University of Ljubljana
Faculty of Electrical Engineering

DOCTORAL PROGRAMME

Intelligent control systems and robotics
Electric energy, photovoltaics
Electronics, microelectronics, optoelectronics
Micro electromechanical systems and nanostructures
Mehatronics, embedded systems
Scientific communications skills

Doctoral programme
ELECTRICAL ENGINEERING

Metrology and quality assurance technologies
Biomedical engineering and informatics
Information and communication technologies
Multimedia technologies

www.fe.uni-lj.si
1. General information

2. Aims of the programme and competences acquired

3. Structure of the programme and study guidelines

4. Admission requirements and enrolment criteria

5. Short presentation of subjects

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 ramifications 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 credits (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 in 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.

<table>
<thead>
<tr>
<th>1st year: organised forms of studies 30 ECTS credits</th>
<th>2nd year: organised forms of studies 10 ECTS credits</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>1st semester</em>: organised studies 15 ECTS credits</td>
<td><em>2nd semester</em>: organised studies 15 ECTS credits</td>
</tr>
<tr>
<td>Course unit</td>
<td>Type</td>
</tr>
<tr>
<td>Subject A</td>
<td>E, S</td>
</tr>
<tr>
<td>Subject B</td>
<td>E, G, S, M</td>
</tr>
<tr>
<td>Research work</td>
<td></td>
</tr>
<tr>
<td>Seminar (Report on research work)</td>
<td>S, O</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>2nd year: organised forms of studies 10 ECTS credits</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>3rd semester</em>: organised studies 10 ECTS credits</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Research work</td>
</tr>
<tr>
<td>Subject of the doctoral dissertation</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3rd year: organised forms of studies 20 ECTS credits</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>5th semester</em>: organised studies 20 ECTS credits</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Research work</td>
</tr>
<tr>
<td>Doctoral dissertation</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

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 SCI.E.

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 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

<table>
<thead>
<tr>
<th>Course coordinator</th>
<th>Lecturers</th>
<th>Course Title</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Dolinar Gregor</td>
<td>Prof. dr. Gregor Dolinar</td>
<td>Selected topics in Mathematics</td>
<td>5</td>
</tr>
<tr>
<td>02 Gyergyek Tomaž</td>
<td>Iizr. prof. dr. Tomaž Gyergyek, Prof. dr. Milan Cerček</td>
<td>Electrical properties of plasmas and introduction to controlled fusion</td>
<td>5</td>
</tr>
<tr>
<td>03 Iglč Aleš</td>
<td>Prof. dr. Aleš Iglč, Prof. dr. Veronika Kralj - Iglč</td>
<td>Electrostatics of Surfaces and Nanostuructures</td>
<td>5</td>
</tr>
<tr>
<td>04 Sinigoj Anton</td>
<td>Iizr. prof. dr. Anton Sinigoj, Prof. dr. Tomaz Šlivnik</td>
<td>Electromagnetics</td>
<td>5</td>
</tr>
<tr>
<td>05 Šlivnik Tomaž</td>
<td>Prof. dr. Tomaz Šlivnik</td>
<td>Computational electromagnetics</td>
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K 2. Department of Power Systems and Devices

<table>
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<tr>
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<tbody>
<tr>
<td>06 Bizjak Grega</td>
<td>Iizr. prof. dr. Grega Bizjak</td>
<td>Simulations and measurements in Lighting Engineering</td>
<td>5</td>
</tr>
<tr>
<td>07 Mihalič Rafael</td>
<td>Prof. dr. Rafael Mihalič, Prof. dr. Dušan Povh</td>
<td>Energy Conversions and Environment</td>
<td>5</td>
</tr>
<tr>
<td>09 Papič Igor</td>
<td>Prof. dr. Igor Papič</td>
<td>Active distribution networks</td>
<td>5</td>
</tr>
<tr>
<td>10 Cepin Marko</td>
<td>Iizr. prof. dr. Marko Cepin</td>
<td>Reliability in Power Engineering</td>
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K 3. Department of Electronics

<table>
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<tr>
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<tbody>
<tr>
<td>11 Amon Slavko</td>
<td>Prof. dr. Slavko Amon</td>
<td>Sensors and Actuators</td>
<td>5</td>
</tr>
<tr>
<td>12 Topič Marko</td>
<td>Iizr. prof. dr. Janez Krč, Prof. dr. Franc Smole, Prof. dr. Miro Žeman</td>
<td>Photovoltaics</td>
<td>5</td>
</tr>
<tr>
<td>13 Smole Franc</td>
<td>Prof. dr. Franc Smole, Prof. dr. Marko Topič, Doc. dr. Marko Jankovec</td>
<td>Nanoelectronics</td>
<td>5</td>
</tr>
<tr>
<td>14 Krč Janez</td>
<td>Iizr. prof. dr. Janez Krč, Prof. dr. Marko Topič, Prof. dr. Franc Smole</td>
<td>Optoelectronics</td>
<td>5</td>
</tr>
<tr>
<td>15 Tumaj Tadej</td>
<td>Prof. dr. Tadej Tuma, Iizr. prof. dr. Arpad Buerven</td>
<td>Optimization in Electronic Design Automation</td>
<td>5</td>
</tr>
<tr>
<td>16 Žemva Andrej</td>
<td>Prof. dr. Andrej Žemva, Iizr. prof. dr. Andrej Trost</td>
<td>Digital electronic systems design</td>
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## K 4. Department of Measurement Systems

<table>
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<th>ECTS</th>
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<tbody>
<tr>
<td>17.Agroz Dušan</td>
<td>Izr. prof. dr. Dušan Agroz</td>
<td>Measurement dynamics and disturbances in the measurement setup</td>
<td>5</td>
</tr>
<tr>
<td>18.Batagel Valentin</td>
<td>Doc. dr. Valentin Batagel</td>
<td>Virtual measurement instruments</td>
<td>5</td>
</tr>
<tr>
<td>20.Drnovšek Janko</td>
<td>Prof. dr. Janko Drnovšek</td>
<td>Metrology and Quality Systems</td>
<td>5</td>
</tr>
<tr>
<td>21.Fefer Dušan</td>
<td>Prof. dr. Dušan Fefer</td>
<td>Acoustics and Ultrasound</td>
<td>5</td>
</tr>
<tr>
<td>22.Kamnik Roman</td>
<td>Izr. prof. dr. Roman Kamnik</td>
<td>Intelligent mobile transport systems</td>
<td>5</td>
</tr>
<tr>
<td>23.Mihelj Matjaž</td>
<td>Izr. prof. dr. Matjaž Mihelj</td>
<td>Multimodal interactive 3D technologies</td>
<td>5</td>
</tr>
<tr>
<td>24.Munih Marko</td>
<td>Prof. dr. Marko Munih</td>
<td>Selected topics in robotics</td>
<td>5</td>
</tr>
<tr>
<td>25.Pušnik Igor</td>
<td>Izr. prof. dr. Igor Pušnik</td>
<td>Quality of medical instrumentation</td>
<td>5</td>
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</table>

## K 5. Department of Microelectronics

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<tbody>
<tr>
<td>27.Strle Drago</td>
<td>Izr. prof. dr. Drago Strle Prof. dr. Anton Pleteršek</td>
<td>Advanced microelectronics systems: selected topics</td>
<td>5</td>
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## K 6. Department of Mechatronics

<table>
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<th>Course Coordinator</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>28.Fišer Rasko</td>
<td>Izr. prof. dr. Rasko Fišer Prof. dr. Vanja Ambrožič</td>
<td>Electrical servo drives in mechatronics</td>
<td>5</td>
</tr>
<tr>
<td>29.Miljačev Damijan</td>
<td>Izr. prof. dr. Damijan Miljačev</td>
<td>Modern electric machines</td>
<td>5</td>
</tr>
<tr>
<td>31.Vončina Danijel</td>
<td>Prof. dr. Danijel Vončina Doc. dr. Peter Zajec</td>
<td>Control of Electronically Commutated Motors</td>
<td>5</td>
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</table>

## K 7. Department of Systems, Control and Cybernetics

<table>
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<th>ECTS</th>
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<tbody>
<tr>
<td>32.Atanasijević-Kunc</td>
<td>Izr. prof. dr. Maja Atanasijević-Kunc</td>
<td>Selected Topics of Complex Systems Control Design</td>
<td>5</td>
</tr>
<tr>
<td>33.Belč Aleš</td>
<td>Izr. prof. dr. Aleš Belč</td>
<td>Modelling Identification and Simulation of Biological systems</td>
<td>5</td>
</tr>
<tr>
<td>35.Matko Drago</td>
<td>Prof. dr. Drago Matko</td>
<td>Advanced control of autonomous systems</td>
<td>5</td>
</tr>
<tr>
<td>36.Mihelj Franc</td>
<td>Prof. dr. Franc Mihelij</td>
<td>Stochastic Processes and Signals</td>
<td>5</td>
</tr>
<tr>
<td>37.Mušič Gašper</td>
<td>Izr. prof. dr. Gašper Mušič</td>
<td>Industrial informatics</td>
<td>5</td>
</tr>
<tr>
<td>38.Pavesič Nikola</td>
<td>Prof. dr. Nikola Pavesič</td>
<td>Pattern recognition</td>
<td>5</td>
</tr>
<tr>
<td>39.Skrjanc Igor</td>
<td>Prof. dr. Igor Skrjanc</td>
<td>Intelligent control in modern systems</td>
<td>5</td>
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<tr>
<td>40.Zupančič Borut</td>
<td>Prof. dr. Borut Zupančič Prof. dr. Felix Breinrener</td>
<td>Object Oriented Modelling</td>
<td>5</td>
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## K 8. Department of Telecommunications

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<th>Course Coordinator</th>
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<tbody>
<tr>
<td>41.Bester Janez</td>
<td>Prof. dr. Janez Bester</td>
<td>Convergent communications**</td>
<td>5</td>
</tr>
<tr>
<td>42.Hercog Drago</td>
<td>Izr. prof. dr. Drago Hercog</td>
<td>Protocols of Modern Telecommunication Networks</td>
<td>5</td>
</tr>
<tr>
<td>43.Humur Iznok</td>
<td>Doc. dr. Iznok Humar Prof. dr. Marko Jagodič Prof. dr. Janez Bester</td>
<td>Telecommunication systems engineering</td>
<td>5</td>
</tr>
<tr>
<td>44.Kos Andrej</td>
<td>Izr. prof. dr. Andrej Kos</td>
<td>Broadband Communications Systems</td>
<td>5</td>
</tr>
<tr>
<td>45.Košir Andrej</td>
<td>Izr. prof. dr. Andrej Košir</td>
<td>Operations research in telecommunications</td>
<td>5</td>
</tr>
<tr>
<td>46.Pogačnik Matevž</td>
<td>Doc. dr. Matevž Pogačnik</td>
<td>Multimedia content and interactive technologies</td>
<td>5</td>
</tr>
<tr>
<td>47.Tasić Jurij</td>
<td>Prof. dr. Jurij Tasić Doc. dr. Matej Zajc</td>
<td>Digital signal, image and video processing</td>
<td>5</td>
</tr>
<tr>
<td>48.Tomažič Sašo</td>
<td>Prof. dr. Sašo Tomažič</td>
<td>Contemporary Coding and Modulation Methods</td>
<td>5</td>
</tr>
<tr>
<td>49.Vidmar Matjaž</td>
<td>Prof. dr. Matjaž Vidmar Prof. dr. Jožko Budin</td>
<td>Radio communications</td>
<td>5</td>
</tr>
</tbody>
</table>
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 commission 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


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

<table>
<thead>
<tr>
<th>No.</th>
<th>Lecturer</th>
<th>Title</th>
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<tbody>
<tr>
<td>1</td>
<td>Bagaj Tadej</td>
<td>DOC</td>
</tr>
<tr>
<td>2</td>
<td>Batagelj Valentin</td>
<td>DOC</td>
</tr>
<tr>
<td>3</td>
<td>Belčič Aleš</td>
<td>RP</td>
</tr>
<tr>
<td>4</td>
<td>Bešter Janez</td>
<td>IP</td>
</tr>
<tr>
<td>5</td>
<td>Bijač Grega</td>
<td>IP</td>
</tr>
<tr>
<td>6</td>
<td>Blažič Šašo</td>
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<td>Bojkovski Jovan</td>
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<td>Budin Jožko</td>
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<td>Buirman Arpad</td>
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<td>Čepin Marko</td>
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<td>Drnovšek Janko</td>
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<td>Ferčič Dušan</td>
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<td>Felner Dušan</td>
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### 02 Electrical properties of plasmas and introduction to controlled fusion

#### Subject Description

**01 Selected topics in Mathematics**

- Functional analysis:
  - metric spaces (notion of distance, basic properties of metric 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)

#### Literature

- 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)

### 03 Functional analysis

#### Description

**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.

#### Literature

03 Electrostatics of Surfaces and Nanostructures

04 Electromagnetics

05 Computational electromagnetics

06 Simulations and measurements in Lighting Engineering

07 Energy Conversions and Environment

08 Power System Operation in Market Environment

09 Active distribution networks
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.


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.


11 Sensors and Actuators

- Basic definitions, translation principles, classifications of sensors and actuators.
- Basic sensor properties: characteristics, sensitivity, accuracy, resolution, selectivity, minimal detected signal, noise, nonlinearity, repeatability, noise temperature zero drift, overload, stability etc. Analysis of sensor dynamic response.


- 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.

- Analog signal conditioning: basic building blocks, signal discretisation, samplehold circuits, DAC (unipolar, resolution, weighted and R-ZR ladder, current-switched), ADC (unipolar, resolution, parallel-feedback, successive approximations, ramp, delta-sigma, switched capacitors, flash, speed of conversion) etc.


- New advanced sensor and actuator structures.


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, CZT, CdTe), diseleniated and organic solar cells, tandem and multijunction solar cells, thermo-photovoltaics; 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. Efficiency losses; 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 power systems.


13 Nanoelectronics


14 Optoelectronics


15 Optimization in Electronic Design Automation


16 Digital electronic systems design

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 Grenet-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 system. Comparison of the measurement uncertainties with the theoretically achievable Cramér-Rao bounds.

18 Virtual measurement instruments
- Basic concept of virtual measurement instruments
- Software for development of virtual measurement instruments, graphically programming, dataflow concept
- Hardware for the development of virtual measurement instruments, virtual measurement 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

19 Quality and fundamentals of software engineering
- 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 (blackbox 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, ...)

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, BO and EN standards, basic knowledge on preparation of laboratories, development and realization of basic St units, physical constants, hierarchical organisation of metrology systems, international comparability, 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


21 Acoustics and Ultrasound


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, braking, collision avoidance, multigant 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).


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.


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, birobotics
- Walking robots: monopod, biped, and multilegged robots; analysis and synthesis of locomotion in man and robot
- Exotic robots


25 Quality of medical instrumentation
- Medical device directive-MDD, In vitro diagnostic directive-IVD, Active Implantable Medical Devices-AIMD
- Legal metrology (OIML, UL, MBS)
- Quality assurance in medical environment (standard ISO 15189 Requirements for the competence of medical laboratories)
- Standardization in the field of medical instrumentation (ISO, IEC, 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)

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 rules.
- 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.

27 Advanced microelectronics systems: selected topics

The content 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 submi-
cron CMOS technologies (<70nm). The limitations imposed by the technology due to limited supply voltage and increased noise require new architectures of circuits while complexity require new modeling and design tools.
The content will be divided into three main topics:
- Design of low-voltage, HF, low-noise VLSI (Very Large-Scale Integrated) systems, modelling and verification
- Testing of complex mixed-signal integrated, BIST methodologies for digital analog and mixed signal systems
Each topic will be composed of lectures, use of practical seminar work, which will be based on individual research work in selected subject.

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 bunted 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.

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 hy-

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 electromechanical compatibility problems: sources of electromagnetic (EM) emissions, mode of coupling and reduction techniques of EM emissions. Setup for measuring radiated and conducted emissions.

[1] Anton Pietriek, Načrivanje analogih integriranih veršij v tehnologiji CMOS in SOI-BiCMOS, monograph 2006,
[13] [1] Anton Pietriek, Načrivanje analogih integriranih veršij v tehnologiji CMOS in SOI-BiCMOS, monograph 2006,
[13] [1] Anton Pietriek, Načrivanje analogih integriranih veršij v tehnologiji CMOS in SOI-BiCMOS, monograph 2006,
31 Control of Electronically Commutated Motors


32 Selected Topics of Complex Systems Control Design

- Introduction to complex systems (description and mathematical representation of complex systems, model uncertainty, multi-variable 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)
- Khaiton’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)


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 involves a major problem) - systems biology.

Measurement techniques in areas (gas and liquid chromatography, mass spectroscopy, real-time PCR, DNA microarrays, electrophoresis, mass spectrometry, genomics, informatics, etc., ...). Processing of biological signals (normalisation, filtering, modulation).

Object oriented theoretical modelling of biochemical processes (problems of incomplete knowledge of relations between objects). Modelling in pharmacokinetics and pharmacodynamics (problems of incomplete knowledge of theoretical background of drug actions and quantity data).

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.


34 Machine vision

- Introduction: Modeling of visual multisensor systems, mathematical, physical, and computational foundations.
- Selection of mathematical tools and algorithms for analysis of visual information: selected topics in linear algebra, stochastic systems, information theory.
- Selection of algorithms for object detection and tracking, motion analysis, events and activity recognition, behavior analysis.
- Biological-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 vehicles.
- Machine vision in sports, analysis and understanding of individual and team activities.
- Machine vision in advanced user interfaces.


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, nonholonomy, 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.


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 (Wiener 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:

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

**37 Industrial Informatics**


**38 Pattern recognition**


**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 autonomous systems.


**40 Object Oriented Modelling**

Basic principles in OO modelling
- Inheritance, classes, quantities, connectors, partial classes, packages, examples. DyMobA – environment for Modélca 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 step single, step multiple, explicit, implicit, methods for stiff systems, extrapolation methods, problems of discontinuities.
Case studies


**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 services provisioning. Features of analog and digital forms of multimedia elements, and reasons for digitalization. Basic multimedia services (IPv services, mobile video services, web-based video services). Terminal equipment features, required for usage of convergent multimedia services (STD, 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.

42 Protocols of Modern Telecommunication Networks


1. Hercog D., Telekomunikacijski protokoli (Telecommunication protocols), textbook in preparation
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/1, E/D/r, G/G/1, G/M/1.
- Theory of modern telecommunication systems:
  - 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 telecommunication systems, interoperability.
- Simulations and emulation of network elements and services.
- Telecommunications systems design.
  - Network bottlenecks.
  - Congestion control.
  - Utilization, performance evaluation.
- Methods ensuring quality of services.
  - Open and closed loop traffic control.
  - 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 systems.
  - Design of telecommunication systems in terms of availability.
  - Redundancy.
- Energy efficiency of telecommunication system and services.

1. Humar I., Bešter J., Naspranje omrežja s telekomunikacijskim inženiringom, Skripta za podiplomsko študente (v pripravi.
9. Članki, objavljeni v revijah, npr.
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, paravirtualization, 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, DHCHP, 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 infrastructures. Interactions of communications and power distribution systems from the availability, reliability, vulnerability and risk viewpoints.

45 Operations research in telecommunications


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-diffusion, 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)

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 selective linear algebra methods. Digital video coding and video compression, image and video representation, detection and object recognition, watermarking and applications.

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).


49 Radio communications

Field definition and noise, performance of components, subsystems and systems, communication equation, reflection, refraction 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, CCR 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, Keplerian 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.

44 47 48 49
50 Multimedia systems: algorithms and architectures
Multimedia signal processing, linear algebra and non-linear algebra sequential algorithms, architectures of digital signal, image and video processing. Modelling of parallel algorithms, parallel architectures, multithreading, 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 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.

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.

52 Communication in Research 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 meetings; argumentative presentation of own 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 out a presentation at the conference, or in front 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

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.