University *of Ljubljana*
Faculty *of Electrical Engineering*

DOCTORAL PROGRAMME

Intelligent control systems and robotics

Electric energy, photovoltaics

Electronics, microelectronics, optoelectronics

Micro electromechanical systems and nanostuctures

Mehatronics, embedded systems

Scientific communications skills

Multimedia technologies

Information and communication technologies

Biomedical engineering and informatics.

Metrology and quality assurance tecnologies

Doctoral programme
ELECTRICAL ENGINEERING

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Acoustics and Ultrasound 24
Intelligent mobile transport systems 24
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Protocols of Modern Telecommunication Networks 32
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Information Booklet
DOCTORAL PROGRAMME
ELECTRICAL ENGINEERING
on Faculty *of Electrical Engineering* University *of Ljubljana*

1. *General information*

Title/name of the study programme:	**Electrical Engineering**
Type of study programme:	**postgraduate doctoral study programme**
Level of the study programme:	**Level III**
Duration of the study programme:	**3 years (6 semesters)**
Number of ECTS credits:	**180**
Research discipline:	**engineering and technology**
Academic degree:	**Doctor of Science**
Abbreviation of the title:	**dr.** in front of the name

The duration of the postgraduate doctoral study programme of Electrical Engineering is three years, it comprises 180 ECTS credits and is, according to the Bologna scheme, a programme of the 3rd level of higher education. Study obligations are evaluated by the European Credit Transfer System (ECTS), which provides the basis for international exchange of students in countries using the same or a comparable credit system.

The study programme of Electrical Engineering inseparably connects the studies with scientific research and development work. The programme mainly focuses on independent creative research work of students, who are guided by their mentors.

The programme gives priority to optional choice over obligatory forms of studies. In order to adequately cover the increasingly ranified field of modern electrical engineering, the choice of study contents is wide and versatile. The possibility of choosing gives students the opportunity to plan their research careers and follow the needs of future employers as soon as possible. Furthermore, through obligatory seminars and integration of elective generic contents (transferable skills), we offer an appropriate breadth of education. The programme enables mobility in the framework of both organised forms of study and individual research work.

During the studies students are expected to actively participate at Slovenian and international scientific and specialist workshops and conferences. In this way students can develop the skills of scientific communication, critical assessment of the achievements of others and of the results of their own research work. The key obligations of students include the proposal and preparation of the doctoral dissertation. In the doctoral work, in addition to demonstrating their capacity for thinking in a scientific manner and their aptitude for research work, the candidates also give proof of original contributions to science, which are usually published in international scientific publications indexed by SCIE.

2. Aims of the programme and competences acquired

The main aim of the doctoral study programme of Electrical Engineering is to educate independent researchers with broad specialist skills and in-depth basic methodological knowledge.

General aims of the programme

- ✔ to inseparably link the studies with scientific research and development work,
- ✔ to develop a scientific approach and to master scientific thinking,
- ✔ to encourage comprehensive understanding of electrical engineering and its role in the broader scientific context,
- ✔ to encourage students to follow and master of state-of-the-art methods and technologies,
- ✔ to develop communication skills, skills of reporting on scientific research achievements and skills of transferring knowledge,
- ✔ to develop an objective and critical evaluation of achievements of others and of one's own results,
- ✔ to prepare doctoral degree holders for creative scientific research and development work in the field of electrical engineering and broader.

General competences acquired through the programme

- ✔ competence for individual creative scientific research and development work in the field of electrical engineering and broader,
- ✔ competence for following and accurately evaluating the latest achievements in the broader field of electrical engineering,
- ✔ critical evaluation of the results of one's own research and development work,
- ✔ competence for active professional written and oral communication,
- ✔ competence for team work with experts from various fields,
- ✔ professional, environmental and social responsibility.

Subject-specific competences acquired through the programme

- ✔ Deepening of fundamental knowledge in electrical engineering.
- ✔ To conduct independent creative scientific research and technology development, specifically in:
  - Electric energy, photovoltaic.
  - Electronics, microelectronics, optoelectronics, micro electromechanical systems, and nanostructures.
  - Mechatronics, embedded systems, intelligent, control systems, and robotics.
  - Metrology, and quality engineering.
  - Biomedical engineering and informatics.
  - Information, communication, and multimedia technologies.
- ✔ Supplementing the existing knowledge with knowledge from complementary fields and with general skills.

3. Structure of the programme and study guidelines

Structure of the programme

The duration of the doctoral study programme of Electrical Engineering is three years, it comprises 180 ECTS credits and is, according to the Bologna scheme, a programme of the 3rd level of higher education. The programme consists of organised forms of study and individual research work, both of which are evaluated with ECTS credits. The structure of the study programme is presented in Table I.

The first year focuses on organised studies in the form of lectures and seminars, the second and the third year of the programme are entirely devoted to research work and the preparation and presentation of the doctoral dissertation. One semester comprises 30 ECTS credits, one year 60 ECTS credits and the entire doctoral study programme 180 ECTS credits. Organised study comprises 60 ECTS credits; the other 120 ECTS credits are awarded to research work and the doctoral dissertation. An ECTS credit is evaluated with 25 hours of students' work. The total number of all study obligations thus equals 750 hours per semester, 1500 hours per year and the entire study programme amounts to 4500 hours of study obligations.

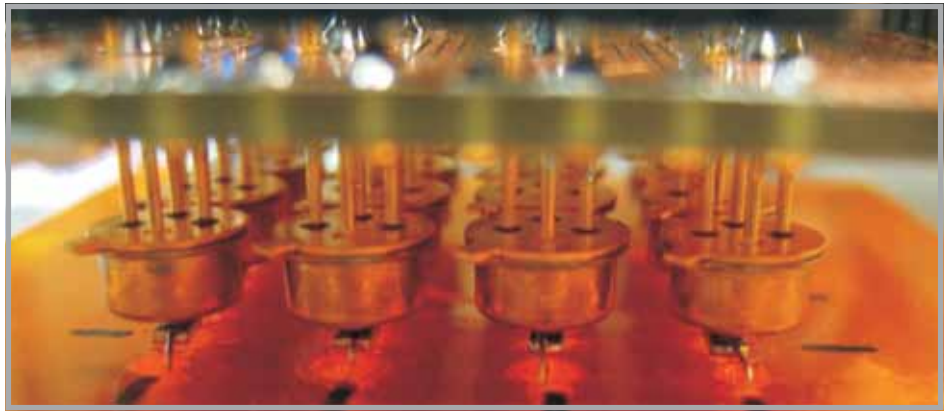


Table I.

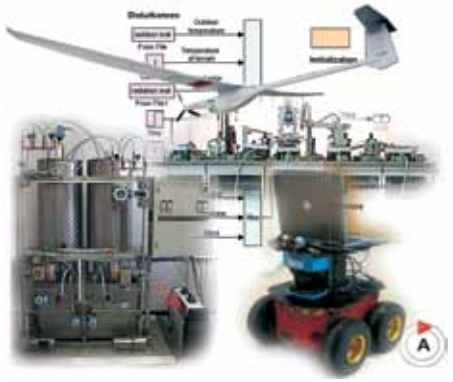
1st year: organised forms of studies 30 ECTS credits					
1st semester: organised studies 15 ECTS credits			2nd semester: organised studies 15 ECTS credits		
Course unit	Type	CR	Course unit	Type	CR
Subject A	E, S	5	Subject C	E, S,	5
Subject B	E, G, S, M	5	Subject D	E, S, M	5
Research work		15	Research work		15
Seminar (Report on research work)	S, O	5	Seminar (Report on preparation for the topic of the doctoral dissertation)	S, O	5
Total		30	Total		30

E: elective; S: specialist; G: generic; O: obligatory; M: mobility

2nd year: organised forms of studies 10 ECTS credits			
3rd semester	CR	4th semester: organised studies 10 ECTS credits	CR
Research work	30	Research work	20
		Subject of the doctoral dissertation	10
Total	30	Total	30

3rd year: organised forms of studies 20 ECTS credits			
5th semester	CR	6th semester: organised studies 20 ECTS credits	CR
Research work	30	Research work	10
		Doctoral dissertation	20
Total	30	Total	30

Study plan



Before enrolling in the programme, students choose a mentor, who advises them on the selection of subjects and guides them through the studies. Together with their mentor, students select four subjects. The seminars are obligatory for all students of the doctoral study programme of Electrical Engineering. The main component of the studies is independent research work for the doctoral dissertation.

Elective subjects

All subjects are elective. Students choose two to four subjects corresponding to 10 to 20 ECTS credits (1st and 2nd semester) among the offered specialist subjects (see Table II) according to the research field of their doctoral dissertation. All subjects are worth 5 ECTS credits.

Transferable skills

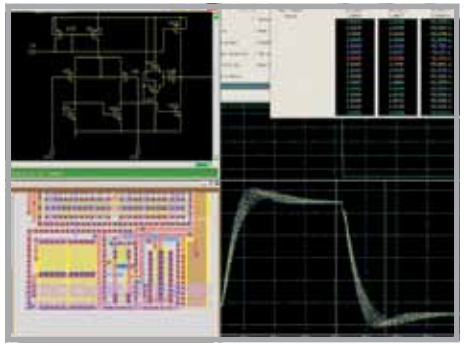
The Faculty of Electrical Engineering at the University of Ljubljana offers one elective subject of communication skills in a scientific work (marked with an asterisk in Table II), which is also included in the Generic subjects unit within the Doctoral school of the University of Ljubljana. Students can choose up to 5 ECTS credits worth of general contents or one general subject (1st semester).

Mobility

Together with their mentor, students can select up to 10 ECTS credits worth of study contents from other doctoral study programmes at the University of Ljubljana and from comparable programmes of other universities (1st and 2nd semester). Students can attend two semesters at another university (up to 60 ECTS credits), so that they can complete one third of their study obligations elsewhere.

Seminars

The seminars (1st and 2nd semester) are compulsory for all doctoral students of Electrical Engineering and are worth 5 ECTS credits each. Seminars are conducted by mentors. Students present the results of their work in written and oral form. Seminars require attendance at presentations by other students and participation in discussions. This ensures the extension of studies beyond the field of the doctoral dissertation as well as interaction between doctoral students.



In the first semester students prepare an overview of the field of their research work. In the second semester, doctoral students report on the pre-preparation of the subject of their dissertation. This ensures an additional time check and a timely approach to dissertation planning.

Research work for the doctoral dissertation

Research work is devoted to the preparation and completion of the doctoral dissertation. It is evaluated with 120 ECTS credits. This includes individual scientific research work directed by the mentor. Research work requires active participation at Slovenian and international scientific and specialist meetings.

Doctoral dissertation proposal

By the end of the 4th semester, students should prepare the proposal of the subject of their doctoral dissertation, which includes an appropriate breakdown of the subject, its incorporation into the field of the research work, an indication of the expected contribution to science, which should be methodologically supported with initial results. Students present the subject of their dissertation in public. The preparation and presentation of the doctoral dissertation are evaluated with 10 ECTS credits.

Doctoral dissertation

As a rule, students complete and publicly present their doctoral dissertation – which together comprises 20 ECTS credits – by the end of the 6th semester. In the doctoral work, in addition to demonstrating their capacity for thinking in a scientific manner and their aptitude for research work, the candidates also give proof of original contributions to science, which are usually published in international scientific publications indexed by SCIE.

The doctoral dissertation is an original contribution to science, which is prepared in accordance with the provisions of the Statute of the University of Ljubljana and the Rules on doctoral studies.

Mentorship

The mentor for preparation of the doctoral dissertation is a person with a corresponding academic title (Assistant Professor, Associate Professor, Professor) or a scientific worker with attested research activity and corresponding bibliography from the field of the doctoral dissertation.

Students choose their mentor at their discretion before or upon enrolment. The responsibility of the mentor is guiding the student through the studies (selection of subjects, seminars, proposal and composition of the doctoral dissertation and ensuring working conditions for the work with research equipment, typically in the mentor's lab.

Students can choose a different mentor by the beginning of the 3rd semester. In this case the student should inform their earlier mentor and the Vice Dean for research and development activities in writing about the change, for which the new mentor must give his or her consent. After the beginning of the 3rd semester the potential change of mentor is discussed by the Commission for scientific research on the basis of a well-founded request of the student.

Co-mentorship is recommended in the case of interdisciplinary or multi-institutional researches. Co-mentorship is deliberated by the Commission for scientific research.

List of elective subjects, course unit codes and semesters

Table II.

K1. Department of Fundamentals of Electrical Engineering, Mathematics and Physics

	Course coordinator	Lecturers	Course Title	ECTS
01	Dolinar Gregor	Prof. dr. Gregor Dolinar	Selected topics in Mathematics	5
02	Gyergyek Tomaž	Izr. prof. dr. Tomaž Gyergyek Prof. dr. Milan Čerček	Electrical properties of plasmas and introduction to controlled fusion	5
03	Iglič Aleš	Prof. dr. Aleš Iglič Prof. dr. Veronika Kralj - Iglič	Electrostatics of Surfaces and Nanostructures	5
04	Sinigoj Anton	Izr. prof. dr. Anton Sinigoj Prof. dr. Tomaž Slivnik	Elektromagnetics	5
05	Slivnik Tomaž	Prof. dr. Tomaž Slivnik	Computational elektromagnetics	5

K 2. Department of Power Systems and Devices

	Course coordinator	Lecturers	Course Title	ECTS
06	Bizjak Grega	Izr. prof. dr. Grega Bizjak	Simulations and measurements in Lighting Engineering	5
07	Mihalič Rafael	Prof. dr. Rafael Mihalič Prof. dr. Dušan Povh	Energy Conversions and Environment	5
08	Pantoš Miloš	Izr. prof. dr. Miloš Pantoš Izr. prof. dr. Andrej Gubina	Power System Operation in Market Environment	5
09	Papič Igor	Prof. dr. Igor Papič	Active distribution networks	5
10	Čepin Marko	Izr. prof. dr. Marko Čepin	Reliability in Power Engineering	5

K 3. Department of Electronics

	Course coordinator	Lecturers	Course Title	ECTS
11	Amon Slavko	Prof. dr. Slavko Amon	Sensors and Actuators	5
12	Topič Marko	Prof. dr. Marko Topič Izr. prof. dr. Janez Krč Prof. dr. Franc Smole Prof. dr. Miro Zeman	Photovoltaics	5
13	Smole Franc	Prof. dr. Franc Smole Prof. dr. Marko Topič Doc. dr. Marko Jankovec	Nanoelectronics	5
14	Krč Janez	Izr. prof. dr. Janez Krč Prof. dr. Marko Topič Prof. dr. Franc Smole	Optoelectronics	5
15	Tuma Tadej	Prof. dr. Tadej Tuma Izr. prof. dr. Arpad Buermen	Optimization in Electronic Design Automation	5
16	Žemva Andrej	Prof. dr. Andrej Žemva Izr. prof. dr. Andrej Trost	Digital electronic systems design	5

K 4. Department of Measurement Systems

	Course coordinator	Lecturers	Course Title	ECTS
17	Agrež Dušan	Izr. prof. dr. Dušan Agrež	Measurement dynamics and disturbances in the measurement setup	5
18	Batagelj Valentin	Doc. dr. Valentin Batagelj	Virtual measurement instruments	5
19	Bojkovski Jovan	Izr. prof. dr. Jovan Bojkovski	Quality and fundamentals of software engineering	5
20	Drnovšek Janko	Prof. dr. Janko Drnovšek	Metrology and Quality Systems	5
21	Fefer Dušan	Prof. dr. Dušan Fefer	Acoustics and Ultrasound	5
22	Kamnik Roman	Izr. prof. dr. Roman Kamnik Prof. dr. Ken Hunt	Intelligent mobile transport systems	5
23	Mihelj Matjaž	Izr. prof. dr. Matjaž Mihelj Prof. dr. Robert Riener	Multimodal interactive 3D technologies	5
24	Munih Marko	Prof. dr. Marko Munih Prof. dr. Tadej Bajd Prof. dr. Jadran Lenačič Prof. eng. Vincenzo Parenti	Selected topics in robotics	5
25	Pušnik Igor	Izr. prof. dr. Igor Pušnik	Quality of medical instrumentation	5

K 5. Department of Microelectronics

	Course coordinator	Lecturers	Course Title	ECTS
26	Pleteršek Anton	Izr. prof. dr. Anton Pleteršek Prof. dr. Janez Trontelj	Integrated Microsystems SoC and analog-digital integrated circuits	5
27	Strle Drago	Izr. prof. dr. Drago Strle Izr. prof. dr. Anton Pleteršek	Advanced microelectronics systems: selected topics	5

K 6. Department of Mechatronics

	Course coordinator	Lecturers	Course Title	ECTS
28	Fišer Rastko	Izr. prof. dr. Rastko Fišer Prof. dr. Vanja Ambrožič	Electrical servo drives in mechatronics	5
29	Miljavec Damijan	Izr. prof. dr. Damijan Miljavec	Modern electric machines	5
30	Nastran Janez	Prof. dr. Janez Nastran Doc. dr. Peter Zajec Izr. prof. dr. David Nedeljković Prof. dr. Danijel Vončina	Power Electronics Converters	5
31	Vončina Danijel	Prof. dr. Danijel Vončina Doc. dr. Peter Zajec	Control of Electronically Commutated Motors	5

K 7. Department of Systems, Control and Cybernetics

	Course coordinator	Lecturers	Course Title	ECTS
32	Atanasijević-Kunc Maja	Izr. prof. dr. Maja Atanasijević-Kunc Izr. prof. dr. Gašper Mušič Izr. prof. dr. Sašo Blažič	Selected Topics of Complex Systems Control Design	5
33	Belič Aleš	Izr. prof. dr. Aleš Belič Doc. dr. Iztok Grabnar Prof. dr. Damjana Rozman	Modelling Identification and Simulation of Biological systems	5
34	Perš Janez	Doc. dr. Janez Perš Doc. dr. Matej Kristan	Machine vision	5
35	Matko Drago	Prof. dr. Drago Matko Izr. prof. dr. Sašo Blažič Doc. dr. Gregor Klančar	Advanced control of autonomous systems	5
36	Mihelič France	Prof. dr. France Mihelič	Stochastic Processes and Signals	5
37	Mušič Gašper	Izr. prof. dr. Gašper Mušič Prof. dr. Felix Breitenecker	Industrial informatics	5
38	Pavešić Nikola	Prof. dr. Nikola Pavešić	Pattern recognition	5
39	Škrjanc Igor	Prof. dr. Igor Škrjanc	Intelligent control in modern systems	5
40	Zupančič Borut	Prof. dr. Borut Zupančič Prof. dr. Felix Breitenecker Izr. prof. dr. Aleš Belič	Object Oriented Modelling	5

K 8. Department of Telecommunications

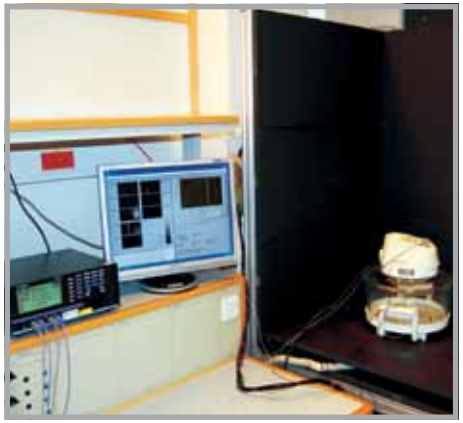
	Course coordinator	Lecturers	Course Title	ECTS
41	Bešter Janez	Prof. dr. Janez Bešter	Convergent communications***	5
42	Hercog Drago	Izr. prof. dr. Drago Hercog	Protocols of Modern Telecommunication Networks	5
43	Humar Iztok	Doc. dr. Iztok Humar Prof. dr. Marko Jagodič Prof. dr. Janez Bešter	Telecommunication systems engineering	5
44	Kos Andrej	Izr. prof. dr. Andrej Kos	Broadband Communications Systems	5
45	Košir Andrej	Izr. prof. dr. Andrej Košir	Operations research in telecommunications	5
46	Pogačnik Matevž	Doc. dr. Matevž Pogačnik	Multimedia content and interactive tech-nologies	5
47	Tasič Jurij	Prof. dr. Jurij Tasič Doc. dr. Matej Zajc	Digital signal, image and video processing	5
48	Tomažič Sašo	Prof. dr. Sašo Tomažič	Contemporary Coding and Modulation Methods	5
49	Vidmar Matjaž	Prof. dr. Matjaž Vidmar Prof. dr. Jožko Budin	Radio communications	5
50	Zajc Matej	Doc. dr. Matej Zajc Prof. dr. Jurij Tasič	Multimedia systems: algorithems and architectures	5

K 9. Department of Biomedical Engineering

	Course coordinator	Lecturers	Course Title	ECTS
51	Likar Boštjan	Prof. dr. Boštjan Likar Prof. dr. Franjo Pernuš	Imaging Technologies	5
52	Miklavčič Damjan	Prof. dr. Damjan Miklavčič Doc. dr. Franc Gider Doc. dr. Jana Kolar	Communication in Reasearch and Development***	5
53	Pernuš Franjo	Prof. dr. Franjo Pernuš Prof. dr. Boštjan Likar	Biomedical Image Analysis	5

***: *generic skills*

4. Admission requirements and enrolment criteria



Enrolment criteria

The following candidates can enrol in the postgraduate doctoral studies of Electrical Engineering:

- ✔ graduates of postgraduate master study programmes;
- ✔ graduates of study programmes providing education for occupations regulated by Directives of the European Union evaluated with at least 300 ECTS credits;
- ✔ graduates of university study programmes established before 11. 6. 2004;
- ✔ graduates of postgraduate study programmes for obtaining a Master's degree established prior to the Bologna reform. The fulfilled study obligations of these candidates are recognised to the extent of 90 ECTS credits;
- ✔ graduates of specialist study programmes after university programmes, established before 11. 6. 2004. The fulfilled study obligations of these candidates are recognised to the extent of 60 ECTS credits;
- ✔ graduates of specialist study programmes after the higher education, established before 11. 6. 2004. Additional study obligations, four compulsory courses and two elective courses of the first year postgraduate study programme in Electrical engineering amounting to 36 ECTS credits, are determined by the commision nominated by the Faculty of Electrical Engineering;
- ✔ graduates of equivalent study programmes at other universities. The equivalence of the obtained education abroad is determined in the process of recognition of education abroad for the continuation of education, in accordance with Article 121 of the Statute of the University of Ljubljana.

Selection criteria when enrolment is restricted

The selection of candidates will be based on the success in postgraduate master studies as follows:

Grade point average in postgraduate master studies, or grade point average of university study programmes established before 11. 6. 2004, excluding thesis and defence assessment.	grade x 7
Master thesis and its defence assessment, or university diploma thesis and its defence assessment established before 11. 6. 2004.	grade x 3

In case of restricted enrolment the candidates with more points will be accepted.
The maximal number of accepted students is 100.

Criteria for recognising knowledge and skills acquired before enrolment in the programme

Knowledge and skills acquired by formal, informal or empirical learning will be recognized in case of restricted enrolment in accordance with Article 9 of the Criteria on accreditation of study programmes. The body deciding on recognition of knowledge and skills acquired before enrolment in the programme is the Commission for scientific research of the Faculty of Electrical Engineering. The factors taken into account when deciding on the recognition of such knowledge and skills are: specialization, another degree at a higher education institution, the existing scientific research work, published scientific works, professional training.

Methods of assessment

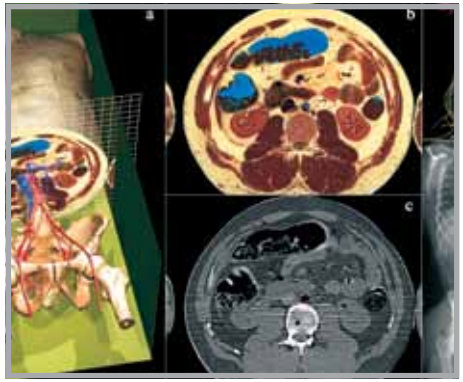
In accordance with Article 132 of the Statute of the University of Ljubljana the performance at examinations is assessed with grades from 1 to 10, positive grades being 6 – 10. Details about the assessment of knowledge are regulated by the Examination rules of the Faculty of Electrical Engineering at the University of Ljubljana.

The programme includes written and oral exams and the assessment of the preparation and presentation of a seminar. Methods of assessment are described in detail under individual course syllabi.

Candidates receive the proposed number of ECTS credits for a course if they perform successfully at the required knowledge assessment for that particular course.

Requirements for progression through the programme

- ✔ Requirements for progression to the 2nd year of the doctoral studies are the completed study requirements worth a total of at least 45 ECTS credits.
- ✔ For progression to the 3rd year of the postgraduate doctoral studies students must have completed all study obligations of organised forms of studies from the first two years of their studies.
- ✔ The last, third year is intended for research work and the preparation and defence of the doctoral dissertation.



Provisions on changing programmes

Termination of the student's education in the study programme in which he/she enrolled and the continuation of the studies in the doctoral study programme of Electrical Engineering is regarded as transfer between programmes. Students' applications for transfer to the doctoral study of Electrical Engineering will be – in accordance with Articles 181-189 of the Statute of the University of Ljubljana – separately dealt with by the Commission for scientific research of the Faculty of Electrical Engineering.

Requirements for completion of the programme

Requirements for completion of the study programme and for acquisition of the academic title of Doctor of Science are: successfully completed all study obligations determined by the programme and the successfully defended doctoral dissertation, which together is worth 180 ECTS credits. Candidates for the doctoral degree should also have at least one published scientific article in a magazine indexed by SCIE, the candidate being the first author. The scientific article should be published or accepted for publication prior to submission of the dissertation for assessment.

Requirements for completion of individual parts of the programme

Completing individual parts of the programme is not possible.

Indication of professional or academic qualification

Students completing the postgraduate doctoral study programme of Electrical Engineering obtain the academic title of Doctor of Science.

List of lecturers

Table III.

	Lecturet	Title
1	Agrež Dušan	IP
2	Ambrožič Vanja	RP
3	Amon Slavko	RP
4	Atanasijević Kunc Maja	IP
5	Bajd Tadej	RP
6	Batagelj Valentin	DOC
7	Belič Aleš	IP
8	Bešter Janez	RP
9	Bizjak Grega	IP
10	Blažič Sašo	IP
11	Bojkovski Jovan	IP
12	Budin Jožko	RP
13	Buermen Arpad	IP
14	Čepin Marko	IP
15	Dolinar Gregor	RP
16	Drnovšek Janko	RP
17	Fefer Dušan	RP
18	Fišer Rastko	IP
19	Gubina Andrej	IP
20	Gyergyek Tomaž	IP
21	Hercog Drago	IP
22	Humar Iztok	DOC
23	Iglič Aleš	RP
24	Jankovec Marko	DOC
25	Kamnik Roman	IP
26	Klančar Gregor	DOC
27	Kos Andrej	IP
28	Košir Andrej	IP
29	Krč Janez	IP
30	Kristan Matej	DOC
31	Likar Boštjan	RP
32	Matko Drago	RP
33	Mihalič Rafael	RP
34	Mihelič France	RP
35	Mihelj Matjaž	IP
36	Miklavčič Damijan	RP
37	Miljavec Damijan	IP
38	Munih Marko	RP
39	Mušič Gašper	IP
40	Nastran Janez	RP
41	Nedeljković David	IP
42	Pantoš Miloš	IP
43	Papič Igor	RP
44	Pavešič Nikola	RP
45	Pernuš Franjo	RP
46	Perš Janez	DOC
47	Pleteršek Anton	IP
48	Pogačnik Matevž	DOC
49	Povh Dušan	RP
50	Pušnik Igor	IP
51	Sinigoj Anton R.	IP
52	Slivnik Tomaž	RP
53	Smole Franc	RP
54	Strle Drago	IP
55	Škrjanc Igor	RP
56	Tasič Jurij	RP
57	Tomažič Sašo	RP
58	Topič Marko	RP
59	Trontelj Janez	RP
60	Trost Andrej	IP
61	Tuma Tadej	RP
62	Vidmar Matjaž	RP
63	Vončina Danijel	RP
64	Zajc Matej	DOC
65	Zajec Peter	DOC
66	Zupančič Borut	RP
67	Žemva Andrej	RP

	Adjunct lecturers	
1	Čerček Milan	RP
2	Gider Franc	DOC
3	Grabnar Iztok	DOC
4	Kolar Jana	DOC
5	Kralj-Iglič Veronika	IP
6	Lenarčič Jadran	RP
7	Rozman Damjana	RP

	Lecturers from abroad	
1	Breitenecker Felix	Professor
2	Hunt Ken	Professor
3	Parenti Vincenzo	Professor
4	Riener Robert	Professor
5	Zeman Miro	Professor

5. Short presentation of subjects

Subject
Description
Literature

01 Selected topics in Mathematics

Functional analysis:
- metric spaces (notion of distance, basic properties of matric spaces, examples of different metrics on vector spaces and on functional spaces)
- normed vector spaces (notion of norm, relations between norms and metrics)
- spaces with scalar product (Hilbert space)
- bounded linear operators, matrices (contraction mapping principle and fixed point, spectral theory, eigenvalues and eigenvectors)
- wavelets

Discrete mathematics:
- graphs (notion of graphs and applications, flow and duality, planar graphs)
- Boolean algebras (signals and digital circuits)
- cryptography (basic principles of encryption)

Numerical solution of partial differential equations by the finite element method
- variational (weak) formulation of the problem (appropriate function spaces, equivalence of shapes)
- discretization (triangulation, choosing a basis, small support of the basis, description of the problem in the matrix form)
- numerical solving (choice of the method, convergence, stability)

[1] M. Pedersen, Functional Analysis in Applied Mathematics and Engineering, Chapman & Hall/CRC, 1999.
[2] G. Tomšič, Osnovni pojmi funkcionalne analize. 3rd corrected edition Ljubljana: Fakulteta za elektrotehniko, 2004.
[3] R. Diestel, Graph Theory, Springer-Verlag, GTM 173, 3rd edition, 2005.
[4] J. H. Van Lint in R. M. Wilson, A Course in Combinatorics, Cambridge University Press, 2nd edition, 2001.
[5] P.G. Ciarlet, Handbook of numerical analysis: Finite elements methods, North-Holland, Amsterdam, 1991.
[6] J. Jianming, The Finite Element Method in Electromagnetics, Wiley-IEEE Press, 2002.

02 Electrical properties of plasmas and introduction to controlled fusion

- Definitions of the Debye length, plasma parameter, plasma frequency.
- Motion of a charged particle in electric and magnetic field.
- Diffusion in a plasma and plasma conductivity.
- Kinetic and hydrodynamic description of a plasma.
- Basic equations of MHD and some fusion oriented examples.
- Plasma waves.
- Particle interactions in plasmas (collisions).
- Introduction to fusion, fusion reactions, inertial and magnetic plasma confinement, tokamaks and stellarators
- Nonlinear phenomena: plasma sheaths, plasma-wall interaction, plasma diagnostics with Langmuir and emissive probes.
- Introduction to particle-in-cell computer simulation of bounded plasma systems.

[1] F. F. Chen, *Introduction to plasma physics and controlled fusion*, 2nd Edition, vol. 1, Plenum Press, New York, (1984).
[2] J. A. Bittencourt, Fundamentals of Plasma Physics, 3rd edition, Springer, 2004.
[3] J. Wesson, *Tokamaks*, 3. Edition, Oxford University Press, (2003)
[4] A. A. Harms, K. F. Schoepf, G. H. Miley, D. R. Kingdon, Principles of Fusion Energy, An Introduction to Fusion Energy for Students of Science and Engineering, World Scientific, (2005)
[5] P. C. Stangeby, *The plasma boundary of magnetic fusion devices*, Institute of Physics Publishing, Bristol and Philadelphia, (2000)
[6] C. K. Birdsall, A. B. Langdon, *Plasma Physics via computer simulation, Institute of Physics Publishing*, Bristol and Philadelphia, (1991)

03 Electrostatics of Surfaces and Nanostructures

Basis of statistical thermodynamics, self-assembly of membrane nanostructures, theory of electric double layer (charged surface in contact with electrolyte solution), membrane electrostatics, colloidal dispersions, interactions between like-charged surfaces mediated by charged nanoparticles, adsorption of charged nanoparticles to a charged substrate, experimental methods.

[1] HJ Butt, K Graf, M Kappl, Physics abd Chemistry of Interfaces, WILEY-VCH Verlag GmbH&Co.KgaA, Weinheim, 2003.
[2] A. Iglič, V. Kralj-Iglič: Izbrana poglavja iz fizike mehke snovi, Založba FE in FRI, Ljubljana, 2006
[3] K. Bohinc, T. Slivnik, A. Iglič, V. Kralj-Iglič: Membrane electrostatics – a statistical mechanical approach to the functional density theory of electric double layer, v: Advances in Planar lipid Bilayers and Liposomes, vol. 8, 2008 (textbook in preparation)
[4] V. Kralj-Iglič, Bohinc K., A. Iglič: Attractive interaction between like-charged surfaces, v: Advances in Planar lipid Bilayers and Liposomes, vol. 10, 2009 (textbook in preparation)
[5] A. Iglič, V. Kralj-Iglič: Stabilization of hydrophilic pores in charged lipid bilayers by anisotropic membrane inclusions, v: Advances in Planar lipid Bilayers and Liposomes, vol. 6, chap.1, pp 1-26, 2008.

04 Electromagnetics

Theory of electromagnetic field: Maxwell's and associated equations, boundary conditions, Poynting's theorem, uniqueness theorem, symmetry of Maxwell's equations, reciprocity, equivalent sources, Helmholtz equations, potentials, potential of single and double layer source distributions, Green's formulae, classification of electromagnetic fields. Mathematical formulations of electromagnetic problems: differential equations, integral equations and variational principles. Some cases of electromagnetic fields: electrostatic, current field, magnetostatic, quasi-static fields, dynamic fields and waveguide structures.

[1] T. L. Chow: Introduction to Electromagnetic Theory, Jones and Bartlett, Boston, 2006
[2] A. R. Sinigoj: ELMG polje, Založba FE, Ljubljana, 1996.
[3] J. A. Stratton: Electromagnetic theory, McGraw-Hill, New York, 1941.
[4] P. P. Silvester, R. L. Ferrari: Finite elements for electrical engineers, University Press, Cambridge, 1996.
[5] P. K. Kythe: Introduction to boundary element methods, CRC Press, New Orleans, 1995.
[6] D. B. Davidson: Computational electromagnetics for RF and microwave engineering, Univ. Press, Cambridge, 2005.

05 Computational electromagnetics

Fundamental equations of electromagnetic field (Maxwell equations in different forms, boundary conditions, conditions at infinity, singularities in the field). Formulations of electromagnetic field problems. Numerical methods for electromagnetic field problems (finite differences, finite elements, boundary elements, multipole methods, other methods). Solutions of discretizate problems (decomposition methods, method of conjugate gradients, iteration methods, eigenvalue problems). The most recent methods.

[1] Jean Van Bladel: Electomagnetic Fields, 2nd ed, IEEE Press, 2007
[2] Jianming Jin: The Finite Element Method, 2nd ed, Wiley Interscience, 2002
[3] A.Taflove: Computational Electrodynamics: The Finite-Difference Time-Domain Method, 3rd ed,Artech House, 2005
[4] Nail A.Gumerov, Ramani Duraiswani, Fast Multipole Methods for the Helmholtz Equation in Three Dimensions, Elsevier, 2005

06 Simulations and measurements in Lighting Engineering

Physical nature of light and phenomena connected with propagation of light. Photometry and Radiometry. Natural and artificial light sources. Basic recommendations and norms for lighting installations. Basics of lighting installation planning. Analytical determination of available daylight. Use of software tools for calculations and simulations of daylight and artificial lighting in interior, for qualitative and quantitative evaluation of light propagation in interiors and for calculation of luminance, glare and contrast. Combined use of daylight and artificial light. Lighting control for better working environment and better economy of lighting with less energy consumption. Radiometrical and photometrical instruments and measurement procedures. Realization of photometrical measurements with adequate accuracy.

[1] več avtorjev: IESNA Lighting Handbook, Ilumination Engineering Society, USA, 2000
[2] Joseph B. Murdoch: Illuminating Engineering, Vision Communications, 2003
[3] Arne Valberg: Light vision color, Wiley, 2005
[4] Gregg D. Ander: Daylighting: performance and design, Wiley 2003
[5] Casimer DeCusatis: Handbook of Applied Photometry, AIP Press, 1997

07 Energy Conversions and Environment

The role of energy-sources exploitation in the development of human civilisation and society. A global view of the problems of energy supply, and the factors influencing energy-consumption needs. The basic physical laws of energy conversion and the technologies for primary energy-sources exploitation (trends in development). The environmental and social acceptability of energy-conversion technologies. Dilemmas and the technical problems of covering energy needs, applying renewable energy sources, and a comparison with classical technologies. The environmental impact of energy conversions - facts or fashion trends. The rational use of energy vs. "saving regardless of costs". Strategic trends and regulations in the EU in the field of energy supply. Economic assessment of meeting energy needs (economic assessment of various solutions and energy-saving measures). Looking to the future.

[1] Sørensen, Bent: Renewable energy conversion, transmission, and storage, Amsterdam [etc.] : Elsevier/Academic Press, cop. 2007
[2] Twidell, John, Weir, Anthony D.: Renewable energy resources, London, New York : Taylor & Francis, 2006
[3] Boyle, Godfrey, Everett, Bob, Ramage, Janet: Energy systems and sustainability, Oxford University Press, Milton
[4] Dirk Naxeiner, Michael Miersch: Lexikon der oko Irrtumer, EICHBORN GmbH&co., Verlag kG, Frankfurt an Main, June 1998
[5] Požar. H.:Osnove energetike I, II, III, Školska knjiga, Zagreb, 1992

08 Power System Operation in Market Environment

Impact of electric energy on power system operation: role of producers, role of consumers and their demands, role and limitations of transmission and distribution systems, new methods for static and sensitivity analyses, optimal power flow calculation for different criteria. Ancillary service management: load forecast, power system reserve forecast, active power and frequency regulation, reactive power and voltage regulation. Reliability concepts in power systems: reliability and availability, adequacy of power sources and network, reliability indices for energy delivery. Probability concepts in power system operation.

[1] Gubina F., Delovanje elektroenergetskega sistema, Založba ULFE, 2006
[2] Wood, A.J., Power generation, operation and control, Wiley, 1996.
[3] Kundur, P., Power System Stability and Control, Mc Graw Hill, 1994
[4] Ilić, M., Galiana, F., Fink, L., Power System Restructuring Engineering and Economics, Kluwer Academic Publishers, 1998.
[5] Kirschen D., Strbac G.: Power System Economics: Introduction; Wiley, 2000.

09 Active distribution networks

Consequences of growing environmental concern, general lack of energy resources in western Europe, availability of new technologies for production of electrical energy, penetration of distributed energy resources - DER in distribution networks.
Gradual transition of classical passive distribution network into an active network with resources on the consumption side, specification of the concept of an active distribution network. Overview of distributed energy resources, interconnection requirements and assessment of potential in Slovenia. The influence of distributed energy resources on the operation of a distribution network: voltage profile, power flows, reactive power, power quality, protection, control, maintenance and planning.
Key technologies enabling the operation of an active distribution network: energy resources with control capabilities, energy storage systems, modern compensation devices, advanced information and communication technologies.

[1] N. Jenkins, R. Allan, P. Crossley, D. Kirschen, G. Strbac: 'Embedded generation', IEE, London, UK, 2000.
[2] SOLID-DER project: 'Coordinated Action to consolidate RTD activities for large-scale integration of DER into European electricity market', EC 6th FP, http://www.solid-der.org.
[3] MICROGRIDS project: 'Large scale integration of micro-generation to low voltage grids', EC 5th FP, http://microgrids.power.ece.ntua.gr/.
[4] DISPOWER project: 'Distributed Generation with High Penetration of Renewable Energy Sources', EC 5th FP, http://www.dispower.org/.
[5] DGFACTS project: 'Improvement of the quality of supply in distributed generation networks through the integrated application of power electronics', EC 5th FP, http://dgfacts.labein.es/dgfacts/index.jsp.

10 Reliability in Power Engineering

Basic principles of reliability, safety, risk and their mutual relations. Set theory, basic probability theory and Boolean algebra.
Measures of reliability on component and system level, measures of the safety on the plant level. Risk criteria. Risk-informed decision-making principle.
Methods for assessment and improvement of reliability and safety: theory and examples: fault tree analysis, event tree analysis, failure modes and effects analysis. Common cause failures - methods and examples.
Databases and probabilistic models.
Improvement of reliability of power systems: redundancy, independence, separation, diversity, fail-safe principle and single failure criterion.
Improvement of safety culture in power engineering, organisation and management of systems.
Optimisation methods (genetic algorithms, simulated annealing) and their application in power systems for production, transmission and distribution of electrical energy.

[1] Allan R. N., Billinton R.; Reliability Evaluation of Power Systems, Springer, 1996.
[2] Kumamoto H., Henley E. J.; Probabilistic Risk Assessment and management for Engineers and scientists, IEEE press, 2002.
[3] Grid Reliability and the Impact on Plant Risk and the Operability of Offsite Power, Generic Letter 2006-02, US NRC, Washington, 2006.
[4] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/gen-letters/2006/gl200602.pdf

11 Sensors and Actuators

- Basic definitions, transduction principles, classifications of sensors and actuators.
- Basic sensor properties: characteristics, sensitivity, accuracy, resolution, selectivity, minimal detected signal, treshold, nonlinearity, repeatability, noise, temperature zero drift, overload, stability etc. Analysis of sensor dynamic response.
- Review of standard silicon microelectronic technologies. Review of micromachining: basic materials properties, deposition, etching, LIGA, sacrified film, laser application, opening sealing, substrate bonding, sensor chip encapsulation/packaging, 3D structures fabrication.
- Analog signal conditioning: sensor systems, basic circuits, opamps, basic circuits with opamps, instrumentation amplifier, summing amplifier, sources (current, voltage, band gap references), filters, comparators and Schmitt triggers, analog converters (current/voltage/charge/frequency) etc.
- Digital signal conditioning: basic building blocks, signal discretisation, sample&hold circuits, DAC (uni/bipolar, resolution, weighted and R-2R ladder, current-switched), ADC (uni/bipolar, resolution, parallel-feedback, successive approximations, ramp, delta-sigma, switched capacitors, flesh, speed of conversion) etc.
- Review of sensor and actuator structures and applications: Piezoresistive sensors. Piezoelectric sensors. Pyroelectric sensors. Capacitive sensors. Resonant sensors. Thermoelectric sensors. Radiation sensors. Magnetic sensors. Chemical sensors. Optical fiber sensors, etc.
- New advanced sensor and actuator structures.

[1] Senzorji in aktuatorji, S. Amon, skripta (on web, textbook in preparation).
[2] S.E.Lyshevsky, Nano- and Micro- Electromechanical Systems, CRC Press, 2005.
[3] J. Fraden, Handbook of Modern Sensors, AIP Press, 1997.
[4] P. Horowitz, W. Hill, The Art of Electronics, Cambridge University Press, 1997.

12 Photovoltaics

Solar cells: principle of operation, materials, technologies, properties and advanced concepts of the solar cells based on crystalline silicon (Si), thin-film solar cells (Si, CIS, CdTe), dye-sensitized and organic solar cells, tandem and multi-junction solar cells, thermophotovoltaics; analysis of optical and electrical losses, modelling, simulations and characterisation; 3rd generation solar cells.
Photovoltaic modules: properties, technological trends and standards for crystalline silicon, thin-film and concentrator PV modules. Efficiencies, loss analysis and energy yield. Modelling, simulations and characterisation.
Photovoltaic systems: grid-connected and off-grid systems, design, building and maintenance; power regulators and converters, protection devices, connection to the grid, economy of PV systems.

[1] A. Luque, S. Fonash: Handbook of Photovoltaic Science and Engineering, Wiley, 2003.
[2] Roth W., Brecl K., Krč J., Likovič A., Nemac F., Opara Krašovec U., Smole F., Škarja G., Topič M., Vukadinović M: Soltrain: Izkoriščanje sončne energije za proizvodnjo električne energije s pomočjo fotonapetostnih sistemov, slovenski priročnik, Ljubljana, Fakulteta za elektrotehniko, 2004.
[3] M.A.Green: Third Generation Photovoltaics: Advanced Solar Energy Conversion, Springer, 2005.
[4] A. Martí and A. Luque (Eds): Next Generation Photovoltaics: High Efficiency through Full Spectrum Utilization, Wiley, 2003.
[5] A. Luque and Viacheslav M. Andreev: Concentrator Photovoltaics. Springer, 2007.

13 Nanoelectronics

Definition of nanoelectronics and nanotechnology. The prospects of nanoscience. Classical and quantum particles and waves. Free and confined electrons. Coulomb blockade. Quantum dots, quantum wells and quantum wires. Tunneling, tunnel junctions and applications of tunneling. The top-down approach. The bottom-up approach. Device scaling and nonideal effects. Electronic devices based on quantum heterostructures and superlattices. Single-electron transistor. Growth, fabrication, and measurement techniques for nanostructures. Manipulation and assembly. Self-assembly. Molecular nanoelectronics. Computer architectures based on molecular electronics. Switches and complex molecular devices. Nanoelectronic circuit architectures. Electromagnetic, optical and electronic properties of nanostructures. Transport properties of semiconductor nanostructures. Ballistic transport. Nanomagnetics and spintronics. Nanophotonics. Polymer electronics. Organic active and passive devices and circuits. Carbon nanotubes and nanowires. Structure and properties of carbon nanotubes. Electronic, optoelectronic, magnetic, chemical and thermoelectrical properties of carbon nanotubes. Electronic devices and circuits based on nanotubes. Chemical and biological nanosensors. Nano- and micromachines. Modeling and simulation of quantum- and nanosystems.

[1] William A. Goddard, Donald W. Brenner, Sergey Edward Lyshevski, Gerald J. Iafrate, Nanoscience, Engineering, and Technology, CRC Press LLC, 2003.
[2] Paul Harrison, Quantum Wells, Wires and Dots, Theoretical and Computational Physics of Semiconductor Nanostructures, John Wiley & Sons, Ltd, 2005.
[3] Edward L. Wolf, Nanophysics and Nanotechnology, Wiley-VCH Verlag GmbH & Co. KGaA, 2004.
[4] M. Meyyappan, Carbon Nanotubes, Science and Applications, CRC Press LLC, 2005.
[5] George W. Hanson, Fundamentals of Nanoelectronics, Pearson Prentice Hall, 2008.

14 Optoelectronics

Advanced materials in optoelectronics: heteroatomous, thin-film inorganic and organic semiconductor materials. Characterisation and properties of optoelectronic materials.
Light sources: classification of broad-band, narrow-band and spectrally selective light sources; thermal sources (black and grey body), gas lamps and flashes; electroluminescent sources; vacuum fluorescent sources; plasma sources; light emitting diodes, laser diodes; lasers. Displays: plasma, liquid crystal, laser, holographic.
Detection of optical signals: thermal and photonic detectors, static and dynamic characteristics and performances of fotodetectors, read-out analog and digital electronics for detector arrays. Noise of detectors and circuits. Color detectors: metameric error, configurations of color detectors and Moire effect, color detector arrays. CCD and CMOS detector arrays and cameras. Optocouplers. Optical fibers. Assemblies of optoelectronic systems. Advanced optoelectronic systems.

[1] J. Singh, Electronic and Optoelectronic Properties of Semiconductor Structures. Academic Press, 2007.
[2] E. Uiga, Optoelectronics, Prentice Hall, 1995.
[3] S. O. Kasap, Optoelectronics and Photonics: Principles and Practices, Prentice Hall, 2001.
[4] P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall, 1997.

15 Optimization in Electronic Design Automation

(I) Term definition and optimization method overview. Unconstrained methods: first and second order gradient algorithms, direct algorithms and genetic algorithms. Constrained methods: parameter constrains, penalty functions, parameter space transformations. Analog circuit sensitivity in frequency and time. (II) Introduction to an analog circuit optimization tool. The simplex algorithm and its parallelization. Choosing a seed. Measurement definition and cost function formulation. Including design corners into the cost function. Cost function properties (cost profile and noise). A demo run of the tool and result interpretation. (III) A medium size circuit is run by each student on a personal computer. A large analog optimization case is run on a computer farm.

[1] Circuit Simulation with SPICE OPUS, Theory and Practice, T. Tuma, A. Buermen, textbook in preparation.

16 Digital electronic systems design

Systems in the integrated circuit. Technology and circuit entities. Design flowchart of digital electronic systems. VHDL systems design. VHDL data types and RTL models. VHDL components, subprograms and packages. Communication interfaces and buses. USB and LIN interfaces. Embedded IP (Intellectual Property) cores: processors, memories, communication units. Applications of soft processor cores in programmable devices.

Hardware/Software co-design and system modeling using high-level languages: SystemC, SpecC, UML. Feasibility analysis and systems partitioning to hardware and software. Optimization of hardware and software system parts.

Testing of digital electronic systems. Fault modelling, fault simulation and automatic test pattern generation. Circuit design for boundary and built-in test. Circuit optimization exploiting testing.

[1] Vahid, F., Givargis, T., Embedded System Design: A Unified Hardware/Software Introduction, John Wiley & Sons, Inc., 2002.
[2] Jerraya, A.A., Wolf, W., Multiprocessors Systems-on-Chip, Morgan Kaufmann Publishers, 2005.
[3] Rowen, C., Engineering the Complex SoC, Prentice Hall, 2004. Springer, 2005.
[4] M.M. Mano, Logic and Computer Design Fundamentals, Prentice Hall, 2007.
[5] A. Trost, Načrtovanje digitalnih vezij v jeziku VHDL, Založba FE/FRI 2007.

17 Measurement dynamics and disturbances in the measurement setup

Amplitude and time dynamics of the generalized measurement channel: signal conditioning, sampling, and quantization. Uncertainty principles: the time-frequency uncertainty and the time-amplitude uncertainty. The principle of the limited signal decreasing and leakage effect. Analysis and synthesis of the characteristic parameters of the measurement signals and systems in the time, frequency, and information domain.

Analysis and estimation of the basic periodic parameters (frequency, amplitude, and phase) in the time and frequency domain in the presence of noise. Comparison of the measurement uncertainties with the theoretically achievable Cramér-Rao bounds.

The measurement system sensitivity on measurement, influence, and disturbance quantities. Sources and kinds of disturbances. Coupling mechanisms to external sources: galvanic, capacitive, inductive and radiative coupling. Methods of improving the response of the measurement systems with hardware and software. Hardware approach: shaping the impulse response of the front stages, symmetry of the inputs, shielding, grounding and earthing in the measurement systems. Software approach: filtering, averaging, and analysis with discrete Fourier transformation. Selected topics on hardware and software dynamics for acquisition, conversion and estimation of the process quantities. Automatic acquisition of the measurement data and their processing with computers.

[1] W. McC. Siebert, Circuits, Signals and Systems, The MIT Press, McGraw-Hill, Cambridge, New York, 1986.
[2] F. J. Harris: »On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform«, Proceedings of the IEEE, vol. 66, no. 1, pp. 51-83, January 1978.
[3] D. Agrež, »Dynamics of frequency estimation in the frequency domain«, *IEEE Transactions on Instrumentation and Measurement*, vol. 56, no. 6, pp. 2111-2118, December 2007.
[4] R. Pallas-Areny, J.G. Webster, Sensors and signal conditioning, John Wiley & Sons, 2001.
[5] H. W. Ott, Noise reduction techniques in electronic systems, John Willey&Sons, 1988.

18 Virtual measurement instruments

- Basic concept of virtual measurement instruments
- Software for development of virtual measurement instruments, graphical programming, dataflow concept
- Hardware for the development of virtual measurement instruments, communication interfaces, multifunction data-acquisition cards
- Basic concepts of data acquisition
- Use of machine vision in virtual measurement instrumentation
- Synthetic instrumentation
- Control of virtual measurement instruments using the TCP/IP network
- Life cycle of a virtual measurement instrument
- Concepts and good programming practice in the development of virtual measurement instruments
- Software solutions for the automation of a measurement laboratory based on the central-database concept
- Methods for testing and validation of virtual measurement instruments

[1] Virtual Instrument - no Virtual Reality but Real PC Based Measuring System, Vladimr Haasz et al, IEEE 2005
[2] Virtual Instrumentation and Traditional Instruments, National instruments, 2008
[3] Computerized Instrumentation, Tran Tien Lang, Wiley, 1991
[4] Študijska skripta Uvod v programsko okolje LabVIEW, Valentin Batagelj, 2007
[5] Synthetic Instrumentation: Contemporary architectures and applications, Peter Pragastis et al, RF Design, 2004

19 Quality and fundamentals of software engineering

- Software Engineering: Basics and definitions, Properties of software products in comparison to other industrial products, Software life cycle, Quality characteristics in accordance with ISO 9126 standard.
- Testing of software products: Procedure how to test software product (description of the product, user manual, software and data), Limitation of software testing.
- Software reliability: Definition, comparison between hardware and software reliability, software failures, expenses which are related to software faults, reliability assessment, prediction of reliability
- Advanced techniques of software testing: Software testing psychology, Functional testing (black-box testing), Structural testing (white-box testing), Techniques of software testing, Static techniques, Creation of control testing list.
- Test case design: Boundary-value analysis, Logic coverage testing, Random guessing, Error guessing, Cause effect guessing.
- Role and progress of software based on open code software (Linux, BSD, CVS, ...)

[1] Glenford J. Myers, Corey Sandler, Tom Badgett, and Todd M. Thomas: »The Art of Software Testing«, John Wiley & Sons, 2004
[2] Debra S. Herrmann: »Software Safety and Reliability: Techniques, Approaches, and Standards of Key Industrial Sectors«, Wiley-IEEE Computer Society Pr, 2000
[3] B.P. Butler, M.G. Cox, S.L.R. Ellison and W.A. Hardcastle: »Statistics Software Qualification-Reference Data Sets«, The Royal Society of Chemistry, 1996
[4] P. Ciarlini, A.B. Forbes, F. Pavese, D. Richter: »Advanced Mathematical & Computational Tools in Metrology IV,V and VI«, World Scientific Publishing Co, 2000, 2001, 2004
[5] Ian Sommerville: »Software Engineering«, Adison Wesley, 2004

20 Metrology and Quality Systems

International standardization and compatibility of products, services and processes for regulated and voluntary field: basic principles of metrology systems and standardization, organization of the accreditation organization, certification systems, review of European technical legislation, control and analyses of active quality systems, ISO and EN standards, basic knowledge on preparation of laboratories. Development and realization of basic SI units, physical constants, hierarchical organisation of metrology systems, international compatibility, metrology development, elements of formal measurement theory, symbolical representation, information contents, measurement theory, measurement error and measurement uncertainty analyses, classification of errors, calibration, etalons, basic of quantum metrology, reference materials, processing and evaluation of measurement results, testing, calibration, measurement system parameters. Quality control, quality assurance, total quality assurance, quality costs, bad quality costs, organizational knowledge, business functions and processes, administration management, decision-making, coordination, systems and planning techniques, quality information systems, products and services quality. Become aware of modern quality assurance techniques with examples of interlaboratory comparisons, risk assessment in testing procedure evaluation and preparation of optimal experiment

[1] Pham, D.T., Oztemel, E., Intelligent Quality Systems, Springer-Verlag, 1996
[2] Montgomery, D.C.: Introduction to Statistical Quality Control. 4th edition. New York: John Wiley & Sons Inc. 2001
[3] A.J.Marlow: Quality control for Technical Documentation, Amazon, 2005
[4] Regtien, P.P.L.: Measurement Science for Engineers. London, Sterling: Kogan Page Science. 2004
[5] www.sist.si, www.iso.org, www.iec.ch, www.iecee.org, www.cenelec.org, www.itu.int, www.cenorm.be, www.gov.si/sa, www.ilac.org, www.mirs.si, www.euramet.eu, www.wto.org, www.ansi.org, http://ts.nist.gov, www.conformityassessment.org, www.wssn.net, www.oiml.org, www.asq.org, http://ec.europa.eu/enterprise/newapproach/

21 Acoustics and Ultrasound

Principles of physical acoustics, human ear and perception of sound. Human talk, music and noise. Spreading of sound. Transfer of sound wave through the air and structures and appearance shapes. Absorption of sound and feature of absorbers. Measurement and computer modeling os structural acoustics, building speaker systems, deaf room. Modern analitical and experimental procedure for sound isolation and sound damping. Protection against outside noise, urbanistic plan. Microphone as acousto-electrical transducer. Speaking and musical recording, sound picture. Speaker as electro-mechanical transducer. Modeling and simulation of acoustic systems. Analogies between mechanical, acoustical and electrical systems. Ultrasonic transducers. Digital processing of acoustic signals. Audio and video compresion. Blind source separation, convolution mixing, wavelet analysis, coctall-party problem. Multimedia systems, sound effects, compression of audio records, MIDI protocol, MPEG encoding, algorithms and standards. Evaluation of digital systems and digital recorded audio signals in real time. Devices for sound reproduction, noise and dynamic reduction systems. Noise and vibrations. Physical characteristics of noise and vibrations. Noise and vibrations influence on people's health and feeling. Vibration Isolation. Active noise control. Infrasound. Noise and vibrations measurement and evaluation of the measurement results considering standards and regulations.

[1] Thomas D. Rossing, Neville H. Fletcher: Principles of Vibration and Sound, Springer-Verlag; 2nd edition, January , 2004, 330 pages, ISBN: 0387405569.
[2] William M. Hartmann: Signals, Sound, and Sensation (Modern Acoustics and Signal Processing) (Hardcover - Sep 14, 2004) ISBN-10: 1563962837, ISBN-13: 978-1563962837.
[3] Atul Puri, Tsuhan Chen: Multimedia Systems, Standards and Networks, Marcel Dekker, Inc., New York, Basel, 2000, 636 pp ISBN: 0-8247-9303-X.
[4] M. David Egan: Architectural Acoustics (J. Ross Publishing Classics) (Paperback - Jan 23, 2007) ISBN-10: 1932159789, ISBN-13: 978-1932159783.
[5] David Howard and Jamie Angus: Acoustics and Psychoacoustics, Third Edition (Paperback - Jun 6, 2006) ISBN-10: 0240519957, ISBN-13: 978-0240519951.

22 Intelligent mobile transport systems

Introduction (definition of a mobile transport system, a brief history of development, areas of utilization); Principles and configurations of drivelines (wheel, hybrid); Mechanical configurations and mathematical models; Perception and sensory integration (measurement and assessment of kinematic and dynamic motion parameters, perception of environment, description of uncertainty); Autonomous control (systems for autonomous guidance, breaking, collision avoidance, multiagent control); Driveline control (traction control, slip prevention, hybrid driveline); Stability control (active suspension, rollover prevention); Safety systems (active safety systems, warning systems); Simulation environments (driving simulators, impact dynamics, man-machine interaction in driving).

[1] J. Y. Wong: Theory of Ground Vehicles, John Willey & Sons, Inc., Hoboken, 2001.
[2] R. Siegwart, I.R. Nourbakhsh: Introduction to Autonomous Mobile Robots, The MIT Press, Cambridge, 2004.
[3] U. Kiencke, L. Nielsen: Automotive Control Systems for Engine, Driveline, and Vehicle, Springer, Berlin, 2000.
[4] R. Rajamani: Vehicle Dynamics and Control, Springer, Berlin, 2005.

23 Multimodal interactive 3D technologies

Course content is defined in a way to first enable the student to understand basics of interactive 3D presentations and then learn how to design interactive 3D applications and select adequate presentation technologies.
Content: psychophysiology of human visual, auditory and haptic sensing; methods for modeling, generation, and rendering of three-dimensional stimuli of all three modalities (visual, auditory and haptic); technologies for spatial presentation of synthesized 3D stimuli (3D displays, autostereoscopic screens, holographic displays, 3D projection systems, spatial sound generation, haptic robots for presentation of kinesthetic and tactile stimuli); technologies and methods for user movement tracking, interaction with the virtual environment and navigation within the virtual environment; virtual and augmented reality, immersion and presence, multi-user virtual environments and telepresence; methods for measurement of users' psychophysiological responses and strategies for real time adaptation of virtual environment based on users' psychophysiological state; use of interactive 3D technologies in areas such as product design, sales and marketing, architecture and design, education, medicine, research and development.

[1] M. Mihelj: Haptični roboti, Založba FE in FRI, 2007.
[2] G. Burdea, P. Coiffet: Virtual Reality Technology, Wiley, 2003.
[3] S.K. Ong, A.Y.C. Nee, Soh K. Ong: Virtual Reality and Augmented Reality Applications in Manufacturing, Springer; 2004.
[4] W. Sherman, A. B. Craig: Understanding Virtual Reality, Morgan Kaufmann, 2003.
[5] P. Banerjee, D. Zetu: Virtual Manufacturing,Wiley; 2001.

24 Selected topics in robotics

- Analysis and synthesis of serial and parallel robot mechanisms
- Advanced approaches in kinematics, dynamics, control and sensory systems in robotics
- Parallel robot systems: kinematic singularities, manipulability, sensitivity of constructional errors
- Robotic grasping systems: multifinger robot grippers, grasping in man and robot, tendon systems
- Robot systems in medicine: rehabilitation robotics, robotics in surgery, biorobotics
- Walking robots: monopod, biped, and multilegged robots, analysis and sysnthesis of locomotion in man and robot
- Exotic robots

[1] Siciliano B, Khatib O, Handbook of Robotics, Springer, 2008.
[2] Murray R, Li Z, Sastry SS, Mathematical introduction to robotic manipulation, CRC Press, 1993.
[3] Lenarčič J, Bajd T, Robotski mehanizmi, Založba FE&FRI, 2003.
[4] Taylor RH, Computer-integrated surgery: technology and clinical applications, MIT Press, 1996.
[5] Tsay LW, Robot analysis, Wiley, 1999.
[6] Arimoto S, Control theory of multi-fingered hands, Springer, 2008.

25 Quality of medical instrumentation

- Medical device directive-MDD, In-vitro diagnostic directive-IVD, Active Implantable Medical Devices-AIMD
- Legal metrology (OIML, UL RS, MIRS)
- Quality assurance in medical environment (standard ISO 15189 Requirements for the competence of medical laboratories)
- Standardization in the field of medical instrumentation (ISO, IEC, FDA, DIN, EN standards)
- Procedure for development of new standards in the field of medical instrumentation (procedures, clinical evaluations, risk analysis)
- Overview of field of medical instrumentation (relevant types of instrument related to the requirements of standards)
- Basics of metrology (measurement error, measurement uncertainty, calibration, testing) with practical examples in the field of calibration of medical instrumentation (medical weighing instruments, clinical thermometers, non-invasive blood pressure meters)

[1] European Union, Council directive 93/42/EEC of 14 June 1993 concerning medical devices (Medical Device Directive), Official Journal L 169, 12/07/1993 str. 0001 - 0043
[2] ISO 15189 – Requirements for competence of medical laboratories
[3] ISO/IEC 17025:2005 General requirements for the cometence of testing and calibration laboratories
[4] ISO/IEC 17020 General criteria for the operation of various types of bodies performing inspection
[5] ISO/IEC 80601-2-56 Medical Electrical Equipment – Part 2-56: Particular requirements for basic safety and essential performance of clinical thermometers for body temperature measurement

26 Integrated Microsystems SoC and analog-digital integrated circuits

Module A.

- Blocks of the Application Specific Integrated circuit based on integrated sensors and RF design.
- Basic from technologies, process parameters and modeling of integrated sensors. What are process parameters and what are design roles.
- Acquisition and signal conditioning of acquired sensors signals (LNA amplifiers).
- HF ICs, amplifiers, PA.
- RFID technologies, smart active-passive labels SAL, other low power systems SoC.
- Design for reliability and test, Peripheral structures.
- CAD tools and there usage in ASIC design - research projects-examples.

Module B.

Integrated systems SoC and state-of-the-art in nanoelectronics, solutions for the analogue functions, method of improvements. Circuits in sub-um technology; RF CMOS and BiCMOS circuits; analog-digital (mixed-signal) circuits; systems-on-chip (SoC) - practical approach: optoelectronic integrated circuits (OEICs), integrated magnetic and chemical sensors, MEMS technologies, smart active/passive labels technology (SAL), integrated ISO protocols, GEN2 protocol. Practical examples and cooperation in research program (FERI, LMFE, IDS-microchip).

Module C.

The following topics are dealt with in the lecture: What is the protection of intellectual property, why does it exist, who benefits. Patents, trademarks, designs etc. Patents in Slovenia. Patent documents, Copyright aspects of circuit diagrams. Understanding and Implementing the Marketing process for technical products, design effort, NRE, royalties, cost of ASIC processing, MLM cost, dedicated MLM versus MPW, cost of wafers.

Module D.

Understanding Measurement Technology, ASIC evaluation, failure analysis, methods for physical failure localization and identification include liquid crystal thermal mapping, FIB (focus ion beam), contact-les analysis. Different examples of device/circuit testing relevant for industry will be discussed.

[1] Anton Pleteršek, Načrtovanje analognih integriranih vezij v tehnologiji CMOS in SOI-BiCMOS, monograph 2006,
[2] E. Carey, S. Lidholm, Millimeter-Wave Integrated Circuits, Springer 2005,
[3] Journal of Nanoparticle Research, Springer Publisher, Netherlands,
[4] Journal of Solid State Circuit, IEEE.
[5] Willy Mc. Sansen, Analog Design Essentials, Published by Springer 2006.
[6] Trontelj, Janez, Trontelj, Lojze, Shenton, Graham. Analog digital ASIC design. London [etc.]: McGraw-Hill Book Company, 1989. XVI, 249 pp, ilustr. ISBN 0-07-707300-2.

27 Advanced microelectronics systems: selected topics

The subject is continuation of the subject Microelectronic systems from 2nd degree.

It covers modern and innovative architectures and implementations of mixed signal analog-digital integrated systems in deep submicron CMOS technologies (<70nm). The limitations imposed by the technology due to limmited supply voltage and increased noise require new architectures of circuits while complexity require new modelling and design tools.

The content will be devided into three main topics:

- Design of low-voltage, HF, low-noise VLSI dynamical systems in CMOS and BICMOS technologies,
- Cointegration of MEMS/NEMS senzors and VLSI integrated system, modelling and verification
- Testing of complex mixed-signal integrated, BIST methodologies for digital analog and mixed signal systems

Each topics will be composed of lectures, some individual study/seminar, which will than be a basis for individual research work in selected subject.

[1] F. Maloberti, »Data Converters«, Springer, 2007
[2] R. Plasche, »Integrated Analog-to-Digital and Digital-to-Analog Converters«, Kluwer, 2002
[3] R. J. Baker, »CMOS Circuti design, Layout and simulation«, Wiley interscience, 2005
[4] C. Tomazou, G. Moshytz, B. Gilbert »Trade-offs in Analog Circuti Design«, Kluwer, 2002
[5] G.T.A. Kovacs, »Micromachinned transcducers source book«, McGraw-Hill 1998.
[6] M. Burns, G.W.Roberts, »An Introduction to Mixed-signal IC test and Mesurements«, Oxford University press, 2001.

28 Electrical servo drives in mechatronics

The overview of methods and procedures for control of modern servo drives with AC machines: induction, synchronous (with surface-mounted and buried magnets) and reluctance machines. Controlled drives in mechatronics (speed control in current supplied electrical machines; field oriented control - FOC; direct torque control - DTC). Problems concerning robustness of the control considering incorrectly identified and/or fluctuating parameters of the drive. Position and/or speed sensorless methods in AC drives. Sensorless control. The application of observers and MRAS in servo drives. Application of modern microprocessors in dynamically demanding electrical controlled systems: tasks, problems, configurations, software.

Electrical drives with linear motors and their significance in industrial applications.

Electrical drive systems in automotive vehicles (primary and auxiliary drives). Electrical traction systems - supply and drive principles, high speed applications, magnetic levitation systems, trends.

Electrical machines in wind energy conversion systems and pump power plants.

On-line condition monitoring and diagnostics of electrical drives, detection of electrical and mechanical faults of AC motors, application of artificial intelligence methods in integrated approach to control and supervision of modern servo drives.

[1] Ambrožič, V., Additional written materials to the textbook Modern control of AC drives (in Slovene), Založba FER, 1996.
[2] Bose, B. K., Modern Power Electronics and AC Drives, Prentice Hall, 2001
[3] Bin Wu, High-Power Converters and AC Drives, Wiley Interscience, 2006.
[4] Sabri Cetinkunt, Mechatronics, John Wiley &Sons, 2007.
[5] Miller J. M., Propulsion Systems for Hybrid Vehicles, IEE Press, 2004.

29 Modern electric machines

A review of world development in a field of modern electric machines. Influence of drive system in selection and in design of electric machine. Theoretical basis of modern electric machine operation such as: electronically commutated machines, AC machines and hybrid machines. Energy and power in circuit describing electromechanical system. Concept of electric machine based on general circuit theory. Circuit models of electric machines coupled with mechanical equations. The use of finite element method in electromagnetic design of electric machines. Modern optimization theories applied in a filed of electric machines construction. Description of magnetic materials using methods of artificial intelligence. Application of numerical methods to solve the circuit models of electric machines. Synthesis of earned knowledge in concrete problems based on modern electric machine design.

[1] Nicola Bianchi: Electrical Machine Analysis Using Finite Elements (Power Electronics and Applications), Taylor and Francis Press, 2005
[2] Ong C. M.: Dynamic Simulation of electric machinery, Printice Hall, 1998
[3] Drago Dolinar, Gorazd Štumberger, Modeliranje in vodenje elektromehanskih sistemov, FERI, Maribor, 2002
[4] P. C. Krause, O. Wasynczuk, S. D. Sudhoff, Analysis of Electric Machinery and Drive Systems, IEEE Press, (2nd edition), 2002
[5] P. S. Bimbhra, Generalized Theory of Electric Machinery, Khanna Publishers, Delhi, 1995; Reprint: 2004

30 Power Electronics Converters

Semiconductor devices physics and their use in power electronics systems. State-of-the-art topologies for low voltage - high current applications such as: alternative power sources, hybrid electric drives, and high-dynamic electric drives.

Practical design issues, such as snubbers, semiconductor stresses due to the high slope of current and voltage, losses and efficiency.

Control issues such as: PWM, hysteresis and time-discrete controller, vector control, direct current control principle. Predictive and repetitive control methods in power electronics.

Serial and parallel converters for reactive power compensation of fundamental and high-harmonics components. Converters for active power flow control.

Effects of power converters to the supply grid voltage and to the adjacent electronic devices. Study of electromagnetic compatibility problems: sources of electromagnetic (EM) emissions, mode of coupling and reduction techniques of EM emissions. Setups for measuring radiated and conducted emissions.

[1] J. Nastran: Močnostna elektronika - interna skripta, Univerza v Ljubljani, Fakulteta za Elektrotehniko, 2006.
[2] N. Mohan, T.M.Undeland, W.P.Robbins: Power electronics: converters, applications and design, Hoboken-Wiley 2003.
[3] M.H. Rashid: Power electronics: circuits, devices and applications, Englewood Cliffs (N. J.) - Prentice-Hall, 2003.
[4] B.K. Bose: Power electronics and motor drives: advances and trends, Burlington - Elsevier/Academic Press, 2006.

31 Control of Electronically Commutated Motors

Principle of operation and modeling of the brush-less permanent magnet motor. Principle of operation and modeling of the switched reluctance motor. Principle of operation of the unipolar, bipolar and bifilar wound stepper motor. Bridge, half-bridge and asymmetric switched-mode power converter topologies with different number of switches for power supply of brush-less motor. 120° el. and 180° el. angle switch-on control mode of brush-less motor. Optimization of brush-less motor control algorithm by magnetic flux weakening method and the modification of the switch-on angle. Optimization of torque-speed characteristic. Methods for cogging torque reduction. Sensors for position and speed detection of the rotor. Sensorless control of brush-less motors. Phase current control. Design and implementation of rotor speed and motor torque controllers.

[1] B. K. Bose, Modern Power Electronics and AC Drives, Prentice Hall, 2002
[2] R. Krishnan, Switched Reluctance Motor Drives, CRC Press, 2001
[3] P. C. Krause, O. Wasynczuk, S. D. Sudhoff, Analysis of Electric Machinery and Drive Systems, John Wiley & Sons, 2002
[4] S. A. Nasar, I. Boldea, L.E. Unnewehr, Permanent Magnet, Reluctance and Self-Synchronous Motors, CRC Press, 1993
[5] Y. Dote, S. Kinoshita, Brushless Servomotors, Clarenson Press, Oxford, 1990

32 Selected Topics of Complex Systems Control Design

- Introduction to complex systems (description and mathematical representation of complex systems, model uncertainty, multivariable and large-scale systems, systems with time-delays, non-minimum-phase systems, nonlinear systems)
- Presentation of performance limitations using analysis functions and the concept of robustness
- Presentation of corresponding control design approaches, which include also the concepts of optimal control strategies (in implicit or explicit manner):
- Optimal control problem (principles and criterions, linear quadratic controller, state observers, combination of optimal control with modern design methods)
- Khariton's design approach
- H2 in Hinf control design
- Adaptive control design
- Extension to expert system development
- Technology of control realization for complex systems (computer control systems and programmable logical controllers, corresponding software, network technologies, remote control)

[1] S. Skogestad, I. Postlethwaite, Multivariable Feedback Control, Analysis and Design, John Wiley and Sons Ltd, Chichester, 2006.
[2] M. Morari, E. Zafiriou, Robust Process Control, Prentice-Hall, Inc. 1989.
[3] Astrom, Wittenmark, Adaptive control, Addison-Wesley Longman Publishing Co., Inc. Boston, MA, USA, 1994.
[4] R. Karba, M. Atanasijević-Kunc, Multivariabilni sistemi, (textbook in preparation, expecting in 2009 published by FE and FRI).
[5] J. Stenerson, Fundamentals of Programmable Logic Controllers, Sensors and Communication, Third Edition, Pearson/Prentice Hall, 2004.

33 Modelling Identification and Simulation of Biological systems

Basic principles of biological systems which are important for modelling and identification of systems dynamics (integral feedback loop presents a major problem) - systems biology.
Measurement techniques in areas (gas and liquid cromatography, mass spectroscopy, real-time PCR, DNA microarrays, electroencephalography, magnetoencephalography, fMRI, ...).
Processing of biological signals (normalisation, filtering, modulation).
Object oriented theoretical modelling of biochemical processes (problems of incomplete knowlege of relations between objects).
Modelling in pharmacokinetics and pharmacodynamics (problems of incomplete knowledge of theoretical background of drug actions and data quantity).
Identification of biological systems on basis of measurements (problems of data quantity and quality).
Neural net modelling
Fuzzy modelling
Cases from pharmacokinetics, pharmacodynamics, systems biology and neurophysiology.

[1] F. C. Hoppensteadt, C. S. Peskin: Modeling and simulation in medicine and the life sciences, Springer, 2002.
[2] W. A. Ritschel, G. L. Kearns: Handbook of basic pharmacokinetics ... including clinical applications, 6th edition, APhA, 2004.
[3] K. Kaneko: Life: an introduction to complex systems biology, Springer, 2006.
[4] M. Kurzynski: The thermodynamic machinery of life, Springer, 2006.
[5] P. L. Nunez, R. Srinivasan: Electric fields of the brain, 2nd edition, Oxford University Press, 2006.

34 Machine vision

- Modeling of visual multisensor systems, mathematical, physical, biological and computational foundations.
- Selected mathematical tools and algorithms for analysis of visual information: selected topics in linear algebra, stochastic systems, information theory.
- Selected algorithms for object detection and tracking, motion analysis, events and activity recognition, behavior analysis.
- Biologically inspired architectures for visual perception.
- Machine vision in industry: robot vision, visual inspection and measurements.
- Machine vision in intelligent visual surveillance systems, biometric systems.
- Machine vision in intelligent transportation systems, machine vision in transport infrastructure and vechicles.
- Machine vision in sports, analysis and understanding of individual and team activities.
- Machine vision in advanced user interfaces.

[1] D. Forsyth, J. Ponce, Computer Vision, a modern approach, Prentice Hall, 2003.
[2] M. Sonka, V. Hlavac, R. Boyle, Image processing, analysis and machine vision, CENGAGE-Engineering; 3rd edition, 2007.

35 Advanced control of autonomous systems

- Introduction to autonomous systems - Mobile systems, Unmanned aerial vehicles, Space crafts
- Methods for localisation and mapping, Simultaneous localisation and mapping, Extended Kalman filter, position, orientation and feature estimation methods - particle filter
- Higher level control - strategies of multi-agent systems control
- Path planning - the principle of optimality, path optimisation with constraints (obstacle avoiding, nonholonomity, dynamic constraints, actuator constraints), satellite orbits
- Optimal control in the presence of disturbances
- Frequency domain robust control design methods
- Trajectory tracking control of autonomous systems
- Control of autonomous systems to the final state
- Adaptive control of autonomous systems
- Matrix inequality control of autonomous systems

[1] J. Andrade-Cetto, A. Sanfeliu, Environment Learning for Indoor Mobile Robots, Springer, 2006.
[2] J.-P. Laumond, Robot Motion Planning and Control, Lecture Notes in Control and Information Science 229, Springer, 1998 (dostopno tudi na: http://www.laas.fr/~jpl/book.html).
[3] A. E. Bryson, Applied Linear Optimal Control, Cambridge University Press, 2002.
[4] G. Balas, R. Chiang, A. Packard, M. Safonov, Robust Control Toolbox 3, User's Guide, MathWorks, 2008
[5] K. J. Åström, B. Wittenmark, Adaptive Control, Second Edition, Addison-Wesley Publishing Company, Inc., Reading, 1995.

36 Stochastic Processes and Signals

Introduction:
- definition of stochastic process and random signal. Introduction of some important issues from mathematical modeling in statistics and probability theory.

Random signals processing:
- time and sample mean, random signals filtering (Wienner and Kalman filter), probability distribution evaluation (Expectation-Maximization (EM), Maximum A Posteriori (MAP) and »Maximum Likelihood Linear Regression« (MLLR) procedures)

Modeling of stationary and non-stationary stochastic processes:
- Gauss process, Poisson process, Gauss-Markov process, non-stationary stochastic processes representation using Hidden Markov Models (HMM)

Examples from speech signals processing, modeling of speech perception and production:
- source-filter model for speech production, speech perception model and deconvulution of speech signals, time-frequency representations of speech signals, speech detection, speech signal modeling using HMM

[1] Robert M. Gray, Lee D. Davisson: An Introduction to Statistical Signal Processing. Ambridge University Press, ISBN 0-521-83860-6, (2004), 463 pp.
[2] Huang X., Acero A., Hon H.W.: Spoken Language Processing: A Guide to Theory, Algorithm and System Development, Prentice Hall, ISBN 0-13-022616-5, (2001), 455 pp.
[3] X. Rong Li: Probability, Random Signals and Statistics, CRC Press LLC, ISBN-0-8493-0433-4, (1999), 455 pp.

37 Industrial informatics

Objective of the course is to introduce the significance of models and formal methods in the process of development and analysis of industrial information systems. The focus is on Petri net based modelling and analysis. Petri nets are a general framework for dealing with industrial information systems throughout the life-cycle, from specifications, design and analysis to the implementation.
Basics of industrial information systems. Production planning and scheduling systems, manufacturing execution systems, manufacturing automation systems.
Significance of models and formal methods in development and analysis of industrial information systems. Discrete-event, continuous and hybrid systems and corresponding modelling techniques.
Introduction to Petri nets. Graphical and mathematical representation. Properties and analysis techniques. Reachability analysis. Linear algebraic analysis. Timed, continuous and hybrid Petri nets. Petri net simulation.
Modelling of processes by Petri nets. Bottom-up and top-down modelling techniques. Process data based model building, process and data mining.
Use of models during development and analysis of industrial information systems. Automatic control code generation. Model based control and optimization of industrial processes. Planning and scheduling.

[1] T. Boucher, A. Yalcin. Design of Industrial Information Systems, Academic Press, 2006.
[2] R. David, H. Alla. Discrete, Continuous, and Hybrid Petri Nets, Springer, 2005.
[3] W.M.P. van der Aalst. Process Mining: Discovery, Conformance and Enhancement of Business Processes, Springer, 2011.

38 Pattern recognition

Introduction: definitions, pattern representations, pattern recognition by classification and analysis, applications of pattern recognition in economy, traffics, medicine, robotics, banking, forensics, man-machine communication, etc.
Pattern preprocessing: restoration, enhancement, normalization.
Pattern segmentation: basic concepts, images and speech signals segmentation.
Feature generation: heuristic methods, optimal feature selection and extraction.
Analysis of learning sets: similarity measures, hard and fuzzy clustering, clustering test, clustering techniques.
Pattern classification: classification of feature vectors by matching, decision, inference and artificial neural networks; context-dependent classification by Hidden Markov Models, classification by graph matching, combining classifiers.

[1] Duda, R.O., P. E. Hart and D. G. Stork, Pattern Classification, 2nd edition, Wiley, 2001.
[2] S. Theodoridis, K. Koutroumbas: Pattern Recognition (3rd edition), Academic Press, 2006.
[3] Pavešić, N., Razpoznavanje vzorcev: Uvod v analizo in razumevanje vidnih in slušnih signalov, 2nd edition, Založba FE in FRI, 2000.

39 Intelligent control in modern systems

Introduction to intelligent systems. Basic principles of fuzzy and neuro control systems. Basic principles of adaptive control systems: indirect and direct adaptive control. gain-scheduling, auto-tuning controllers. Introduction to the principles of predictive control algorithms. Fuzzy model based predictive control algorithms. Fuzzy model based adaptive control. Examples of intelligent control in modern systems of high technology: chemical, pharmaceutical, biochemical and in the case of autonoumus systems.

[1] O. Nelles. Nonlinear System Identification, Springer 2000.
[2] I. Škrjanc. Inteligentne metode v identifikaciji sistemov, textbook in preparation, 2008.

40 Object Oriented Modelling

Basic principles in OO modelling
- Causal and acausal modelling, OO modelling. 'Physical' connection of components, hybrid modelling, visual modelling.

Modelica language
- Inheritance, classes, quantities, connectors, partial classes, packages, examples.

Dymola - environment for Modelica modelling
- Structure of the environment, modelling and experimentation, interface with Matlab-Simulink. Strategies for automatic algebraic manipulation: from physical laws to state space form. Algebraic loops, structural singularities.

Numerical problems in simulation
- Integration methods: single step, multi step, explicit, implicit, methods for stiff systems, extrapolation methods, problems of discontinuities.

Case studies
- Modelica library for process-hydraulic systems. Modelling in stone wool production. Modelling of thermal flows in buildings, modelling in pharmcogenomics.

[1] B. Zupančič: DYMOLA-MODELICA - advanced object oriented modelling and simulation environment, delovno gradivo za predavanja na TU Dunaj, 2008
[2] B. Zupančič, R. Karba, D. Matko, Simulacija dinamičnih sistemov. 1st edition, Univerza v Ljubljani, Fakulteta za elektrotehniko in računalništvo, 1995.
[3] F.E. Cellier, Continuous System Modeling, Springer - Verlag, NY, USA, 1991.
[4] F.E. Cellier, E. Kofman, Continuous System Simulation, Springer Science+Business Media, Inc., NY, USA, 2006
[5] P. Fritzson, Principles of Object Oriented Modeling and Simulation with Modelica 2.1, IEEE Press, John Wiley&Sons, Inc., Publication, USA, 2004

41 Convergent communications

Knowledge and understanding of basic operation principles of communications systems, architectural models, elements and protocols, and services. Presentation of fixed-mobile communications systems and services.
Basics of convergent communications systems and services, and multimedia features and feasibilities (text, picture, sound, video). Overview of multimedia content formats and related technical requirements for transmission and end-user's services provisioning.
Features of analog and digital forms of multimedia elements, and reasons for digitalization. Basic multimedia services (IPTV services, mobile video services, web-based video services). Terminal equipment features, required for usage of convergent multimedia services (STB, mobile terminal, personal computer, tablet PC). Role and features of end-user interfaces, interconnection of applications and interactivity.
Basics of Web 2.0 and related effects (web communities, wikipedia, etc.) and peer-to-peer architectures.
Basics of data security requirements and principles, security in convergent communications systems.
Overview of selected topics of usage: data/information search engines, entertainment, intelligent home, e-learning, e-health, e-business, etc.

[1] Chapman N., Chapman J., Digital Multimedia, John Wiley & Sons; 2004
[2] Poikselka M., Mayer G., Khartabil H., Niemi A., The IMS: IP Multimedia Concepts and Services, John Wiley & Sons, 2006.
[3] Shneyderman A., Casati A.Fixed Mobile Convergence, McGraw-Hill, 2008
[4] Hanrahan H. Network Convergence: Services, Applications, Transport, and Operations Support, John Wiley & Sons, 2007

42 Protocols of Modern Telecommunication Networks

Protocols, protocol stacks, communication planes (recapitulation). Examples and analysis of several protocol stacks. Protocol stacks of convergent networks. Network interconnection. Tunnelling, examples of tunnelling. Protocol efficiency. Efficiency from the viewpoint of users or network. Tasks of classical and modern network protocols. Addressing, address translation, examples. Switching, routing, routing protocols. Multicast communication. Distributed state management involving multiple entities. Protocol message coding, ASN.1. Segmentation and reassembly of protocol messages, examples. Error detection and correction: generalised sliding window protocol, hybrid methods. Quality of service. Protocol stack layer as a quality of service transformer. Quality of service provision. Flow control and congestion control (classification, examples and current trends). Medium access control in fixed and mobile networks, examples. Signaling protocols in access and transport networks. Security management protocols. Network management, management protocols. Topics in mobile networks protocols: mobility management and radio resources management. Topics in convergent networks protocols. Overview of current trends. Overview of information sources.

[1] Hercog D., Telekomunikacijski protokoli (Telecommunication protocols), textbook in preparation
[2] Stallings W., Data and Computer Communications, Pearson Prentice Hall, Upper Saddle River, N.J.: the latest edition
[3] Sauter M., Communication Systems for the Mobile Information Society, John Wiley & Sons, Chichester: 2006
[4] Wisely D., Eardly Ph., Burness L., IP for 3G: Networking Technologies for Mobile Communications, John Wiley & Sons, Chichester: 2002
[5] Telecommunication standards ITU-T, ETSI, IETF, 3GPP

43 Telecommunication systems engineering

Introduction to Telecommunication engineering. Telecommunication traffic concepts. Grade of service.
- Overview of probability theory and statistics.

Theory of classical telecommunication systems:
- Time interval distributions, arrival processes. The Poisson process.
- Erlang's loss system and Erlang B formula. Loss systems with full accessibility. Overflow theory. Multi-Dimensional Loss systems.
- Delay systems. Erlang C Formula.
- Applied Queuing Theory. Networks of Queues: M/M/n, M/G/1, M/D/n, M/D/1, E/D/r, GI/G/1, GI/M/1.

Theory of modern telecommunication systems.
- Temporal and amplitude traffic burstiness. Telecommunication traffic timescale independency.
- Telecommunication traffic behavior at long scales. Self-similarity. Heavy tails.
- Telecommunication traffic behavior at short scales. Multifractals.
- Overall network traffic description. Generalized network traffic model.
- Traffic and load characteristics for different network applications. Elastic and non-elastic network applications.

Network traffic measurement, testing telecommunications systems, interoperability.
Simulations and emulation of network elements and services.
Telecommunications system design.
- Network bottlenecks.
- Congestion control.
- Utilization, performance evaluation.

Methods ensuring quality of services.
- Metrics for telecommunication systems quality. Controlled entities. Traffic nature in convergent networks. Fluid and elastic traffic. Open and closed loop traffic control.
- Mechanisms ensuring Quality of services. Overprovisioning. Resource reservation. Access control. Service differentiation.
- User perceived quality measurement (QoE, MOS). Quality management.

Management and control in telecommunication networks.
- Models for telecommunication network management (TM, eTOM, ITIL).
- Protocols and information models (CMIP, SNMP, CIM, MIB), accounting.
- Telemanagement.

Availability of telecommunications system
- Design of telecommunication systems in terms of availability.
- Redundancy.

Energy efficiency of telecommunication system and services.

[1] Humar I., Bešter J.: Načrtovanje omrežij s telekomunikacijskim inženiringom, Skripta za podiplomske študente (v pripravi)
[2] Raghavan S., Anandalingam G.: Telecommunications Modeling, Policy, and Technology, Springer 2010.
[3] Raghavan S., Anandalingam G.: Telecommunications Planning: Innovations in Pricing, Network Design and Management, Springer 2010.
[4] Promise J-I.: Mobile Communications Network Planning: Network Planning Issues and Strategies for Improving Network Resource Utilization, Lambert 2010.
[5] Iversen V. B.: Teletraffic Engineering and Network planning, Technical University of Danmark, jan. 2007
[6] Alberto Leon-Garcia, Indra Widjaja: Communication Networks, Fundametnatl Concepts and Key Architectures, McGraw-Hill, 2000.
[7] Haojin Wang: Telecommunications Network Management, McGraw Hill, 2000.
[8] Sansò Brunilde, Soriano Patrick: Telecommunications Network Planning, Springer, 1999.
[9] Članki, objavljenih v revijah, npr:
- IEEE Communications Surveys & Tutorials, http://www.comsoc.org/livepubs/surveys/index.html

44 Broadband Communications Systems

Basic broadband systems concepts (architectures, hierarchy, network elements). Advanced broadband systems concepts (protocols, mechanisms, algorithms, standards). Virtualization of network and system resources (emulation, paravirtualizaton, techniques and protocols of virtual private networks). Transmission and interconnection techniques (unicast, multicast, anycast, peer-to-peer mechanisms, ad-hoc, mesh, sensor networks, GRID). Support system mechanisms and protocols (tunneling mechanism, AAA concepts, PPP protocols, DHCP, RADIUS, DIAMETER).
High availability level (redundant schemes, protection techniques, reconstruction techniques, modeling, statistical methods). Security approaches (filter techniques, mechanisms, algorithms, protocols).
Management of complex systems (cognitive networks). Interconnection and interdependencies of communications and other infrastructural systems. Interactions of communications and power distribution systems from the availability, reliability, vulnerability and risk viewpoints.

[1] Martin P. Clark: Data Networks, IP and the Internet: protocols, design and operation, Wiley (2003), ISBN 0-470-84856-1
[2] Alberto Leon-Garcia, Indra Widjaja: Communication Networks, Fundametnatl Concepts and Key Architectures, McGraw-Hill, 2000.
[3] Članki, objavljenih v revijah, npr: IEEE Communications Surveys & Tutorials, http://www.comsoc.org/livepubs/surveys/index.html

45 Operations research in telecommunications

Algorithm and computational complexity (algorithm design, computational complexity estimation, numerical errors). Graph theory (representation, operations on graphs, selected graph properties, basic graph algorithms) and data structures.
Introduction to operations research and optimization. Optimization task (formulation, objective function, set of solutions). Combinatorial optimization, linear and integer programming (simplex method, selected known problems). Network analysis (maximal flow, minimal cost, shortest path, optimal labeling). Nonlinear optimization (gradient and Newton method, constraint optimization). Dynamic programming and game theory. Markov chains (classification of states, ergodicity). Queuing theory. Decision theory (theory, basic applications). Heuristic optimization techniques. Selected optimization problems in telecommunications (topology control, optimal resource assignment, optimal routing, optimal error recovery).

[1] M. W. Carter, C. C. Price: Operations Research, A Practical Introduction, CRC Press, 2000.
[2] M. X. Cheng, Y. Li, D.-Z. Du: Combinatorial Optimization in Communication Networks, Springer, 2006.
[3] R. Johnsonbaugh, M. Schaeffer: Algorithms, Prentice Hall, 2004.

46 Multimedia content and interactive technologies

Basics of MM systems:
- Content capturing and processing
- Content exchange and interactive access to multimedia content (IPTV, TV/radio-difusion, Web)
- Content protection.

MM content
- Content description and search
- High- and low-level metadata
- Content description standards
- Semantics and ontologies
- Description formats (XML)

Personalization
- Personalization basics and usage overview
- Importance of user-system interaction and user feedback
- Personalized content selection
- Personalized content presentation
- Approaches and techniques (collaborative, content-based, hybrids)

[1] Ze-Nian Li and Mark S. Drew, Fundamentals of Multimedia, Prentice-Hall, 2004
[2] Herve Benoit, Digital Television, Third Edition: Satellite, Cable, Terrestrial, IPTV, Mobile TV in the DVB Framework, Focal Press, 2008 (3. Edition)
[3] Članki, objavljenih v revijah, npr: USER MODELING AND USER-ADAPTED INTERACTION The Journal of Personalization Research http://www.umuai.org/

47 Digital signal, image and video processing

Signal theory, basic analog signal processing, colour spaces, colour standards, methods of intelligent signal processing, ICA, PCA and select linear algebra methods, image and video coding, image and video compression, detection and object recognition, watermarking, and applications.

[1] Gonzales, R. C., Woods, R. E., Digital Image Procesing, Addison Wesley, 1992.
[2] Tekalp, A. M., Digital Video Processing, Prentice Hall, 1995.
[3] H.R. Wu and K.R. Rao Digital Video Image Quality and Perceptual Coding CRC Press, 2005.
[4] R. J. Clarke, Digital Compression of Still Images and Video, Academic Press, 1995.
[5] J. Arnold, M. Frater, M. Pickering, Digital television, J. Wiley, 2007.
[6] S. V. Vaseghi, Multimedia Signal Processing, J. Wiley, 2007.
[7] Haykin, S., Adaptive filter theory, Prentice Hall, 1991.

48 Contemporary Coding and Modulation Methods

Transmission channel characteristics (discrete information channel, binary symmetric channel, AWGN channel, models of real channels). Theoretical bounds of digital transmission (random coding and noisy channel coding theorem, Nyquist criterion for ISI free transmission, spectral efficiency). Deployment of redundancy for error detection and error correction. Basics of finite fields mathematics. Linear block codes (systematic and non-systematic codes, low density parity codes, interleaving) Trellis codes (trellis diagram, convolution codes). Product codes. Decoding (error detection and retransmission, error correction, forward error correction and maximum likelihood decoding, hard and soft decoding, Viterbi and MAP algorithms, iterative decoding). Multiple input multiple output systems (diversity gain, multiplexing gain, time-space coding).
Modulation methods(amplitude modulation, phase modulation, frequency modulation, quadrature amplitude modulation). Spread spectrum (frequency hopping, time hopping, random carrier modulation, direct sequence modulation). Multiple carrier transmission. (OFDM, DMT). Adaptive modulation methods.

[1] Bernard Sklar, Digital Communications: Fundamentals and Applications (2nd Edition), Prentice Hall, 2001
[2] John Proakis and Masoud Salehi, Digital Communications, 5th edition, McGraw-Hill, 2007

49 Radio communications

Field definition and noise, performance of components, subsystems and systems, communication equation, reflection, diffraction and absorption losses, electromagnetic and scalar formulation of problems, single-obstacle diffraction, Millington dual-obstacle diffraction, Deygout dual- and multiple-obstacle approximations, empirical models: Okumura/Hata, CCIR method, other models, adaptation of models for urban and semi-urban environments, statistics of received field, fading, diversity-reception methods, diversity gain, bit-error rate, system noise temperature, optimum and adaptive reception, adaptive antennas, fundamentals of celestial mechanics, solution of motion equation, Kelperian laws, satellite launch, rocket equation, Keplerian orbital elements, orbit perturbations, useful satellite orbits for communication, satellite-position calculation, antenna tracking, power sources in space, satellite thermal management, effects of ionising radiation on communication equipment, capacity of satellite communications, free-space radio communication, atmospheric and rain effects, antenna and receiver noise, spectral and power efficiency of modulation, examples of satellite-communication systems.

[1] Collin, R.E., Antennas and Radiowave Propagation, McGraw-Hill, 1985.
[2] Lee, W.C.Y, Mobile Communications Engineering, McGraw-Hill, 1998.
[3] Matko, D., (ed.), Uporaba vesoljskih tehnologij, Didakta, 1996.
[4] Maral, G., Bousquet, M., Satellite Communications Systems, Systems, Techniques and Technology, Wiley, 1993.
[5] Yuen, J.H., (ed.), Deep Space Telecommunications Systems Engineering, Plenum Press, 1983.

50 Multimedia systems: algorithms and architectures

Multimedia signal processing. Linear algebra and non-linear algebra sequential algorithms, architectures of dogotal signal, image and video processing. Modelling of parallel algorithms, parallel architectures, mutithreading, parallel algorithms for digital signal, image and video processing examples: coding, convolution, transforms, filtering, compression and scaling.
Student can focus also on algorithm complexity, algorithm signal flow graph, algorithm dependence graph, algorithm engineering, algorithm optimisation for selected architecture: regular and irregular architectures, approaches to algorithm mapping, parallel multimedia, signal preprocessing and recognition.

[1] K. K. Parhi, VLSI Digital Signal Processing Systems: Design and Implementation, Wiley.
[2] K. K. Parhi, et. al, Digital Signal Processing for Multimedia Systems, Marcel-Dekker.
[3] M. Mandal, Multimedia Signals and Systems, Springer.
[4] S. W. Smith, The Scientist and Engineer's Guide to Digital Signal Processing, California Tech. Pub.
[5] Ling Guan et all. Multimedia Image and Video Processing; CRC press

51 Imaging technologies

Image acquisition techniques: digital photography, cameras and illumination units for visible and invisible part of the electromagnetic spectrum, microscopy, radiography, computed tomography, magnetic resonance imaging, ultrasonic imaging, advanced and emerging imaging techniques.
Methods for image restoration, reconstruction, calibration, processing, analysis, integration, measuring and understanding of image content with the emphasis on robustness, reliability, stability and applicability in real-time.
Design and integration of imaging technologies and computer vision systems in everyday life, industry and biomedicine for the extraction of multidimensional information about the inspected space, objects and subjects.

[1] Machine Vision: Theory, Algorithms, Practicalities, E. R. Davies, Morgan Kaufmann, 2005.
[2] Handbook of Machine Vision, A. Hornberg, Wiley-VCH, 2006.
[3] Medical Imaging Signals and Systems, J. L. Prince, J. Links, Prentice Hall, 2005.

52 Communication in Reasearch and Development

The course covers topics for developing competences which students will need in their future work for efficient integration and work in their teams; communication within their organization (across the hierarchy); efficient running of negotiations and business meetings; argumentative presentation of owns views and opinions, considering views and opinions of others; presenting results of one's own research work to peers, expert as well as to general public

1. working and communicating in teams
2. Running a business meeting
3. Negotiation
4. Solving conflicts within the team
5. Public presentation - preparing and carrying our a presentation at the conference, or infront of peers, or presenting and defending dissertation
6. written report - writing and abstract, paper, project proposal or dissertation
7. communicating to general public - strategy, contacting media, press releases, press conference, interviews

[1] Rugg, G., Petre, M., The Unwritten Rules of PhD Research, Open University Press, The McGraw-Hill Education, 2004.
[2] Fischer, R., Ury, W., Patton, B., Getting to yes, Penguin Books, 1991.
[3] Basadur, M., The Power of Innovation, Pitman Publishing, 1995.
[4] Kobayashi, I., 20 ključev, Lisac & Lisac, 2003.
[5] Communicating science - a scientist's survival kit, EC, http://ec.europa.eu/research/science-society/pdf/communicating-science_en.pdf

53 Biomedical Image Analysis

Medical image processing and analysis is a vital and innovative interdisciplinary field of research.
The fundamentals of computational medical image processing and analysis will be explored, leading to current research in segmentation, registration, quantitative image analysis, visualization, and image-guided interventions. Student will develop practical experience through projects.

[1] Handbook of Medical Imaging, Medical Image Processing and Analysis, Vol. 2, M. Sonka in J.M. Fitzpatrick (Ur.), SPIE - The International Society for Optical Engineering, 1st edition, 2000.
[2] Handbook of Medical Image Processing and Analysis, Isaac N. Bankman (Ur.), Academic Press, 2nd edition 2008.
[3] Terry Peters in Kevin Cleary: Image-Guided Interventions: Technology and Applications, Springer, 2008.
[4] Cancer Imaging. Instrumentation and Applications, Vol. 2, M.A. Hayat (Ur.), Academic Press, 2008.

APPLICATION FORM
FOR ADMISSION TO THE DOCTORAL STUDY PROGRAMME ELECTRICAL ENGINEERING, STUDY YEAR
_____/_____

Family name ....., Name ....., Nationality.....

Date of birth....., Place of birth.....

Correspondence address.....

Email .....,Phone……. .....

Employment information – Position.....

Assistant	YES	NO	Candidate;
Young researcher	YES	NO	Candidate;
Young researcher in economy	YES	NO	Candidate

Name of the institution....., Phone.....

COMPLIANCE WITH THE ADMISSION REQUIREMENTS (circle the fulfilled requirement)

- 2nd cycle study programme,
- Study programme educating for professions regulated by EU directives, or another long non-structured master's study programme, equivalent to 300 ECTS credits,
- Study programme leading to a university degree, adopted before 11 June 2004,
- Study programme leading to a master's degree; recognized are completed study obligations equivalent to 90 ECTS credits,
- Specialization study programme after the completed study programme leading to a university degree, adopted before 11 June 2004; recognized are completed study obligations equivalent to 60 ECTS credits
- Specialization study programme after the completed higher education professional study programme, adopted before 11 June 2004 with completed additional study obligations equivalent to 36 ECTS credits, prescribed by the relevant Faculty of Electrical Engineering Commission from a list of Year 1 subjects of the 2nd cycle study programme Electrical Engineering: four obligatory specialist subjects, depending on the study track and two elective specialist subjects,
- Equivalent programme from another University. The equivalence of the previously acquired education is determined within the procedure for recognizing education acquired abroad for the continuation of education in accordance with Article 121 of the University of Ljubljana Statute.

Date of graduation..... University....., Faculty.....

Grade point average (without the grade for dissertation)....., b) Grade for dissertation.....
(all candidates shall attach a certified copy of the diploma certificate and the original or certified copy of the grade point average and the grade for undergraduate dissertation)

I propose the following mentor.....,
The mentor shall have an academic or scientific qualification and proven research activity with corresponding bibliography in the field of the doctoral dissertation (100 SCIRIS points in case of basic research or 40 SICRIS points in case of applied research and proof of successful transfer of project results into practice).

Attachments:
a) certified copy of the diploma certificate
b) original (or certified) copy of grade point average with the grade for undergraduate dissertation
c) other _____

Date of application .....

I declare that the stated data are accurate

Signature .....

Send the application form by registered post by 1 September 2011 at the latest to the following address:
Univerza v Ljubljani, Fakulteta za elektrotehniko, Tržaška 25, 1000 Ljubljana

Notes

University *of Ljubljana*
Faculty *of Electrical Engineering*

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