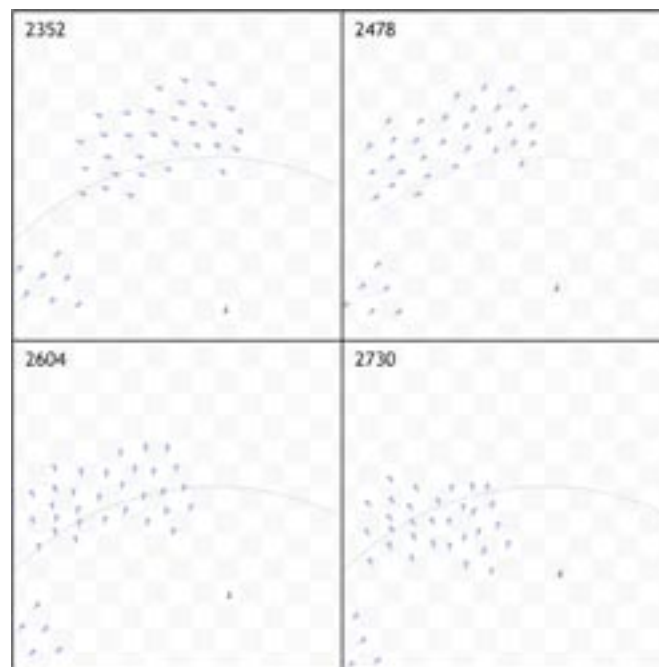


Fuzzy logic based bird flocking simulation displaying behaviour typical for pigeon flocks, where birds, while performing turns, change their position in the flock.

## LABORATORY GUESTS

Ass. Prof. Ovid Azaria Farhi, Ass. Prof. Petar Dimitrov Petrov, Ass. Prof. Yordan Tsonev Chervenkov, Technical University of Varna, Varna, Bulgaria 27. 6. – 5. 7. 2007. Research visit in the framework of the SOCRATES/Erasmus Bilateral Agreement.

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

M. Mraz, N. Zimic, I. Lapanja, J. Virant and B. Skrt. Fuzzy techniques in intelligent household appliances, L. Jain and P. De Wilde (eds.) *Practical Applications of Computational Intelligence Techniques,* pp. 121–145, London, UK: Kluwer Academic Publishers, 2001.

M. Mraz, N. Zimic, I. Lapanja and J. Virant. Notes on fuzzy cellular automata. *Journal of the Chinese Institute of Industrial Engineers,* 17(5):469–476, 2000.

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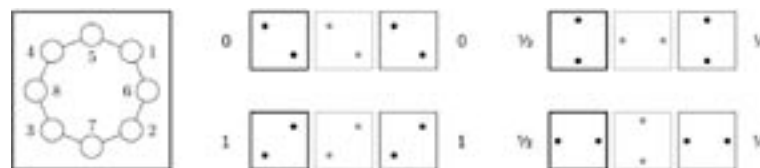


The ternary quantum-dot cell and ternary wire, where the mechanism of transferring logic values 0, ″ or 1 no longer requires electric current but takes advantage of inter-electron Coulomb repulsion.

# Information Systems Laboratory

**Head:** Assistant Professor Dr. Marjan Krisper

**Fax:** (+386 1) 476 8704

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://www.fri.uni-lj.si/si/katedre_in_laboratoriji/informatika/infolab/

| Staff | E-mail | Ext. |
|---|---|---|
| Assistant Professor **Dr. Marjan Krisper** | marjan.krisper@fri.uni-lj.si | 388 |
| Assistant Professor **Dr. Marko Bajec** | marko.bajec@fri.uni-lj.si | 814 |
| Senior-Lecturer **Dr.Rok Rupnik** | rok.rupnik@fri.uni-lj.si | 814 |
| Senior-Lecturer **Aljaž Zrnec, M.Sc.** | aljaz.zrnec@fri.uni-lj.si | 367 |
| Assistant-Lecturer **Alenka Rožanec, M.Sc.** | alenka.rozanec@fri.uni-lj.si | 198 |
| Senior-Lecturer **Damjan Vavpotič, M.Sc.** | damjan.vavpotic@fri.uni-lj.si | 367 |
| Junior researcher **Dejan Lavbič, B. Sc.** | dejan.lavbic@fri.uni-lj.si | 367 |
| Junior researcher **Ana Šaša, B. Sc.** | ana.sasa@fri.uni-lj.si | 367 |
| Junior researcher **Štefan Furlan, B. Sc.** | stefan.furlan@fri.uni-lj.si | 367 |
| Technical assistant **Matej Grom, M.Sc.** | matej.grom@fri.uni-lj.si | 782 |
| Resaerch-Assistant **Aleš Kumer, M.Sc.** | ales.kumer@fri.uni-lj.si | 186 |
| Research-Assistant **Gaber Terseglav, M.Sc.** | gaber.terseglav@fri.uni-lj.si | 186 |

## RESEARCH ACTIVITIES

The Information Systems Laboratory is involved in basic research in the field of Information and Database 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 methodology socio-technical suitability to both organisation and project-specific requirements. From the topic two PhD theses have been developed. An approach for reengineering methodologies (Agile methodology framework) and supporting tools (Agile methodology toolset – see figure below) present the most important results of this research.

*IT/IS Strategy Planning.* The strategy planning is one of the research areas that have been traditionally present in the Information systems laboratory since its existence. In 2004 we published the second edition of the methodology that focuses on how to build strategic plans for information systems. The methodology is based on many years of practical experiences in developing strategic plans for a range of organisations. In the context of IT/IS planning we focus research on: IS/IT architectures, information systems reengineering, business process reengineering, electronic business, and 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 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 a 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 on this area with the 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.

## PROJECTS

The Information systems laboratory has been involved in many research and applied projects. The selection of recent project is listed below.

*MasterProc – Mastering the development process and information technologies in developing solutions for electronic business.* Research project of the Centre of Excellence "Information and Communication Technologies". Ministry of Education, Science and Sport, Ministry of the Economy, and European Regional Development Fund (ERDF), 2004- 2007.

Research program "Competitiveness of Slovenia in 2001-2006". Research project *"Design and Development of multiagent systems for innovative decision support"*, Ministry of education, science and sport, 2004-2006.

*Survey of Multi-agent system implementation and support at multi-agent systems.* Marand d.o.o. 2005-2006.

*Survey of the use of ontologies in multi-agent systems.* Marand d.o.o. 2005-2006.

*Object Oriented Approach to Application Development - based on modelling language UML and application framework MAF – release 2.0.* Marand, d.o.o., 2004-2006.

*Applied Research on Multi agent systems and Prototype of Multi agent system on JADE platform*, Marand d.o.o., 2005-2006.

*Analysis of the existing IT processes in KAD using COBIT model,* Kapitalska družba, 2004-2006.

*IT strategic plan and Information System Planning Methodology,* Kapitalska družba, 2006.

*Strategic Consulting on Information System Implementation*, Intereuropa, 2006.

*Evaluation of IT Processes and Information Systems Development Methodology,* Informatika, 2006-2007.

*Strategic Analysis of Information System and Evaluation of IT Processes Using COBIT Model*, Elektro-Ljubljana, 2005-2006.

*Strategic Analysis of Information System and Evaluation of IT Processes Using COBIT Model*, Elektro-Slovenija, 2006.

*Information System Strategic Plan and Business Process Reengineering Based on eTom Model,* Elektro-Slovenija, 2006-2007.

*Research on the Use of Multiagent Systems, Ontologies and BPEL in Information Systems,* Genis, 2006-2007.

*Design of Universal Billing System*, Marand, 2006-2008.

## LABORATORY GUESTS

Prof. dr. Brain Henderson-Sellers, Technical University of Sydney, Research collaboration on "Mastering the development process and information technologies in developing solutions for electronic business".
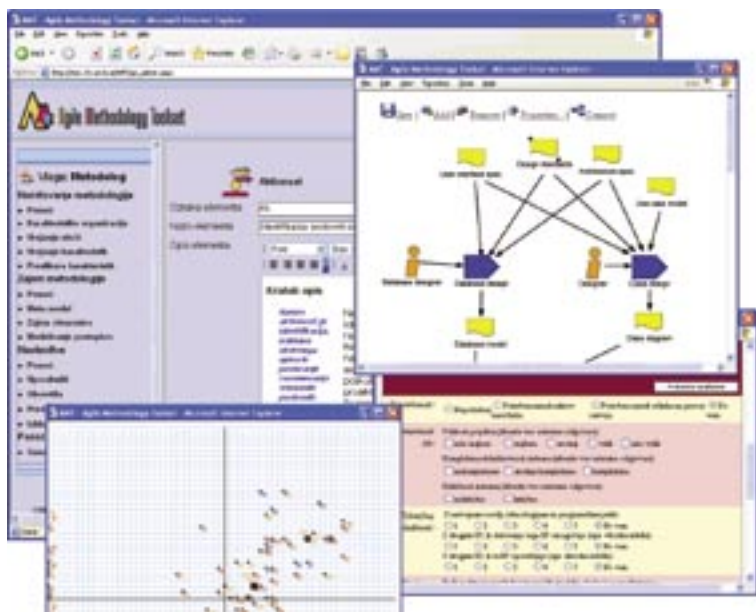


Screenshot of the AMT system

## RESEARCH VISITS

Rok Rupnik: Department of Computer Science, State University of Omsk, 15.7.2006 – 30.7.2006. Collaboration on mobile applications.

M. Bajec and M. Krisper: Department of Computer Engineering, Vilnus Gediminas Technical University, 15.4.2006, 30.4.2006. Collaboration on method-engineering.

## SELECTED PUBLICATIONS

M. Bajec and M. Krisper. A methodology and tool support for business rule management in organisations. *Information Systems*, 30(2005): 423–443, 2005.

M. Bajec, D. Vavpotič and M. Krisper, Practice-driven approach for creating project-specific software development methods, *Information and Software Technology,* Article in Press

R. Rupnik, M. Krisper and M. Bajec. A new application model for mobile technologies. *International Journal of Information Technology and Management*, 3(2/3/4): 282-291, 2004.

R. Rupnik, M. Kukar and M. Krisper. Integrating data mining and decision support through data mining based decision support system. *Journal of Computer Information Systems* (in press).

M. Bajec, V. Mahnič. Portal as a key component in an integrated, user-centric university information system. *Systems integration,* 10(2): 7-20, 2003.

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R. Rupnik and M. Krisper. Context-aware mobile application model. *Electrotechnical Review,* 71(4): 215-219, 2004.

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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.

D. Lavbič, A. Šaša, and M. Krisper. Knowledge management in multi-agent systems. *Proceedings of the First International Conference for New Trends in Knowledge Management,* Maribor, June 13-14, 2006. Maribor: Faculty of Electrical Engineering and Computer Science, Institute of informatics, 2006, str. 128-133.

A. Šaša, M. B. Jurič and M. Krisper. Agents and People Activities in Web-services based Business processes. *2007 Inaugural IEEE International Conference on Digital Ecosystems and Technologies* (IEEE-DEST 2007).

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

D. Vavpotič, M. Bajec and M. Krisper. Scenarios for improvement od software development methodologies. *Advances in information systems development.* Vol. 1, Bridging the gap between academia and industry. New York: Springer, cop. 2006

D. Lavbič. Povezava rezultatov iskanja spletnega inteligentnega agenta s podatki pomembnimi za poslovne odločitve. In: A. Novakovič, N. Schlamberger, M. Indihar Stemberger, M. Učak and J. Drole (eds.). *Management in informatika*: Conf. Proc., pp. 670-675, Dnevi slovenske informatike, Portorož, 2004

M. Bajec, D. Vavpotič and M. Krisper. An approach for creating project-specific software development methodologies. In: Khalid S. (ed.). *Internet and information technology in modern organizations: challenges & answers*: Proc. 5th Intern. Business Information Management Association Conf., pp. 1082-1091, Cairo Egypt, 2005.

# Laboratory for Algorithms and Data Structures

**Head:** Professor Dr. Borut Robič

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://www.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Professor **Dr. Boštjan Vilfan, Dean** | bostjan.vilfan@fri.uni-lj.si | 391 |
| Professor **Dr. Borut Robič** | borut.robic@fri.uni-lj.si | 867 |
| Lecturer **Dr. Boštjan Slivnik** | bostjan.slivnik@fri.uni-lj.si | 363 |
| Teaching Assistant **Dr. Tomaž Dobravec** | tomaz.dobravec@fri.uni-lj.si | 364 |
| Teaching Assistant **Dr. Jurij Mihelič** | jurij.mihelic@fri.uni-lj.si | 819 |
| Research Assistant **Uroš Čibej, B.Sc.** | uros.cibej@fri.uni-lj.si | 363 |

### RESEARCH ACTIVITIES

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

### EQUIPMENT

Equipment consists of a network of PCs running under Linux and Windows XP, and Apple Macs running OS X Tiger. Two HP ProLiant DL320 G4 servers are used by PlanetLab. Additionally, miscellaneous items of computer infrastructure offer adequate computational support for the staff and students performing thesis work, as well as occasional guests.

### RESEARCH PROJECTS

"Exact and non-exact Algorithms and Techniques" (J2-6688-1539-05), funded by the Ministry of Higher Education, Science and Technology, and Slovenian Research Agency (2004-2007)

"Computational Service on GRID Infrastructure" jointly with Jozef Stefan Institute and the company XLAB, Ltd., funded by the Ministry of Higher Education, Sc.and Tech., and Slovenian Research Agency (2004-2006).

"MetaService – Semantic coupling of GRID Services" (V2 0215) jointly with Jozef Stefan Institute and the company XLAB, Ltd., funded by the Ministry of Higher Education, Science and Technology, and Slovenian Research Agency (2006-2008).

"Computational GRID Technologies for more efficient utilization of computer resources in business environment" (V2 0214) jointly with Jozef Stefan Institute and the company XLAB, Ltd., funded by the Ministry of Higher Education, Science and Technology, and Slovenian Research Agency (2006-2008).

### LABORATORY GUESTS

Prof. Anthony Sloane, Macquaire University, Sydney, Australia. 3. 4. 2006. Invited lecture »Eli: Generating Software from Specifications«.

### RESEARCH VISITS

Uroš Čibej: Grid and Distributed Systems laboratory, University of Melbourne, Australia, 17. 7. - 8. 8. 2006. Development of a new data grid simulator and new data structures for advance reservation of CPU in computational grids.

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T. Dobravec, B. Robič, J. Žerovnik. Permutation routing in double-loop networks : design and empirical evaluation. *Journal of Systems Archchitecture* 48:387–402, 2003.

J. Močnik, R. Trobec, B. Robič. Integration of load balancing in CORBA environment. *Parallel Algorithms and Applications* 18:99–105, 2003.

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J. Mihelič, B. Robič. The flexible-attribute problems. *Computational Optimization and Applications* (to appear).

R. Trobec, M. Šterk, B. Robič. Computational complexity of the parallel meshless local Petrov-Galerkin method. *Computer Modeling in Engineering and Sciences* (to appear)

# Laboratory for Architecture and Signal Processing

**Head:** Professor Dr. Dušan M. Kodek

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://laps.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Professor **Dr. Dušan M. Kodek** | duke@fri.uni-lj.si | 392 |
| Lecturer **Igor Škraba, M.Sc.** | igor.skraba@fri.uni-lj.si | 374 |
| Assistant **Robert Rozman, M.Sc.** | robert.rozman@fri.uni-lj.si | 374 |
| Assistant **Andrej Štrancar, M.Sc.** | andrej.strancar@fri.uni-lj.si | 374 |
| Assistant **Damjan Šonc, M.Sc.** | damjan.sonc@fri.uni-lj.si | 374 |
| Technical Assistant **Zvonimir Petkovšek** | zvonimir.petkovsek@fri.uni-lj.si | 374 |

## 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 RISC vs. CISC 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 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 investigated. A general purpose finite wordlength FIR design program has been developed during the course of this work. Spectrum and vibration analyses. DSP processor applications. A low-cost DSP processor based spectrum and vibration analyzer was developed and is in production.

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

## RESEARCH PROJECTS

*Industrial low-bit wireless local network.* Project for Elatec Inženiring d.o.o. (2005-2006).

*Battery powered multilingual translator.* Project for Elatec Inženiring d.o.o. (2005-2006).

*Low cost spectrum and vibration analyzer.* Project for Resa d.d. (2004-2006).

*Control unit for hazardous location Ex Zone.* Project for TV Varnost Elektronika d.d. (2006-2007).

*Development of a universal protocol converter.* Project for Liko Pris d.d. (2005-2006).

*Algorithms for static and dynamic correction of the wind speed measurement for ultrasonic anemometer on an oceanographic buoy.* Project for Morska biološka postaja Piran (2005-2006).

*Development of a data acquisition system for an oceanographic buoy.* Project for Morska biološka postaja Piran (2005-2006).

*VOIP technologies in corporate communication systems.* Project for Comutel d.o.o. (2005-2006).

## RESEARCH VISITS

D. M. Kodek: Department of Computer Science, Princeton University, NJ, USA, 25.3. – 6.4. 2006. Development of algorithms for theoretical bounds on finite wordlength minimax approximation.



Lab-Arhitecture and Signal Processing-picture.JPG): GSM module for remote control system

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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.

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

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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.

# Software Engineering Laboratory

**Head:** Associate Professor Dr. Viljan Mahnič

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://ltpo.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Associate Professor **Dr. Viljan Mahnič** | viljan.mahnic@fri.uni-lj.si | 447 |
| Lecturer **Dr. Igor Rožanc** | igor.rozanc@fri.uni-lj.si | 366 |
| Teaching Assistant **Marko Poženel, M.Sc.** | marko.pozenel@fri.uni-lj.si | 365 |
| Teaching Assistant **Rok Štebe** | rok.stebe@fri.uni-lj.si | 365 |
| External Collaborator **Nataša Žabkar, M.Sc.** | nzabkar@zav-triglav.si phone: (+386 1) 5806 361 | |
| External Collaborator **Rok Preskar** | rok.preskar@hermes-softlab.com phone: (+386 1) 5865 200 | |

## RESEARCH ACTIVITIES

The Software Engineering Laboratory is involved in teaching and research 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, and Data Warehouses. 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 (SW-CMM, ISO 9000 family of standards, SPICE, Bootstrap etc.). Adaptation of SW-CMM 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). Definition of appropriate metrics for the development of applications in a database environment. Development of a metrics model to support the level 4 of SW-CMM in small organizations.

*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.

## 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 (2001-2007).

## LABORATORY GUESTS

Prof. Dr. Jose Marques dos Santos, Rector of the University of Porto, Portugal. Collaboration within the scope of EUNIS (European University Information Systems Association) and lecture "Bologna Process at the University of Porto, and Possibilities for Cooperation with the University of Ljubljana in the Area of Engineering Education".

Prof. Dr. Ivan Vrana, Head of the Department of Information Engineering, Czech University of Agriculture in Prague. Collaboration within the scope of EUNIS (European University Information Systems Association) and lecture "Master's Level Program in Informatics with English as Teaching Language at the Czech University of Agriculture in Prague".

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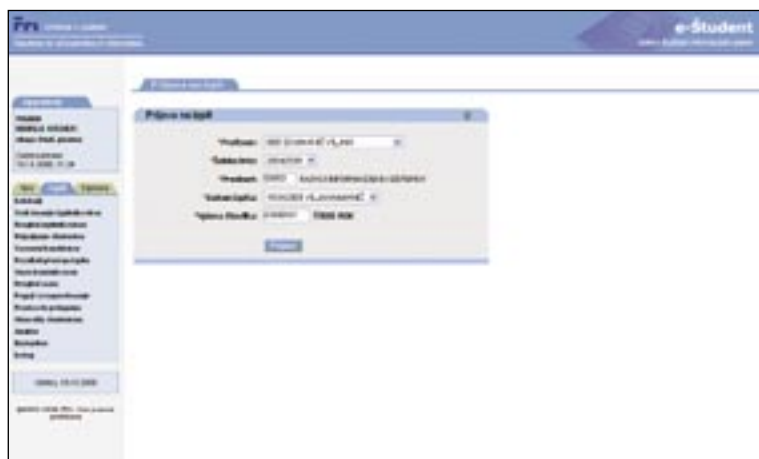


e-Študent: web-based student information portal

# Computer Vision Laboratory

**Head:** Professor Dr. Franc Solina

**Fax:** (+386 1) 4264647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://www.fri.uni-lj.si/en/laboratories/artificial_intelligence_group/lab_computer_vision/

| Staff | E-mail | Ext. |
|---|---|---|
| Professor **Dr. Franc Solina** | franc.solina@fri.uni-lj.si | 389 |
| Assistant Professor **Dr. Aleš Jaklič** | ales.jaklic@fri.uni-lj.si | 878 |
| Assistant Professor **Dr. Bojan Kverh** | bojan.kverh@fri.uni-lj.si | 878 |
| Assistant Professor **Dr. Peter Peer** | peter.peer@fri.uni-lj.si | 878 |
| Teaching Assistant **Matjaž Jogan, M.Sc.** | matjaz.jogan@fri.uni-lj.si | 878 |
| Research Assistant **Borut Batagelj, M.Sc.** | borut.batagelj@fri.uni-lj.si | 878 |
| Technical Assistent **Miha Peternel, M. Sc.** | miha.peternel@fri.uni-lj.si | 878 |
| Research Assistant **Tadej Zupančič, B.Sc.** | tadej.zupancic@fri.uni-lj.si | 878 |

## RESEARCH ACTIVITIES

The laboratory is involved in basic research in computer vision, with emphasis on range image interpretation, object recognition and tracking, face detection and face recogntion, panoramic imaging, and multimedia applications.

Range image interpretation includes range image acquisition, segmentation of range images using the "recover-and-select" paradigm and modeling of shapes using different types of parametric models (i.e. super-quadrics, surface patches). Possible applications include automatic creation of CAD models for reverse engineering applications, creation of models for virtual reality applications, part-based object recognition, and next-view planning for intelligent image acquisition. Superquadric models are used also for object tracking in sequences of intensity images.

We generate panoramic images by assembling multiple images captured in sequence by moving the camera using a pan-tilt robotic manipulator. The sequential image acquisition using the robotic manipulator makes possible also the generation of panoramic stereo pairs and panoramic depth images as a consequence. We use panoramic images for mobile robot navigation, for designing efficient user interfaces for remote camera manipulation and for visual surveillance applications.

For human face detection and recognition in difficult illumination conditions we study the use of skin colour and appearance and fusion of different techniques.

Analysis and tracking of objects in video sequences is applied to studies of human locomotion and roulette gaming instruments.

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 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.

## CURRENT PROJECTS

Computer vision (1539–0214). A basic research program funded by the Slovenian Ministry of Education, Science, and Sport (2004–2008).

Development of a thin client for Loterija Slovenija (2003–).

Leonardo (CPT-CPTNZ 1003): A multi-national exploration in interaction design education and research, Pilot program in cooperation between EU and New Zealand (2004–2007).

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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

**Head:** Professor Dr. Aleš Leonardis

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://vicos.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Professor **Dr. Aleš Leonardis** | ales.leonardis@fri.uni-lj.si | 868 |
| Assistant Professor **Dr. Danijel Skočaj** | danijel.skocaj@fri.uni-lj.si | 4778632 |
| Teaching Assistant **Matjaž Jogan, M.Sc.** | matjaz.jogan@fri.uni-lj.si | 878 |
| Postdoctoral Researcher **Dr. Ondrej Drbohlav** | ondrej.drbohlav@fri.uni-lj.si | 4778632 |
| Postdoctoral Researcher **Dr. Roland Perko** | roland.perko@fri.uni-lj.si | 4778631 |
| Research Assistant **Dr. Matej Artač** | matej.artac@fri.uni-lj.si | 4778630 |
| Research Assistant **Barry Ridge, M.Sc.** | barry.ridge@fri.uni-lj.si | 4778632 |
| Researcher **Matej Kristan, M.Sc.** | matej.kristan@fri.uni-lj.si | 4778632 |
| Researcher **Gregor Berginc** | gregor.berginc@fri.uni-lj.si | 4778630 |
| Research Assistant **Luka Fuerst** | luka.fuerst@fri.uni-lj.si | 4778631 |
| Researcher **Jurij Šorli** | jurij.sorli@fri.uni-lj.si | 4778631 |
| Research Assistant **Aleš Štimec** | ales.stimec@fri.uni-lj.si | 4778630 |
| Researcher **Dušan Omerčević** | dusan.omercevic@fri.uni-lj.si | 4778631 |

## 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 that emerge in natural and urban environments. Examples include mobile robots, intelligent environments, mobile computing devices, 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 modeling 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 concerned with the semantics of the relationship between the visual 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 words describing the scene. 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 smart vision-based positioning using mobile computing devices in urban environments as well as in other applications of cognitive systems.

Our theoretical findings on visual learning and recognition very often ground in a realistic scenario of spatial orientation of mobile robots (specifically, we use in-door and out-door iRobot mobile platforms equipped with omnidirectional and stereo camera setups), which represent a target system for many of the methods developed. In the long run, we aim at developing algorithms for autonomous exploration and building of cognitive maps which can be used by agents for navigation and spatial reasoning in unbounded environments. 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. Such cognitive agents will 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 semantical level.

Research in the area of range image interpretation includes range image acquisition (using a structured light range scanner), segmentation of range images using the "recover-and-select" paradigm and modeling of shapes using different types of parametric models. Possible applications include automatic creation of CAD models for reverse engineering applications, creation of models for virtual reality applications, and part-based object recognition.



Mobile robot localization using omnidirectional vision.

## CURRENT PROJECTS

*Computer vision,* 1539–0214. A basic research program, Slovenian Ministry of Higher Education, Science and Technology  (2004–2008).

COSY - Cognitive Systems for Cognitive Assistants (IST-2002-2.3.2.4 FP6-004250-IP). FP6 IST Programme Project, European Commission (2004-2008).

MOBVIS - Vision Technologies and Intelligent Maps for Mobile Attentive Interfaces in Urban Scenarios (IST-2002-2.3.4.1, FP6-511051-STREP), FP6 IST Programme Project,  European Commission (2005-2008).

VISIONTRAIN - Computational and Cognitive Vision Systems: A Training European Network (MRTN-CT-2004-005439, FP6-2002-Mobility-1). FP6 IST Programme Project, European Commission (2005-2009).

EuCognition - The European Network for the Advancement of Artificial Cognitive Systems (FP6-2640). ). FP6 IST Programme Project, European Commission (2006-2009).

Robust Approaches to Recognition Problems in Computer Vision. A Slovenian–Austrian Intergovernmental Science and Technology Cooperation Project, Slovene Research Agency (2005-2006).

Development of new techniques for recognition and categorization, A Slovenian-Greek Intergovernmental Science and Technology Cooperation Project, Slovene Research Agency (2006-2007).

Mobile robot localisation using panoramic images, A Slovenian-Czech Intergovernmental Science and Technology Cooperation Project, Slovene Research Agency (2007-2008).

## LABORATORY GUESTS

Prof. Dr. Phillip Mckerrow, School of Information Technology and Computer Science, University of Wollongong, Australia, 14. 10. − 14. 11. 2006. Sabbatical visit and collaboration on mobile robot localization; lecture "Ultrasonic sensing for mobile robotics".

Prof. Dr. Daniel Cremers, Department of Computer Science, University of Bonn, Germany, 1. 9. 2006; lecture "Computer Vision at the University of Bonn".

Prof. Dr. John K. Tsotsos, York University, Toronto, Canada, 14. 5. − 16. 5. 2006; lecture "Tracing Back Feed-Forward Neural Activation to Solve the Visual Feature Binding Problem".

Oscar Martinez Mozos, Albert-Ludwigs-Universität Freiburg, Germany, 24. 1. − 24. 2. 2006. Collaboration on mobile robot localization and place categorization.

Prof. Dr. Wolfram Burgard, Institut für Informatik, Albert-Ludwigs-Universität Freiburg, Germany, 24. 1. − 25. 1. 2006. Collaboration on mobile robot localization and place categorization and lecture "Mapping with Mobile Robots in Dynamic Environments".

Konstantinos Konstantinidis, Democritos University of Thrace, 04.09. − 16.09.2006. Collaboration on the development of new techniques for recognition and categorization.

## RESEARCH VISITS

Aleš Leonardis, Dipartimento di Informatica, Sistemistica e Telematica, LIRA, Genova, Italy; Workshop Toward Cognitive Humanoid Robots, 3.12-9.12.2006. Invited lecture, »Hierarchically Learned Structure of Object Categories: From Pixels to Semantic Parts«.

Aleš Leonardis, Danijel Skočaj, School of Computer Science, University of Birmingham, UK, 16.1. – 20. 1. 2006. Collaboration on CoSy project; integration aspects of cognitive systems.

Aleš Leonardis, Danijel Skočaj, KTH Stockholm, Sweden, 24. 3. – 25. 3. 2006. Collaboration on CoSy project; the role of cognitive vision within cognitive systems.

Danijel Skočaj, Department of Computer Science, Darmstadt University of Technology, Germany, 14. 6. – 15. 6. 2006, Collaboration on CoSy project; co-creating the visual subarchitecture of the cognitive system.

Aleš Leonardis, Danijel Skočaj, School of Computer Science, University of Birmingham, UK, 9. 9. – 13. 9. 2006. Collaboration on CoSy project; building the architecture of the cognitive system.

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D. Skočaj, A. Leonardis, and H. Bischof. Weighted and robust learning of subspace representations. *Pattern Recognition*, In press, available online, 2006.

D. Skočaj and A. Leonardis. Incremental and robust learning of subspace representations. *Image and Vision Computing,* In press, available online, 2006

S. Fidler, G. Berginc, and A. Leonardis, "Hierarchical Statistical Learning of Generic Parts of Object Structure", *In Proceedings of IEEE Conference on Computer Vision and Pattern Recognition 2006,* vol. 1, pp. 182-189, 2006.
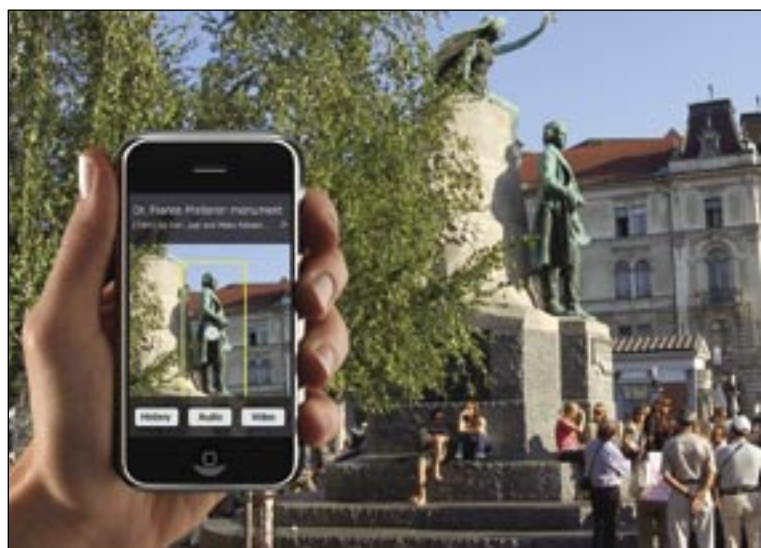


Vision-based positioning and landmark recognition using mobile devices in urban environments

A. Leonardis, H. Bischof, and A. Pinz (Editors), 9th European Conference on Computer Vision - ECCV 2006, Proceedings, Parts I-IV, Series: Lecture Notes in Computer Science , Vols. 3951, 3952, 3953, 3954; Springer, 2006.

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

M. Peternel, A. Leonardis. Visual learning and recognition of a probabilistic spatio-temporal model of cyclic human locomotion. *ICPR 2004,* pp. 146-149, 2004.

B. Kverh, A. Leonardis. A generalisation of model selection criteria. *Pattern analysis and applications*, pp. 51-65, 2004.

H. Bischof, H. Wildenauer, A. Leonardis. Illumination insensitive recognition using eigenspaces. *ComputerVision and Image Understanding,* Volume 95, no. 1, pp. 86-104, 2004.

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.

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

T. Werner, T. Pajdla, V. Hlaváč, A. Leonardis, M. Matoušek. Selection of reference images for image-based scene representations. *Computing*, vol. 68, pp. 163–180, 2002.

J. Maver, A. Leonardis. Recognizing 2-tone images in grey-level parametric eigenspaces, *Pattern recogition. letters*, 23, pp. 1631–1640, 2002.

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

A. Jaklič, A. Leonardis and F. Solina. *Segmentation and Recovery of Superquadrics,* volume 20 of Computational imaging and vision. Kluwer, Dordrecth, 2000.

W.G. Kropatsch, A. Leonardis, and H. Bischof. Hierarchical, adaptive, and robust methods for image understanding. *Surveys on Mathematics for Industry,* 9:1–47, 1999. Springer-Verlag.

H. Bischof, A. Leonardis and Alexander Selb. MDL principle for robust vector quantisation. *Pattern analysis and applications*, 2(1): 59–72, 1999.

F. Solina and A. Leonardis. Proper scale for modeling visual data. *Image and Vision Computing Journal*, 16:89–98, 1998.

A. Leonardis and H. Bischof. An efficient MDL-based construction of RBF networks. *Neural Networks,* 11(5):963–973, July 1998.

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.

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.

R. Bajcsy, S. Wook Lee, and A. Leonardis. Detection of diffuse and specular interface reflections and inter-reflections by color image segmentation. *International Journal of Computer Vision*, 17(3):241–272, 1996.

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

**Head:** Professor Dr. Ivan Bratko

**Fax:** (+386 1) 426 4386

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://www.ailab.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Professor **Dr. Ivan Bratko** | ivan.bratko@fri.uni-lj.si | 393 |
| Associate Professor **Dr. Blaž Zupan** | blaz.zupan@fri.uni-lj.si | 402 |
| Assistant Professor **Dr. Dorian Šuc** | dorian.suc@fri.uni-lj.si | 299 |
| Lecturer **Dr. Janez Demšar** | janez.demsar@fri.uni-lj.si | 813 |
| Assistant **Aleksander Sadikov** | aleksander.sadikov@fri.uni-lj.si | 987 |
| Researcher **Peter Juvan** | peter.juvan@fri.uni-lj.si | 267 |
| Junior Researcher **Gregor Leban** | gregor.leban@fri.uni-lj.si | 267 |
| Junior Researcher **Tomaž Curk** | tomaz.curk@fri.uni-lj.si | 871 |
| Junior Researcher **Minca Mramor** | minca.mramor@fri.uni-lj.si | 267 |
| Junior Researcher **Lan Umek** | lan.umek@fri.uni-lj.si | 871 |
| Junior Researcher **Matej Guid** | matej.guid@fri.uni-lj.si | 987 |
| Researcher **Martin Možina** | martin.mozina@fri.uni-lj.si | 154 |
| Researcher **Jure Žabkar** | jure.zabkar@fri.uni-lj.si | 154 |
| Researcher **Damjan Kužnar** | damjan.kužnar@fri.uni-lj.si | 987 |

## RESEARCH ACTIVITIES

The laboratory carries out research in machine learning, inductive logic programming, AI approaches to systems control, qualitative reasoning, bioinformatics, and information visualization. Research results concern the learning from noisy data in attribute-based learning for classification and regression, evaluation of attributes in machine learning, the automatic discovery of concept hierarchies and constructive induction in machine learning, combining logical and numerical learning, applying machine learning to systems control and qualitative modeling, and reconstruction of human control skill. A notable aspect of much of this research is its application to problems in functional genomics and bioinformatics, medical diagnosis and prognosis, ecological modeling, and mechanical engineering.

The research programme Artificial Intelligence and Intelligent Systems, carried out in part by this laboratory, was in 2006 listed among the best research programmes funded by the Slovenian research agency ARRS. 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 the second dissertation award, after Dorian Šuc, received by PhD students who did their work in the Artificial Intelligence Laboratory, since 1998 when ECCAI introduced these awards.

## RESEARCH PROJECTS

*Artificial Intelligence and Intelligent Systems.* Research Program funded by Slovenian Research Agency (2004-2008).

*ASPIC - Argumentation Service Platform with Integrated Components* (IST-002307). FP6 IST Programme project, European Commission (2004-2007).

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

*XPERO – Learning by Experimentation* (IST-29427). FP6 IST Programme project, European Commission (2006-2009).

*STEROLTALK - Functional genomics of complex regulatory networks from yeast to human: cross talk of sterol homeostasis and drug metabolism* (FP6-2003-LIFESCIHEALTH-I 512096). Project funded by the EU 6th Framework Programme (2005-2008).

*Artificial intelligence approaches to knowledge discovery in functional genomics,* Slovene Research Agency's Slovene-Italian Bilateral Project (with University of Pavia) (2006-2009).

*FACTORY qSPAI – Quality Control In The Production Line Of Sandwich Panels With AI Methods.* Project founded by Slovene Ministry of the Economy and EUREKA (2005-2007).

*Artificial Intelligence Approaches for Knowledge Discovery in Functional Genomics*, Slovene Research Agency's USA-SI Collaboration Grant (2005-2006).

*Development of Machine Learning Tools for Medical Research and Practice,* Slovene Research Agency's USA-SI Collaboration Grant (2005-2006).

*Knowledge-based technologies and decision support in health-care information portals*, Slovene Research Agency and Slovene Ministry of Higher Education, Science and Technology Grant (V2-0221) (2006-2008).

*Development and localization of Orange data-mining software* (OK 2006-1), founded by Ministry of Higher Education, Science and Technology (2006).

The AI Laboratory also participated in European Networks of Excellence: **KDNet** - *European Knowledge Discovery Network of Excellence* and **MONET** – *European Network of Excellence in Model-Based and Qualitative Reasoning.*

## LABORATORY GUESTS IN 2006

Dr. Matej Lexa, Masaryk University Brno, Faculty of Informatics, Czech Republic. 9.1 – 13.1. Research collaboration and lecture on "Biological sequence analysis".

Prof. Dr. Sara Marsal, Unitat de Recerca de Reumatologia (URR), Institut de Recerca Hospital Universitari Vall d'Hebron, Barcelona,Spain, 6.4 – 7.4. Preparation of proposal for a joint project on whole genome association study in rheumatoid arthritis.

Lucia Sacchi, University of Pavia, Italy. 2.7. – 14.7. Research collaboration in inference of temporal gene networks.

Prof Dr. Ricardo Bellazzi, University of Pavia, Italy. 10.7 – 14.7. Research collaboration in inference of temporal gene networks.

## RESEARCH VISITS

Tomaž Curk: Baylor College of Medicine, Houston, USA, 19.8.-20.12.2006. Development and application of rule-based algorithms for genome-wide analysis of gene regulatory regions in Dictyostelium discoideum.

*Short research visits related to research projects:*

Bratko, Možina, Žabkar, Kužnar: X-Media meetings; Sheffield (UK), Koblenz (Germany), Torino (Italy), Hildesheim (Germany);

Bratko, Možina: ASPIC meetings; London (UK), Patras (Greece), Liverpool (UK);

Bratko, Šuc, Guid: XPero meetings; Munich (Germany), Lazise (Italy), TUW Viena (Austria);

Zupan, Curk: University of Pavia, Italy;

Zupan, Demšar: Baylor College of Medicine, US;

Zupan, Demšar: Institut de Recerca Hospital Universitari Vall d'Hebron, Barcelona, Spain.

*Invited talks and lectures:*

Blaž Zupan: Fundan University, Shanghai, China, 18.7.-24.7.2006, Computational Phenomics, an invited lecture at 1st International Conference of Computational Systems Biology.

Blaž Zupan: Hinxton Hall, Sanger Institute and European Bioinformatics Institute, Cambridge, U.K., 21.8.-25.8.2006, a series of lectures on data mining in bioinformatics at Phenomics Summer School.

Ivan Bratko: University of Bari, Italy, invited talk at ISMIS 2006.



Submersible with intelligent and adaptive buoyancy and stability control

## SELECTED PUBLICATIONS

D. Vladušič, B. Kompare, I. Bratko. Modelling Lake Glumso with Q2 learning. *Ecological Modelling,* Vol. 191, no. 1, pp. 33-46, 2006.

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

G. Leban, B. Zupan, G. Vidmar, I. Bratko. VizRank : data visualization guided by machine learning. *Data Mining and Knowledge Discovery,* vol. 13, no. 2, pp. 119-136, 2006.

M. Guid, I. Bratko. Computer analysis of world chess champions. *ICGA Journal*, vol. 29, no. 2, pp. 65-73, jun. 2006.

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A. Sadikov, I. Bratko. Learning long-term chess strategies from databases. *Machine Learning,* vol. 63, no. 3, pp. 329-340, 2006.

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

M. Možina, J. Žabkar, T. Bench-Capon, I. Bratko. Argument based machine learning applied to law, *Artificial Intelligence and Law*, 13: 53-73 , 2006.

J. Žabkar, R. Žabkar, D. Vladušič, D. Čemas, D. Šuc, I. Bratko. Q2 Prediction of ozone concentrations. *Ecological Modelling,* 191(1), 68-82, 2006.

A. Sadikov, I. Bratko. Pessimistic heuristics beat optimistic ones in real-time search. In: G. Brewka: *ECAI 2006 : proceedings*, IOS Press, 2006, pp. 148-152.
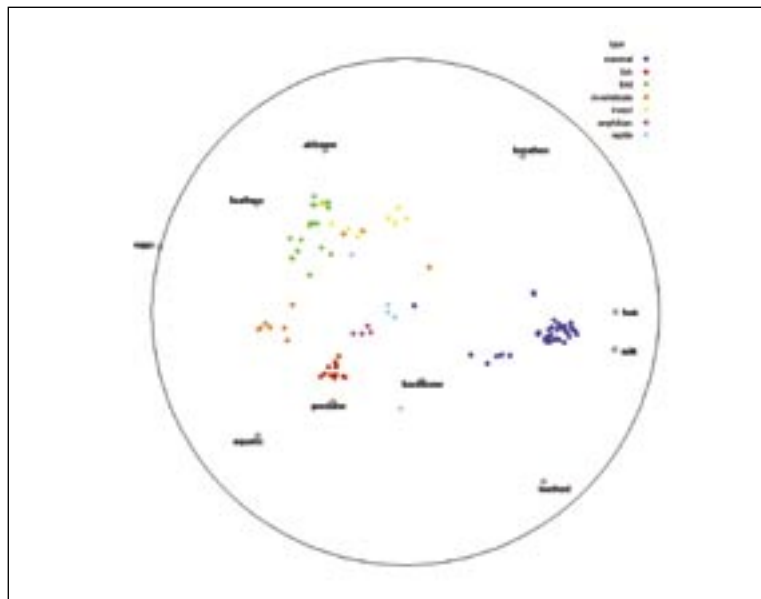


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M. Možina, J. Žabkar, I. Bratko. Argument based rule learning. In: G. Brewka: *ECAI 2006 : proceedings*, IOS Press, 2006, pp. 504-508

M. Možina, J. Demšar, J. Žabkar, I. Bratko. Why is rule learning optimistic and how to correct it. In: J. Fuernkranz, T. Scheffer: *ECML 2006 : proceedings*, Berlin, 2006, pp 330-340.

A. Sadikov, I. Bratko, I. Kononenko. Bias and pathology in minimax search. *Theoretical Computer Science,* 349(2), 268-281, 2005.

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.

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.

P. Juvan, J. Demšar, G. Shaulsky, B. Zupan. GenePath: from mutations to genetic networks and back. *Nucleic Acids Research,* 33, 749-752, 2005.

J. Žabkar, R. Žabkar, D. Vladušič, D. Čemas, D. Šuc, I. Bratko. Q2 Prediction of ozone concentrations. *Ecological Modelling,* 191(1), 68-82, 2006.

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

M. Bohanec, B. Zupan. A function-decomposition method for development of hierarchical multi-attribute decision models. *Decision Support Systems*, 36, 215-233, 2004.

I. Bratko, D. Šuc. Learning qualitative models. *AI magazine,* 24(4): 107-119, 2003.

D. Šuc. Machine Reconstruction of Human Control Strategies. *IOS Press*, 2003.

B. Zupan, I. Bratko, J. Demšar, P. Juvan, T. Curk, U. Borštnik, J. R. Beck, J. Halter, A. Kuspa, G. Shaulsky. GenePath : a system for inference of genetic networks and proposal of genetic experiments. *Artificial intelligence in Medicine*, 29: 107-130, 2003.

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.

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.

B. Zupan, J. Demšar, D. Smrke, K. Božikov, V. Stankovski, I. Bratko, J.R. Beck. Predicting patient's long – term clinical status after hip arthroplasty using hierarchical decision modeling and data mining. *Methods Inf. Medicine,* 40: 25-31, 2001.

D. Šuc, I. Bratko. Skill modelling through symbolic reconstruction of operator's trajectories. *IEEE Trans. Systems, Man and Cybernetics, Part A 30: 617-624, 2000.*

B. Zupan, J. Demšar, M.W. Kattan, J.R. Beck, I. Bratko. Machine learning for survival analysis: a case study on recurrence of prostate cancer. *Artificial Intelligence in Medicine*, 20: 59-75, 2000.

# Laboratory for Cognitive Modeling

**Head:** Professor Dr. Igor Kononenko

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 47 + ext.

**WWW:** http://lkm.fri.uni-lj.si/

| Staff | E-mail | Ext: |
| --- | --- | --- |
| Professor **Dr. Igor Kononenko** | igor.kononenko@fri.uni-lj.si | 68390 |
| Assistant Professor **Dr. Matjaž Kukar** | matjaz.kukar@fri.uni-lj.si | 78627 |
| Assistant Professor **Dr. Marko Robnik Šikonja** | marko.robnik@fri.uni-lj.si | 78627 |
| Assistant **Zoran Bosnić, MSc** | zoran.bosnic@fri.uni-lj.si | 68459 |
| Research Assistant **Luka Šajn, BSc** | luka.sajn@fri.uni-lj.si | 68459 |

## 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. We are developing new approaches to building, evaluating, and explaining 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.

## RECENT PROJECTS AND COLLABORATION

Knowledge synthesis from data and background knowledge: Basic research project funded by Slovenian Ministry of Education, Science and Sports. (2003-2007)

Reliable and Comprehensible Machine Learning Approaches with Applications to Medical Diagnostics and Bioinformatics: Bilateral project funded by Slovenian and Greek Ministry of science. (2005-2007)

Machine Learning of Probabilities with Applications to Web Portals and Medical Diagnostics: Bilateral project funded by Slovenian and Portugese Ministry of science. (2006-2007)

## LABORATORY GUESTS

Prof. dr. Aristeidis Likas, University of Ioannina, Greece. 8. – 12. May 2006. Research collaboration in analysis and application of transductive methods in supervised and unsupervised learning (clustering).

Prof. dr. Joao Gama, researcher at LIACC, the Laboratory of Artificial Intelligence and Computer Science of the University of Porto. 6.-11. November 2006. Research collaboration in data stream analysis.

Rita Ribeiro, researcher at LIACC, the Laboratory of Artificial Intelligence and Computer Science of the University of Porto. 6.-11. November 2006. Research collaboration in application of machine learning on ecological problems.

## RESEARCH VISITS

Marko Robnik Šikonja: University of Hasselt, 8. October – 22. November 2006. Research collaboration in feature evaluation on marketing problems.

Matjaž Kukar, Luka Šajn: University of Ioannina, Greece. 27 November - 2. December 2006 . Research collaboration in application of transductive methods in kernel methods.

Marko Robnik Šikonja, Matjaž Kukar: University of Porto, Portugal. 22 – 28 May 2006. Kick-off meeting for the project Machine Learning of Probabilities with Applications to Web Portals and Medical Diagnostics.

## SELECTED REFERENCES

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

M. Robnik-Šikonja, K. Vanhoof: Evaluation of ordinal attributes at value level. *Data Mining and Knowledge Discovery*, 2007 (in press).

M. Bevk, I.Kononenko: Towards symbolic mining of images with association rules: Preliminary results on textures. *Intelligent Data Analysis*, 10(4)379-393, 2006.

M. Kukar. Quality assessment of individual classifications in machine learning and data mining. *Knowledge and information systems,* 2006, vol. 9, no. 3, pages 364-384.

M. Kukar., C. Grošelj. Transductive machine learning for reliable medical diagnostics. *J. med. syst.,* 2005, vol. 29, no. 1, pages 13-32.

M. Robnik-Šikonja, I. Kononenko. Reliable feature evaluation in classification and regression. V: LIU, John X. (ur.). *Control and Learning in Robotic Systems.* New York: Nova Science Publishers, cop. 2005, str. 281-319

L. Šajn, M. Kukar, I. Kononenko, M. Milcinski. Computerized segmentation of whole-body bone scintigrams and its use in automated diagnostics. *Comput. Methods and Programs in Biomedicine,* 80(1)47-55, 2005.

I. Kononenko, M. Bevk, A.Sadikov, L. Šajn. Classification of different types of coronas using parametrization of images and machine learning. V: KOROTKOV, Konstantin (ur.). *Measuring Energy Fields : State of the Science, (*GDV bioelectrography series, vol. 1). Fair Lawn: Backbone, cop. 2004, str. 193-208.

A. Sadikov, I. Kononenko, F. Weibel. Analyzing coronas of fruits and leaves. In: K. Korotkov (ed.). *Measuring Energy Fields : State of the Science,* (GDV bioelectrography series, vol. 1). Fair Lawn: Backbone, 2004, str.143-154

I. Kononenko, I. Jerman (eds.). Mind-body studies : proceedings of *6th International Conference on Cognitive Science*, Ljubljana, 13-17th October 2003. Ljubljana: Institut "Jožef Stefan" (190 pages).

M. Kukar. Transductive reliability estimation for medical diagnosis. *Artificial Intelligence in Medicine,* 29:81-106, 2003.

M. Robnik-Šikonja, D. Cukjati, I. Kononenko Comprehensible evaluation of prognostic factors and prediction of wound healing. *Artificial Intelligence in Medicine,* 29: 25-38, 2003.

M. Robnik-Šikonja, I. Kononenko. Theoretical and Empirical Analysis of ReliefF and RReliefF, *Machine Learning Journal,* 53: 23-69, 2003.

D. Cukjati, M. Robnik-Šikonja, S. Reberšek, I. Kononenko, D. Miklavčič. Prognostic factors, prediction of chronic wound healing and electrical stimulation. *Medical & Biological Engineering & Computing*, 39:542–550, 2001.

I. Kononenko: Machine learning for medical diagnosis: History, state of the art and perspective, Invited paper, *Artificial Intelligence in Medicine*, 23(1):89–109, 2001.

# Laboratory for Mathematical Methods in Computer and Information Science

**Head:** Associate Professor Dr. Neža Mramor Kosta

**Fax:** (+386 1) 426 4647

**Phone:** (+386 1) 4768 + ext.

**WWW:** http://lmmri.fri.uni-lj.si/

| Staff | E-mail | Ext. |
|---|---|---|
| Associate Professor **Dr. Neža Mramor Kosta** | neza.mramor@fri.uni-lj.si | 258 |
| Associate Professor **Dr. Aleksandar Jurišić** | aleksandar.jurisic@fri.uni-lj.si | |
| Associate Professor **Dr. Bojan Orel** | bojan.orel@fri.uni-lj.si | 870 |
| Assistant Professor **Dr. Gašper Fijavž** | gasper.fijavz@fri.uni-lj.si | 871 |
| Assistant **Dr. Marko Boben** | marko.boben@fri.uni-lj.si | 871 |
| Assistant **Sanja Fidler, B.Sc.** | sanja.fidler@fri.uni-lj.si | 871 |
| Assistant **Peter Kink, B.Sc.** | peter.kink@fri.uni-lj.si | 259 |
| Assistant **Matjaž Urlep, B.Sc.** | matjaz.urlep@fri.uni-lj.si | |
| Assistant **Martin Vuk, M.Sc.** | martin.vuk@fri.uni-lj.si | 259 |
| Assistant **Damjan Vrenčur, B.Sc.** | damjan.vrencur@fri.uni-lj.si | |

## RESEARCH ACTIVITIES

The research activities of the laboratory involve various fields of mathematics with special emphasis on applications to computer and information science. The following areas of mathematics are studied:

- scientific computing and numerical solutions of differential equations, in particular, methods for geometric integration of differential equations,

- graph theory, mostly topological and structural properties of graphs, vertex colorings of graphs and weighted graphs as a natural generalization of the channel assignment problem,

- algebraic topology, in particular cohomology of topological spaces with group actions, applications of topology to computer science, and computational topology,

- nonlinear dynamical systems and their application in geometry, physics and mechanics,

- linear and nonlinear mathematical techniques in appearance based models and their application to computer vision (in cooperation with the Visual Cognitive Systems Laboratory),

- 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 modeling,

- in the area of incidence structures we study problems related to combinatorial and geometric configurations (the study of combinatorial properties of configurations via their incidence graphs, and the study of possibility of the realization of configurations in other incidence structures).

- algebraic combinatorics (discrete structures and algebraic methods: coding theory, design theory and statistical design, theory of orthogonal polynomials and covering spaces, finite geometries and group theory, theory of association schemes and graph theory, in particular distance-regular graphs)

- cryptography and computer security (implementations of public key cryptography and smart cards, provable security of cryptographic protocols)

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

Several members of the lab are also members of 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 the following institutions: NTNU Trondheim, Norway, and University in Bergen, Norway.

## PROJECTS

*Algorithms for control of scanning probe microscopes using quartz tuning forks* (L2-6045), funded by Slovenian Research Agency and Elatec, electronic engineering, d.o.o. Ljubljana (2004 – 2006).

*Secure mail with ECC* (M2-0022), funded by Slovenian Research Agency and CRP1 (2004-2006).

*Certificate Agency with ECC* (M1-0139), funded by Slovenian Research Agency and CRP2 (2006-2008).

*Anonymization of data* (L1-9659-0101-06), funded by Slovenian Research Agency and Ministry of Health (2007).
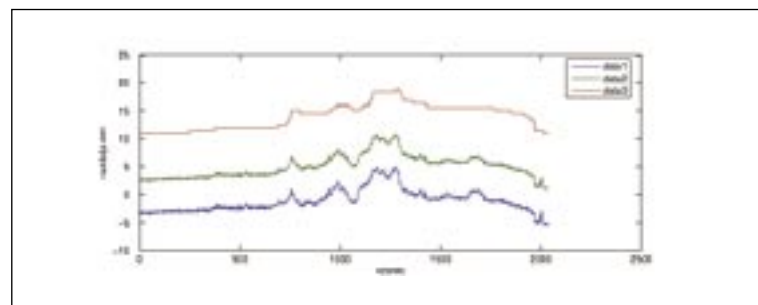


A shape generated with tools developed in cooperation with members of the lab

## LABORATORY GUESTS

RNDr. Eva Trenklerova, J.P. Šafarik University, Košice, Slovakia, 21.5. to 10.6.2006, Ph.D. student, work on Ph.D. thesis on basic embeddings of compacta into the plane.

Prof. Dr. Henry King, University of Maryland, June 8 – 12 2006, joint research work on computational topology and discrete Morse theory, lecture on Semiconfiguration spaces of linkages, or how to design a device which will draw a picture or sign your name.

Prof. dr. Arieh Iserles, Cambridge University, UK, June 8-12 2006, research work on geometric integration and lecture "From high oscillation to rapid approximation ".

Prof. dr. Anne Kvaernoe, University in Trondheim, Norway, June 8-12 2006,  research work on geometric integration and lecture "B-series for stiff ODEs".

Prof. dr. Hans Munthe-Kaas, University in Bergen, Norway, June 8-12 2006, research work on geometric integration and lecture "On the Hopf-algebraic structure of Lie group integrators".

Prof. dr. Syvert Norsett, Norwegian University of  Trondheim, Norway, June 8-13, research work on geometric integration and lecture "A walk into the forest of high oscillations".

Prof. dr. Alexander Ostermann, University in Innsbruck, Austria, June 8-12 2006, preparing research proposal on new integration methods for ODEs and lecture "Towards an implementation of exponential integrators".

Prof. dr. Antonella Zanna, University in Bergen, Norway,  June 8-12 2006, research work on geometric integration and lecture "Explicit, volume preserving splitting methods for divergence-free polynomial vector fields".

Prof. Dr. Jan Jaworowski, Indiana University, Bloomington, Indiana, USA,  October 4 – 15 2006, joint research work on equivariant topology, two lectures on The transfer map and degree of maps of free G-manifolds.

## RESEARCH VISITS

Bojan Orel: Castellon Conference on Geometric Integration, Castellon, Spain, 17. – 25. 9. 2006, planning new research projects and lecture "Accumulation of  global error in Lie group methods".

Martin Vuk: Institut de Recherche Mathématique Avancée, Strasbourg, Francija, 21. 8. - 14. 10. 2006. Work on thesis on nonlinear integrable dynamical systems.

Neža Mramor Kosta: Institute of Computer Science at Faculty of Science, J.P. Šafarik University, Košice, Slovakia, 16. 10. – 19. 10. 2006, PhD defense (as coadvisor) and lecture on "Topological modeling of data points".

Aleksandar Jurišić: Graduate School of Information Science, Tohoku University, Sendai, Japan, November 7 – December 2, 2006, a four hour lecture: An Introduction to Public Key Cryptography.
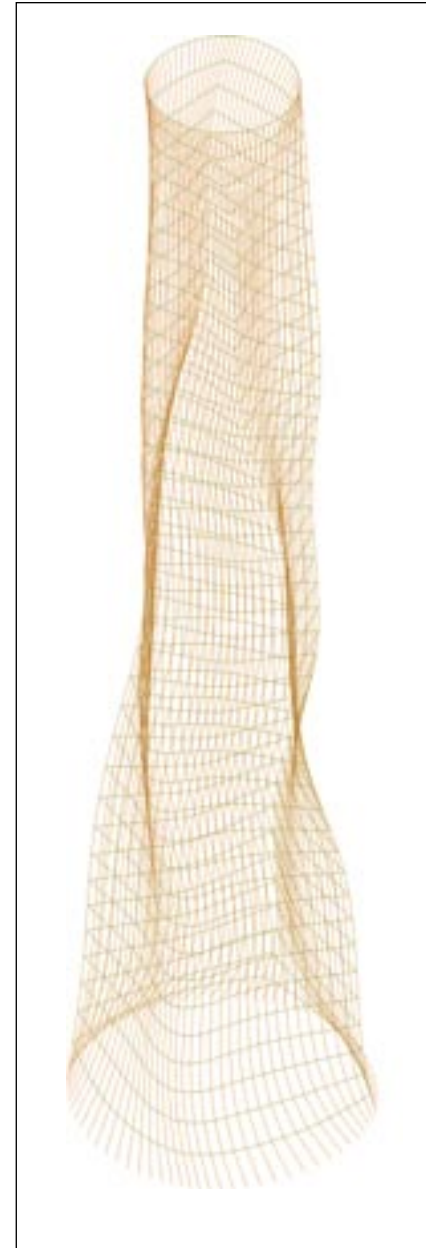


The results of a simulated surface scan of a scanning probe microscope

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